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Development and evaluation of an educational fantasy comic for geometry transformation learning: enhancing junior high school students' mathematical reasoning and self-esteem

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Abstract

Background: Indonesian students' mathematical literacy remains low, as evidenced by the 2022 PISA results, which indicate difficulties in understanding concepts and solving contextual problems. Geometry transformation topics require strong abstract thinking and visualization skills; however, conventional instruction often emphasizes memorization rather than conceptual understanding. In addition, students' low self-esteem further hinders their engagement and achievement in mathematics learning. Therefore, innovative instructional media are needed to support both cognitive and affective learning outcomes.
Aims: This study aims to develop an educational fantasy comic as a learning medium for geometry transformation and to examine its effectiveness in enhancing junior high school students' mathematical reasoning and self-esteem.
Method: This research employed a Research and Development (R&D) approach using the ADDIE model, consisting of Analysis, Design, Development, Implementation, and Evaluation stages. The participants were junior high school students. Data were collected through expert validation, questionnaires, mathematical reasoning tests, and self-esteem scales, and analyzed using descriptive quantitative and qualitative techniques.
Results: The validation results indicated that the developed comic achieved a score of 82.73%, categorized as "very valid." The practicality test showed an average score of 4.12 (82.42%), indicating that the comic was highly practical for classroom use. Furthermore, the effectiveness results demonstrated that students who learned using the educational fantasy comic exhibited better mathematical reasoning skills and higher self-esteem compared to those receiving conventional instruction.
Conclusion: The educational fantasy comic is a valid, practical, and effective learning medium that enhances students' mathematical reasoning and self-esteem, offering an engaging and meaningful alternative for geometry transformation learning.

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INTRODUCTION

Mathematics is a fundamental discipline that plays a crucial role in developing students' logical, critical, creative, and systematic thinking skills. It equips learners with the ability to analyze problems, construct arguments, and make decisions based on structured reasoning (Demircioglu et al., 2023; Ramadhani et al., 2023). In school mathematics, higher-order thinking skills such as critical thinking, reasoning, and problem-solving are key learning objectives that must be achieved (Azid et al., 2022; Kosasih et al., 2022; Zana et al., 2024). However, many students still experience difficulties in mastering these competencies effectively. This issue is reflected in the relatively low performance

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of Indonesian students in international assessments, indicating limited mathematical literacy (Kusmaryono & Kusumaningsih, 2023; Tanudjaya & Doorman, 2020; Wijaya et al., 2024). Students often struggle to understand mathematical concepts deeply and apply them in real-life contexts (Montesdeoca, 2023; Wisenöcker et al., 2024). These difficulties suggest that learning processes have not fully supported meaningful knowledge construction. As a result, students tend to rely on memorization rather than developing conceptual understanding. This condition highlights the need for innovative instructional approaches that promote active learning and reasoning. Therefore, improving students' mathematical reasoning ability has become an urgent priority in mathematics education.

One of the mathematical topics that requires strong reasoning and visualization skills is geometry transformation. This topic involves concepts such as translation, rotation, reflection, and dilation, which demand a deep understanding of spatial relationships and coordinate systems (Leme da Silva & Jahn, 2024; Uygun, 2020). Students are required not only to perform procedures but also to interpret transformations conceptually. However, many students experience difficulties when learning this material (Barrot et al., 2021; Rusmawati, 2021). They often memorize formulas without understanding the underlying concepts and struggle to visualize the results of transformations (Maifa et al., 2025). These challenges are further compounded when students are asked to solve contextual problems involving spatial reasoning. The abstract nature of geometry transformation makes it difficult to be taught using conventional teaching methods (İbili et al., 2020; Kuzle, 2023; Uygun, 2020). In many classrooms, instruction is still dominated by teacher-centered approaches that emphasize procedural knowledge. Learning media used are often limited and less supportive of visualization processes (Abdulrahaman et al., 2020; Boström & Sjöström, 2022; Stanciulescu et al., 2024). Consequently, students face barriers in developing a comprehensive understanding of geometric transformation concepts.

In addition to cognitive challenges, affective factors such as self-esteem also play a significant role in students' mathematics learning. Self-esteem influences students' confidence, motivation, and persistence in solving problems (Moyano et al., 2020; Neroni et al., 2022; Voica et al., 2020). Students with low self-esteem tend to doubt their abilities and avoid engaging in challenging tasks (C. Chen et al., 2023; Zhang, 2022). This condition negatively affects their learning outcomes and participation in classroom activities. Mathematics is frequently perceived as a difficult subject, which further reduces students' confidence levels (Aguilar, 2021; Jankvist & Niss, 2020; Schuh et al., 2023; Skilling et al., 2021). Therefore, effective learning should address both cognitive and affective aspects simultaneously. One potential solution is the use of educational fantasy comics as an innovative learning medium (Wardani, 2024). Educational comics present mathematical concepts through visual narratives that make abstract ideas more concrete and easier to understand (Cohn, 2020; Tay et al., 2024). The integration of fantasy elements can stimulate students' imagination and create a more engaging learning experience (Bai et al., 2022; Zuo et al., 2022). Through storytelling and character development, students can relate to the learning material emotionally and cognitively. As a result, educational fantasy comics have the potential to enhance both mathematical reasoning and self-esteem in a meaningful way.

Existing studies have widely explored the use of mathematics comics, visual learning approaches, and technology-enhanced instructional methods in mathematics education. Several studies have demonstrated that mathematics comics can improve students' critical thinking, character development, and logical-mathematical intelligence, as well as enhance engagement and learning motivation (Johar et al., 2023; Lestari et al., 2021; Safitri et al., 2021). In parallel, other research highlights the effectiveness of visual-based and interactive learning approaches, such as game-based learning, collaborative learning, and visual arts integration, in improving students' mathematical achievement, visual literacy, and geometry understanding (Schoevers et al., 2020).

Additionally, studies on geometry learning emphasize the importance of visualization and transformation concepts in supporting students' conceptual understanding and spatial reasoning, although these are often implemented through modules or general instructional strategies rather than narrative-based media (González-Campos et al., 2022). However, despite these advancements, several limitations remain. Most existing studies focus either on cognitive outcomes (e.g., achievement, critical thinking, or mathematical intelligence) or on general engagement, without specifically targeting higher-order thinking skills such as mathematical reasoning within a contextual and visual narrative framework. Furthermore, although visual approaches are widely used, there is still limited research integrating structured storytelling media, such as educational comics particularly those incorporating fantasy elements into mathematics learning, especially in geometry transformation topics that require strong abstract and spatial reasoning. In addition, affective factors such as self-esteem have been recognized as important predictors of mathematics achievement, yet they are often examined independently rather than as part of an integrated instructional intervention (Ching et al., 2021; DeVries et al., 2021). Therefore, a significant research gap exists in developing and empirically evaluating an innovative learning medium that integrates educational fantasy comics with geometry transformation content to simultaneously enhance students' mathematical reasoning and self-esteem, combining cognitive, visual, and affective dimensions within a single, structured instructional design.

Based on the identified problems and research gaps, this study aims to develop an educational fantasy comic as an innovative learning medium for geometry transformation. The study seeks to design learning materials that integrate visual storytelling with mathematical concepts to support students' understanding. The developed comic is expected to facilitate students in visualizing transformation processes more effectively. In addition, this research aims to improve students' mathematical reasoning by encouraging them to analyze and interpret problems through contextual narratives. The study also focuses on enhancing students' self-esteem by creating an engaging and supportive learning environment. Furthermore, this research evaluates the validity of the developed comic through expert judgment. The practicality of the learning media is also examined based on students' and teachers' responses. The effectiveness of the comic is assessed by comparing learning outcomes between students who use the media and those who follow conventional instruction. This study is expected to provide an alternative instructional strategy that is more interactive and student-centered. Ultimately, the research aims to contribute to improving the quality of mathematics learning by integrating cognitive and affective dimensions within a single learning medium.

LITERATURE REVIEW

Mathematics education plays a significant role in developing students' higher-order thinking skills, particularly mathematical reasoning. Mathematical reasoning refers to the ability to think logically, analyze relationships, construct arguments, and justify conclusions based on evidence (Cresswell & Speelman, 2020; Hjelte et al., 2020; Sukirwan et al., 2020). It is considered a core competency that enables students to solve both routine and non-routine problems effectively. In the learning process, reasoning skills are closely linked to conceptual understanding and the ability to connect mathematical ideas (Jawad, 2022; Jonsson et al., 2020; Mukuka et al., 2023). Students with strong reasoning abilities are better equipped to interpret problems, identify patterns, and formulate appropriate strategies (Anggraeni et al., 2023). However, many students struggle to develop these skills due to limited opportunities to engage in meaningful problem-solving activities (Dood & Watts, 2023; Karan & Brown, 2022; Koehler & Vilarinho-Pereira, 2023; Tan et al., 2023). Traditional teaching approaches often emphasize procedural knowledge rather than encouraging reasoning

processes (M. Chen et al., 2022; Makransky et al., 2021; Saks et al., 2021). As a result, students may rely on memorization without understanding the underlying concepts. This condition highlights the importance of designing learning environments that actively promote reasoning skills. Therefore, instructional innovations are necessary to support the development of mathematical reasoning in classroom settings.

Geometry transformation is one of the mathematical topics that requires both reasoning and spatial visualization skills. This topic involves understanding how objects change position, orientation, and size through transformations such as translation, rotation, reflection, and dilation. These processes demand the ability to mentally manipulate shapes and interpret relationships between coordinates. Students must not only apply formulas but also understand the conceptual meaning behind each transformation (Noster & Siller, 2025; Zhao et al., 2022). However, many learners experience difficulties in visualizing geometric transformations, especially when learning is delivered through abstract explanations (Chang et al., 2024; İbili et al., 2020; Maifa et al., 2025; Ziatdinov & James R. Valles, 2022). The lack of appropriate instructional support often leads to misconceptions and fragmented understanding (Bao & Fritchman, 2021; Guffey & Slater, 2020; Morris, 2025). Visual representation is essential in helping students grasp geometric concepts more effectively (Žakelj & Klančar, 2022; Ziatdinov & James R. Valles, 2022). Learning media that provide clear and dynamic visualizations can bridge the gap between abstract theory and concrete understanding (Girwidz & Kohnle, 2021; Korkut & Surer, 2023; Lacković & Olteanu, 2020). Therefore, incorporating visual elements into geometry learning is crucial for improving students' comprehension. This emphasizes the need for innovative learning media that can support visualization and reasoning simultaneously.

In addition to cognitive aspects, affective factors such as self-esteem play a crucial role in mathematics learning. Self-esteem refers to an individual's perception of their own abilities and self-worth (AlHarbi, 2022; Isserow, 2023). In the context of mathematics education, self-esteem influences students' confidence in solving problems and participating in learning activities (Acosta-Gonzaga, 2023; Fisher et al., 2022; Moyano et al., 2020). Students with high self-esteem tend to be more resilient, motivated, and willing to face challenges (Abdolrezapour et al., 2023; Namaziandost et al., 2023; Shengyao et al., 2024). Conversely, students with low self-esteem often experience anxiety and avoid engaging in complex tasks. This condition can negatively affect their academic performance and learning outcomes. Mathematics is frequently perceived as a difficult subject, which further lowers students' confidence levels (Aguilar, 2021; Schuh et al., 2023; Zander et al., 2020). Therefore, fostering positive self-esteem is essential in creating a supportive learning environment. Learning strategies that encourage success experiences and reduce anxiety can improve students' self-perception (Pacifico et al., 2025; Winarsunu et al., 2023). Consequently, integrating affective support into instructional design is necessary to enhance both learning engagement and achievement.

Educational media play an important role in facilitating effective learning experiences. One type of media that has gained attention is educational comics, which combine visual elements and narrative storytelling. Comics present information in a structured yet engaging format that can attract students' attention (Fitria et al., 2023; Linardatos & Apostolou, 2023; Tay et al., 2024). The use of images and dialogues helps simplify complex concepts and makes learning more accessible. In mathematics learning, comics can transform abstract ideas into concrete representations (Lestari et al., 2021; Tay et al., 2024). Narrative elements within comics provide contextual situations that support meaningful learning (Cohn, 2020). Students can follow storylines and relate mathematical concepts to real-life scenarios. This approach not only enhances understanding but also increases motivation and interest in learning. Moreover, comics can create a relaxed learning atmosphere that

reduces anxiety. Therefore, educational comics are considered a promising medium for improving both cognitive and affective aspects of learning.

Fantasy-based educational comics offer additional advantages by incorporating imaginative elements into the learning process. The use of fantasy settings, characters, and storylines can stimulate students' imagination and emotional engagement. These elements make learning more enjoyable and encourage students to actively participate in the learning process. Through fantasy narratives, students can explore mathematical concepts in a more meaningful and contextualized way. Characters in the story can serve as role models who demonstrate problem-solving strategies and persistence. This can positively influence students' attitudes and self-confidence in learning mathematics. Despite these potential benefits, the use of fantasy-based comics in mathematics education remains relatively limited. Most existing studies focus on general educational comics without integrating specific learning objectives such as reasoning and self-esteem. Furthermore, research on geometry transformation often lacks innovative media that combine visualization and storytelling. Therefore, there is a need to develop and evaluate educational fantasy comics that integrate cognitive and affective dimensions.

METHOD

Research Design

This study employed a Research and Development (R&D) approach aimed at designing, developing, and evaluating an educational fantasy comic as an instructional medium for geometry transformation learning. The developed media was intended to enhance students' mathematical reasoning and self-esteem simultaneously. The R&D approach was selected because it enables the transformation of theoretical concepts into practical and applicable educational products. The development process followed the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. In the Analysis stage, the researchers identified learning needs, student characteristics, and difficulties encountered in learning geometry transformation, particularly related to abstract visualization and low self-confidence. In the Design stage, the structure of the fantasy comic was systematically planned, including storyline development, character design, and the integration of geometry transformation topics such as translation, reflection, rotation, and dilation. In the Development stage, the comic was produced in both print and digital formats, incorporating illustrations, narratives, and interactive elements such as quizzes and reflection activities, followed by expert validation and limited trials. In the Implementation stage, the developed comic was applied in classroom learning activities, where students engaged with the material through guided instruction and discussion. In the Evaluation stage, both formative and summative evaluations were conducted to assess the validity, practicality, and effectiveness of the product. The overall ADDIE process is illustrated in Figure 1.

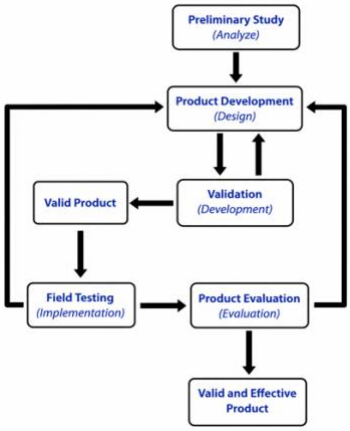

Figure 1. ADDIE Development Model

Participant

This study was conducted during the second semester of the 2025/2026 academic year at SMP Negeri 12 Lubuklinggau. The participants were selected using purposive sampling, consisting of two ninth-grade classes. One class was assigned as the experimental group, while the other served as the control group. Each class consisted of 24 students, resulting in a total of 48 participants. The experimental class received treatment using the educational fantasy comic as a learning medium, while the control class was taught using conventional instructional methods. The selection of these groups aimed to compare the effectiveness of the developed media in improving students' mathematical reasoning and self-esteem. Students in both groups had relatively similar academic backgrounds and learning conditions. The teacher involved in the study acted as a facilitator during the learning process. The participants represented the target users of the developed media. Their involvement provided relevant data for evaluating the feasibility and effectiveness of the product. Therefore, the selected participants supported the objectives of the research.

Instrument

Data were collected using multiple instruments to ensure comprehensive evaluation of the developed learning media. Interviews were conducted to identify initial learning needs and challenges faced by students. Observations were carried out to examine the learning process and students' engagement during instruction. Validation sheets were used by experts to assess the validity of the developed comic in terms of content, design, and instructional aspects. Questionnaires were administered to measure students' responses and the practicality of the learning media. A self-esteem scale was used to evaluate students' affective development related to confidence in mathematics learning. In addition, a mathematical reasoning test was administered to assess students' cognitive outcomes. Each type of data was collected using appropriate instruments and techniques. The instruments were designed to align with the objectives of the study. The selection of multiple instruments enabled data triangulation and increased reliability. The details of instruments and data collection techniques are presented in Table 1.

Table 1. Instruments and data collection techniques

No	Data Type	Instrument	Technique
1	Learning needs	Interview	Interview
2	Learning process	Observation	Observation
3	Product validity	Validation sheet	Expert validation
4	Students' responses	Questionnaire	Questionnaire
5	Self-esteem	Questionnaire	Questionnaire
6	Mathematical reasoning	Test	Test

Data Analysis

The data analysis in this study involved both qualitative and quantitative approaches. Qualitative analysis was used to process data obtained from interviews, observations, and open-ended questionnaire responses. These data were analyzed through categorization, interpretation, and systematic summarization. Quantitative analysis was applied to numerical data obtained from validation results, questionnaires, and test scores. Instrument validity was tested using the Pearson Product Moment correlation with the help of SPSS, where an item was considered valid if the correlation coefficient exceeded the critical value at a 5% significance level. Reliability testing was conducted using Cronbach's Alpha to measure the consistency of the instruments. The reliability criteria are presented in Table 2.

Table 2. Realibity criteria

Alpha Range	Category
$\alpha < 0.30$	Very Low
$0.30 < \alpha < 0.60$	Low
$0.60 < \alpha < 0.70$	Moderate
$0.70 < \alpha < 0.90$	High
$\alpha \geq 0.90$	Very High

Furthermore, product quality was evaluated based on three main aspects: validity, practicality, and effectiveness. The criteria for validity, practicality, and effectiveness are presented in Table 3, Table 4, and Table 5, respectively.

Table 3. Validity criteria of the comic

Percentage Range	Validity Category	Description
< 41%	Not Valid	The comic is not valid and requires major revision
41% – 60%	Fairly Valid	The comic can be used but requires significant revision
61% – 80%	Valid	The comic can be used with minor revisions
81% – 100%	Very Valid	The comic is valid and can be used

Table 4. Practicality criteria

Percentage Range	Practicality Category	Description
< 41%	Not Practical	The comic is difficult to use
41% – 60%	Fairly Practical	The comic can be used but requires significant revision
61% – 80%	Practical	The comic is easy to use with minor revisions
81% – 100%	Very Practical	The comic is very easy to use

Table 5. Effectiveness Criteria

Percentage Range	Practicality Category	Description
< 40%	Not Effective	The media does not significantly improve learning outcomes, mathematical reasoning, or students' self-esteem
40% – 59%	Fairly Effective	The media influences learning outcomes, but improvement in reasoning and self-esteem is not optimal
60% – 79%	Effective	Most students achieve learning mastery and show improvement in mathematical reasoning and self-esteem
> 80%	Very Effective	Most students achieve mastery, demonstrate significant improvement in reasoning and self-esteem, and learning objectives are optimally achieved

The use of these criteria ensured that the evaluation process was objective, systematic, and measurable. Data analysis results were then interpreted to determine the feasibility of the developed media.

Procedure

The research procedure followed the stages of the ADDIE model in a systematic and iterative manner. In the Analysis stage, preliminary studies were conducted through interviews and observations to identify students' difficulties in learning geometry transformation and their affective conditions. In the Design stage, the framework of the educational fantasy comic was developed, including storyline construction, character development, and integration of mathematical content. In the Development stage, the comic was produced and validated by experts, followed by revisions based on feedback. A limited trial was also conducted to obtain initial responses from students. In the Implementation stage, the revised comic was used in classroom learning activities, where students actively engaged with the material through reading, discussion, and problem-solving tasks. During this stage, data were collected using tests, questionnaires, and observations. In the Evaluation

stage, both formative and summative evaluations were conducted to assess the effectiveness of the learning media. The statistical analysis procedure used in this study is illustrated in Figure 2.

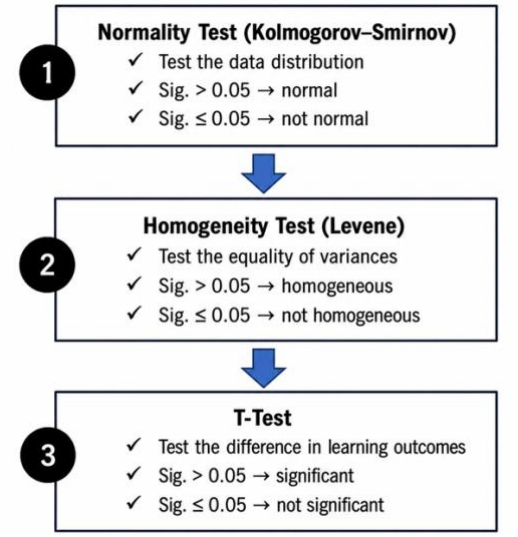

Figure 2. Statistical analysis procedure

This procedure ensured that all data met the necessary statistical assumptions before hypothesis testing was conducted. The final results were used to determine the effectiveness of the developed educational fantasy comic in improving students' mathematical reasoning and self-esteem.

RESULTS AND DISCUSSION

Results

This section presents the research findings based on the ADDIE development stages, consisting of Analysis, Design, Development, Implementation, and Evaluation. The results describe the process and quality of the educational fantasy comic developed for geometry transformation learning. The quality of the product was evaluated based on three main aspects: validity, practicality, and effectiveness. The effectiveness of the comic was examined in relation to students' mathematical reasoning and self-esteem. The results are presented systematically according to each development stage.

Analysis stage

The analysis stage was conducted to identify students' learning needs, instructional problems, and the suitability of the learning media to be developed. Data were obtained through interviews with teachers, student questionnaires, classroom observations, and document analysis. The findings showed that geometry transformation was perceived as a difficult topic because it involves abstract concepts, spatial visualization, and coordinate-based reasoning. Students had difficulty understanding transformation processes such as translation, reflection, rotation, and dilation when these concepts were presented only through verbal explanation or textbook-based instruction. The analysis also revealed that the learning process was still dominated by teacher-centered instruction. Teachers tended to explain concepts through lectures and examples from textbooks, while students were mostly passive during the learning process. The use of instructional media was limited, especially media that could support visualization and student engagement. Students also reported low confidence when solving geometry transformation problems, particularly problems requiring visual interpretation and mathematical reasoning. These findings indicated the need for an instructional medium that could present abstract mathematical concepts in a more concrete, visual, and engaging way.

Table 6. Results of needs analysis

Data Source	Aspect Examined	Main Findings	Learning Needs Implication
Teacher	Teaching method	Learning was still dominated by lectures and textbooks	Innovative and interactive learning media are needed
Teacher	Students' understanding	Students had difficulty understanding transformation concepts such as rotation, reflection, translation, and dilation	Media that support concept visualization are needed
Students	Perception of the material	Geometry transformation was considered difficult and abstract	The material needs to be presented more concretely and attractively
Students	Learning motivation	Students were less interested and easily bored	Learning media that increase students' interest are needed
Students	Self-esteem	Students lacked confidence and were afraid of making mistakes	Media that can build students' confidence are needed
Observation	Student activity	Students tended to be passive during learning	Media that encourage active participation are needed
Observation	Learning interaction	Learning was teacher-centered	Student-centered learning activities are needed
Observation	Instructional media	The use of media was still limited	Visual and narrative-based learning media are needed

Based on Table 6, the development of an educational fantasy comic was considered relevant to students' learning needs. The comic was expected to help students visualize geometry transformation concepts, increase learning engagement, and strengthen students' confidence in learning mathematics. Therefore, the analysis stage became the basis for designing a comic that integrates mathematical content, visual representation, narrative context, and affective support.

Design stage

The design stage was carried out based on the findings obtained from the needs analysis. At this stage, the educational fantasy comic was designed to support the learning of geometry transformation through a visual-narrative approach. The comic was structured to combine mathematical content with fantasy-based storytelling, character dialogue, visual illustrations, and reasoning-based exercises. The design emphasized the integration of cognitive and affective aspects, namely mathematical reasoning and self-esteem. The comic consisted of several key components, including a cover, introduction, chapters, storyline, comic panels, and exercises. The learning material was divided into four chapters, each representing a specific topic in geometry transformation. These topics included translation, reflection, rotation, and dilation. Each chapter was designed with a consistent narrative structure: problem presentation, concept exploration, mathematical explanation, and problem resolution.

Table 7. Structure of the educational fantasy comic

Component	Description	Purpose
Cover	The cover contains the title, main character illustrations, and geometry elements	To attract students' attention and represent the content of the comic
Introduction	Introduces the characters, story setting, and learning context	To provide initial orientation and build students' interest
Chapters / Materials	Consists of four chapters covering reflection, translation, rotation, and dilation	To present geometry transformation content systematically
Storyline	Problem → exploration → explanation → solution	To guide students' conceptual understanding gradually

Comic Panels	Each page contains 3–5 panels presenting situations, conflicts, processes, and solutions	To support visual flow and narrative clarity
Exercises	Story-based mathematical reasoning questions	To measure and train students' understanding

Table 7 shows that each component of the comic was designed to support both learning flow and student engagement. The use of storyline and panels was intended to help students follow the transformation concepts step by step. The exercises were placed within the story context to encourage students to analyze, interpret, and solve mathematical problems meaningfully. The integration of comic elements into learning was also mapped based on instructional components and expected indicators. This mapping ensured that the comic did not only function as entertainment media but also as structured instructional material.

Table 8. Integration of the comic into learning

Learning Component	Expected Indicator	Implementation in the Comic
Transformation material	Students understand geometry transformation concepts	Concepts of reflection, translation, rotation, and dilation are presented through stories and visual illustrations
Mathematical reasoning	Students are able to analyze and solve problems	Contextual problems are embedded in the storyline
Concept visualization	Students are able to visualize transformation processes	Coordinate images and shape transformations are displayed visually
Self-esteem	Students develop confidence in learning mathematics	Motivational dialogues and confident characters are inserted into the story
Student engagement	Students become active and interested in learning	The story is designed to be interactive and attractive
Practice activities	Students can apply concepts independently	Story-based exercises are provided in each chapter

Table 8 demonstrates that the comic was designed to integrate learning objectives with visual, narrative, and affective elements. The comic also included motivational dialogue and character development to encourage students' confidence. This design was expected to reduce students' anxiety and increase their willingness to participate in mathematics learning. The final design of the comic consisted of four main chapters. Chapter 1, Petualangan Dimensi Fantasia, introduced the concept of translation. Chapter 2, Cermin Ajaib Dunia Fantasia: Bayangan yang Memberontak, focused on reflection. Chapter 3, Kutukan Rotasi Sang Monster Bayangan, introduced rotation. Chapter 4, DilatasiMan, focused on dilation. Each chapter used fantasy situations to contextualize the mathematical concepts.

Table 9. Design results of the educational fantasy comic

Component	Chapter 1	Chapter 2	Chapter 3	Chapter 4
Topic	Translation	Reflection	Rotation	Dilation
Story title	Petualangan Dimensi Fantasia	Cermin Ajaib Dunia Fantasia: Bayangan yang Memberontak	Kutukan Rotasi Sang Monster Bayangan	DilatasiMan
Storyline	Max and Luna are transported into Fantasia through a transporter machine. They learn that	Max and Luna find a magical mirror that produces incorrect reflections. They learn reflection	Max and Luna encounter Rotarion, a monster that randomly rotates	Max and Luna face Rokar, a powerful giant. They learn dilation using scale factors to

	objects can move according to specific displacement patterns. When facing a broken path, they use translation to shift positions on a coordinate plane.	concepts to determine accurate images across a given line.	objects. They learn about center of rotation and angle of rotation to solve the problem.	understand changes in size and position.
Mathematical focus	Direction, distance, and coordinate displacement	Reflection line and image position	Center of rotation and angle of rotation	Scale factor, enlargement, and reduction
Learning activity	Observing displacement and solving translation problems	Identifying reflected images and solving reflection tasks	Determining rotation results based on angle and center	Analyzing size changes and applying dilation rules
Affective support	Encourages courage to try	Encourages accuracy and confidence	Encourages self-persistence in facing challenges	Encourages self-confidence in solving final tasks

The design results showed that the educational fantasy comic was developed as a structured learning medium that integrates mathematical concepts with story-based learning. The narrative structure was expected to help students understand geometry transformation in a more concrete and meaningful way.

Development stage

The development stage involved producing the comic prototype, validating the product, revising the product, and conducting a limited trial. The comic was developed in visual and narrative form, supported by illustrations, character dialogue, mathematical explanations, quizzes, and self-reflection activities. The prototype was validated by material and media experts to determine its feasibility before being implemented in classroom learning. The validation process assessed three main aspects: content feasibility, comic construction, and language. Content feasibility referred to the accuracy and relevance of the geometry transformation material. Comic construction referred to the organization, visual structure, and suitability of the comic format. Language referred to clarity, readability, and appropriateness for junior high school students.

Table 10. Material validation results of the educational fantasy comic

No	Assessment Aspect	Score
1	Content feasibility	40
2	Comic construction	31
3	Language	20
	Average percentage	**82.73%**

The validation result showed that the educational fantasy comic obtained an average percentage of **82.73%**. Based on the validity criteria, this result falls into the **very valid** category. This indicates that the comic met the required standards in terms of content, construction, and language. Therefore, the product was considered feasible to be used in the next development stage after minor revisions.

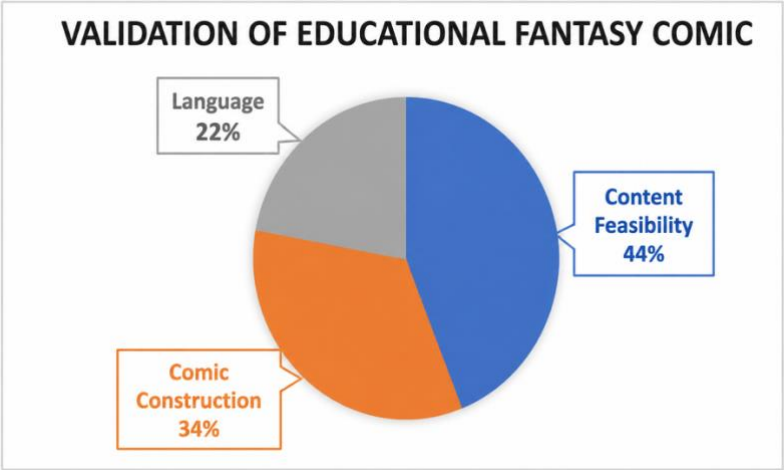

Figure 3. Material validation results of the educational fantasy comic

Figure 3 presents the validation results visually, showing the contribution of each assessed aspect to the overall validity score. The visual presentation supports easier interpretation of the validation findings. The high validation percentage indicates that the product had strong feasibility as an instructional medium for geometry transformation learning. After expert validation, the product was revised based on validator feedback. The revision process focused on improving content clarity, visual presentation, and language accuracy. After the revision, a limited trial was conducted with students as end users. This limited trial aimed to obtain students' responses regarding the attractiveness, usability, readability, and relevance of the comic.

Table 11. Students' responses to the educational fantasy comic

Aspect	Total Score	Mean	Percentage	Category
Display	124	4.13	82.67%	Very Good
Material	83	4.15	83.00%	Very Good
Language	84	4.20	84.00%	Very Good
Usability and attractiveness	120	4.00	80.00%	Very Good
Overall average		**4.12**	**82.42%**	**Very Good**

Table 11 shows that students gave positive responses to all assessed aspects. The highest score was obtained in the language aspect, with a mean of 4.20 and a percentage of 84.00%. This indicates that the language used in the comic was understandable and suitable for students. The material aspect obtained a mean of 4.15 and a percentage of 83.00%, indicating that the content was perceived as relevant and helpful. The display aspect obtained a mean of 4.13 and a percentage of 82.67%, suggesting that the visual presentation was attractive. The usability and attractiveness aspect obtained a mean of 4.00 and a percentage of 80.00%, which was also categorized as very good. Overall, the comic obtained a mean score of 4.12 with a percentage of 82.42%, indicating that the comic was practical and attractive for use in learning. Reliability testing was also conducted during the limited trial stage to determine the consistency of the instruments used in the study. The reliability test was performed using Cronbach's Alpha with SPSS. Two instruments were tested: the student response questionnaire and the self-esteem questionnaire.

Table 12. Reliability test of the student response questionnaire

Cronbach's Alpha	Number of Items
0.766	11

Table 13. Reliability test of the self-esteem questionnaire

Cronbach's Alpha	Number of Items
0.940	20

The reliability test results showed that the student response questionnaire obtained a Cronbach's Alpha value of 0.766, which indicates high reliability. Meanwhile, the self-esteem questionnaire obtained a Cronbach's Alpha value of 0.940, which indicates very high reliability. These results show that both instruments were reliable and suitable for use in the implementation and evaluation stages.

Table 14. Summary of product quality at the development stage

Evaluation Aspect	Result	Category	Interpretation
Product validity	82.73%	Very valid	The comic is feasible for learning after minor revision
Student response	82.42%	Very good / practical	The comic is attractive and easy to use
Student response questionnaire reliability	0.766	High	The instrument is reliable
Self-esteem questionnaire reliability	0.940	Very high	The instrument is highly reliable

Table 14 summarizes the development stage findings. The results indicate that the educational fantasy comic had strong feasibility, practicality, and instrument reliability before being implemented in classroom learning.

Implementation Stage

The implementation stage was carried out by applying the educational fantasy comic in geometry transformation learning. The comic was used in the experimental class, while the control class received conventional instruction. The learning activities in the experimental class were conducted gradually according to the comic chapters. Students read the story, observed illustrations, discussed mathematical problems, completed quizzes, and solved geometry transformation exercises.

Figure 4. Implementation of the educational fantasy comic in learning

Figure 4 shows the use of the educational fantasy comic during classroom learning. Students interacted with the comic through reading activities, visual observation, discussion, and problem-

solving tasks. The comic provided a structured sequence that guided students from narrative context to mathematical concept exploration. During implementation, the teacher acted as a facilitator. The teacher guided students in connecting the comic storyline with formal mathematical concepts. The teacher also encouraged students to ask questions, discuss ideas, and explain their reasoning. This role was important to ensure that students did not only enjoy the story but also understood the mathematical meaning embedded in the comic.

Figure 5. Teacher as facilitator

Figure 5 illustrates the teacher's role in facilitating learning through the comic. The teacher helped students interpret visual representations, connect story situations with geometry transformation concepts, and reflect on problem-solving strategies. The implementation process showed that the comic supported a more active and student-centered learning environment. Overall, the implementation results indicated that students were more engaged in the learning process. Students appeared more willing to participate in discussions and more confident in expressing their ideas. The combination of fantasy narrative, visual representation, and guided activities helped create a learning environment that was enjoyable and meaningful.

Evaluation Stage

The evaluation stage was conducted to determine the effectiveness of the educational fantasy comic in improving students' mathematical reasoning and self-esteem. Data were obtained from the experimental and control classes. Before hypothesis testing, prerequisite tests were conducted, including normality and homogeneity tests. The normality test was conducted using Kolmogorov–Smirnov and Shapiro–Wilk tests, while the homogeneity test was conducted using Levene's test. After the assumptions were met, hypothesis testing was carried out using the Independent Samples t-test.

Evaluation of Mathematical Reasoning

The first effectiveness analysis focused on students' mathematical reasoning. Normality testing was conducted on pretest and posttest data from both the control and experimental classes.

Table 15. Normality test of mathematical reasoning

Class	Kolmogorov–Smirnov Statistic	df	Sig.	Shapiro–Wilk Statistic	df	Sig.
Pretest Class 9.1 Control	0.165	24	0.090	0.938	24	0.145
Posttest Class 9.1 Control	0.178	24	0.049	0.954	24	0.328
Pretest Class 9.2 Experimental	0.181	24	0.041	0.938	24	0.149
Posttest Class 9.2 Experimental	0.209	24	0.008	0.918	24	0.052

Table 15 shows that the Shapiro–Wilk significance values for all mathematical reasoning data were greater than 0.05. The pretest control class obtained a significance value of 0.145, the posttest control class obtained 0.328, the pretest experimental class obtained 0.149, and the posttest experimental

class obtained 0.052. These results indicate that the mathematical reasoning data were normally distributed. Therefore, the data met the normality assumption required for parametric testing.

Table 16. Homogeneity test of mathematical reasoning

Basis of Test	Levene Statistic	df1	df2	Sig.
Based on mean	0.183	3	92	0.908
Based on median	0.092	3	92	0.964
Based on median and adjusted df	0.092	3	90.653	0.964
Based on trimmed mean	0.158	3	92	0.924

The homogeneity test results in Table 16 show that the significance value based on mean was **0.908**, which is greater than **0.05**. This indicates that the variance of mathematical reasoning data was homogeneous. Since both normality and homogeneity assumptions were met, the Independent Samples t-test was conducted.

Table 17. Independent samples t-test of mathematical reasoning

Assumption	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI Lower	95% CI Upper
Equal variances assumed	0.083	0.774	-2.832	46	0.007	-10.625	3.752	-18.177	-3.073
Equal variances not assumed			-2.832	45.420	0.007	-10.625	3.752	-18.180	-3.070

The Independent Samples t-test showed a significance value of 0.007, which is lower than 0.05. This result indicates a statistically significant difference in mathematical reasoning between the experimental and control classes. The mean difference of -10.625 indicates that the two groups differed in their mathematical reasoning outcomes after the intervention. Therefore, the educational fantasy comic had a significant effect on improving students' mathematical reasoning.

Evaluation of Self-Esteem

The second effectiveness analysis focused on students' self-esteem. Normality testing was conducted on pretest and posttest data from both control and experimental classes.

Table 18. Normality test of self-esteem

Class	Kolmogorov–Smirnov Statistic	df	Sig.	Shapiro–Wilk Statistic	df	Sig.
Pretest Class 9.1 Control	0.137	24	0.200	0.947	24	0.237
Posttest Class 9.1 Control	0.132	24	0.200	0.922	24	0.066
Pretest Class 9.3 Experimental	0.146	24	0.200	0.938	24	0.146
Posttest Class 9.3 Experimental	0.098	24	0.200	0.987	24	0.984

Table 18 shows that all Shapiro–Wilk significance values were greater than 0.05. The pretest control class obtained 0.237, the posttest control class obtained 0.066, the pretest experimental class obtained 0.146, and the posttest experimental class obtained 0.984. These results indicate that the self-esteem data were normally distributed. Therefore, the self-esteem data met the normality assumption.

Table 19. Homogeneity test of self-esteem

Basis of Test	Levene Statistic	df1	df2	Sig.
Based on mean	1.443	3	92	0.235
Based on median	1.391	3	92	0.251
Based on median and adjusted df	1.391	3	82.851	0.251

Based on trimmed mean	1.499	3	92	0.220

The homogeneity test results in Table 19 show that the significance value based on mean was 0.235, which is greater than 0.05. This indicates that the variance of self-esteem data was homogeneous. Therefore, the data fulfilled the requirements for parametric testing using the Independent Samples t-test.

Table 20. Independent samples t-test of self-esteem

Assumption	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI Lower	95% CI Upper
Equal variances assumed	0.039	0.845	-2.392	46	0.021	-6.875	2.874	-12.660	-1.090
Equal variances not assumed			-2.392	45.989	0.021	-6.875	2.874	-12.660	-1.090

The Independent Samples t-test showed a significance value of **0.021**, which is lower than **0.05**. This result indicates a statistically significant difference in self-esteem between the experimental and control classes. The mean difference of **-6.875** shows that the self-esteem scores differed between students who learned using the educational fantasy comic and those who learned through conventional instruction. Therefore, the educational fantasy comic had a significant effect on improving students' self-esteem.

Summary of effectiveness results

To provide a clearer overview of the effectiveness results, the statistical findings are summarized in Table 21.

Table 21. Summary of effectiveness testing

Variable	Normality	Homogeneity	Sig. t-test	Interpretation
Mathematical reasoning	Normal	Homogeneous	0.007	Significant difference
Self-esteem	Normal	Homogeneous	0.021	Significant difference

Table 21 shows that both mathematical reasoning and self-esteem met the assumptions of normality and homogeneity. The t-test results showed significant differences for both variables. These findings confirm that the educational fantasy comic was effective in improving students' mathematical reasoning and self-esteem.

Overall product evaluation

The overall evaluation of the product was based on three main criteria: validity, practicality, and effectiveness. The validity score was obtained from expert validation, the practicality score was obtained from student responses, and the effectiveness results were obtained from statistical hypothesis testing.

Table 22. Overall evaluation of the educational fantasy comic

Evaluation Aspect	Result	Category	Conclusion	Evaluation Aspect	Result	Category
Validity	82.73%	Very valid	The comic is feasible for use in learning	Validity	82.73%	Very valid
Practicality	82.42%	Very good / very practical	The comic is easy and attractive to use	Practicality	82.42%	Very good / very practical

Effectiveness: mathematical reasoning	p = 0.007	Significant	The comic improves mathematical reasoning	Effectiveness: mathematical reasoning	p = 0.007	Significant

Table 22 shows that the educational fantasy comic met all quality indicators. The product was categorized as very valid, very practical, and effective. Therefore, the developed comic can be considered suitable for use as an instructional medium in geometry transformation learning.

Product revision

The evaluation stage also involved product revision based on expert feedback, student responses, and implementation findings. The main revision made by the researchers was related to punctuation marks in comic dialogue. This revision was conducted to improve the readability and clarity of communication among the characters. After revision, the educational fantasy comic became more suitable for students' learning needs. Thus, the evaluation stage did not only measure product effectiveness but also served as a basis for improving the final quality of the learning media.

Final result of product development

Based on the complete ADDIE development process, the educational fantasy comic developed in this study was found to be valid, practical, and effective. The comic successfully integrated fantasy narratives, geometry transformation concepts, mathematical reasoning activities, and self-esteem reinforcement. The product provided students with a visual and contextual learning experience that supported both cognitive and affective learning outcomes. Therefore, the final product can be used as an alternative instructional medium for junior high school mathematics learning, particularly in geometry transformation topics.

Discussion

The findings of this study indicate that the educational fantasy comic developed has met the criteria of validity, practicality, and effectiveness, demonstrating its strong potential as an instructional medium in mathematics education. The integration of narrative and visual elements within the comic provides a meaningful learning experience that bridges abstract mathematical concepts and students' real-world understanding (Abrori et al., 2024; Purba et al., 2025). This result reinforces the growing body of research emphasizing the importance of visual-based and contextual learning in enhancing students' cognitive engagement. The use of comics as a learning medium extends beyond simple visualization by embedding mathematical problems within structured storylines (Matuk et al., 2021; Purba et al., 2025; Tay et al., 2024). This approach allows students to engage in creative mathematical reasoning through contextualized problem-solving situations. Compared to conventional instruction, which often emphasizes procedural fluency, the comic-based approach promotes deeper conceptual understanding. This finding aligns with previous studies that highlight the role of narrative-based learning in fostering higher-order thinking skills (Huang & Liang, 2025; Ismiyanto et al., 2026; Namaziandost et al., 2026; Reyes & Villanueva, 2024). In particular, the contextual nature of the comic supports students in connecting mathematical concepts with meaningful experiences. Furthermore, the storyline structure enables students to follow logical reasoning processes in a sequential manner. Therefore, the overall findings suggest that educational fantasy comics provide an effective alternative to traditional instructional methods in mathematics learning.

From the perspective of validity, the obtained score of 82.73% indicates that the developed comic meets the required standards in terms of content, construction, and language. This high level of validity suggests that the material is accurate, well-structured, and appropriate for the target learners. The visual representation within the comic plays a critical role in transforming abstract mathematical concepts into more concrete forms (Abrori et al., 2024; Lestari et al., 2021). This

supports students in understanding geometry transformation concepts more effectively. Similar findings have been reported in studies that emphasize the effectiveness of visual and contextual learning media in improving conceptual understanding. Compared to traditional textbooks, which rely heavily on symbolic representation, visual media offer more intuitive and accessible explanations (Lacković & Olteanu, 2020; Tang, 2023). The integration of images, dialogue, and narrative context enhances students' comprehension by providing multiple modes of representation (Brown, 2022; Kendeou et al., 2020; Nurjamin et al., 2025). In addition, the alignment between content and instructional objectives ensures that the comic functions as a structured learning tool. The validation results also confirm that the design elements are suitable for supporting both cognitive and affective learning processes. Therefore, the high validity score reflects the appropriateness of the developed comic as an instructional medium.

In terms of practicality, the average score of 4.12 (82.42%) indicates that the educational fantasy comic is easy to use and well accepted by both students and teachers. This finding suggests that the comic is not only attractive but also functional in supporting classroom learning activities. Students reported that the visual and narrative elements made the learning process more engaging and less monotonous. Compared to conventional learning materials, the comic format provides a more interactive and enjoyable experience (Aladsani, 2024). This aligns with previous research showing that visually rich and interactive media can increase student engagement and motivation (Hidayati & Slamet, 2025; Ji et al., 2025; Muir et al., 2022; Wong & Hughes, 2023). The structured presentation of content also allows students to learn independently, which supports self-paced learning. In addition, the integration of exercises within the storyline encourages students to actively participate in problem-solving activities. Teachers also found the comic helpful in facilitating discussions and guiding students' understanding. The practicality of the comic reflects its usability in real classroom contexts without requiring significant changes to existing teaching practices. Therefore, the results confirm that the educational fantasy comic is a practical and user-friendly learning medium.

The effectiveness results demonstrate that the educational fantasy comic significantly improves students' mathematical reasoning compared to conventional instruction. The use of contextual narratives within the comic encourages students to analyze situations, identify patterns, and construct logical arguments. This process supports the development of higher-order thinking skills, particularly mathematical reasoning. Compared to traditional methods, which often emphasize procedural practice, the comic-based approach requires students to engage in active problem-solving (Ismiyanto et al., 2026). This finding is consistent with previous studies indicating that meaningful and contextual learning experiences enhance reasoning skills (Basid et al., 2024; Lee et al., 2024; Thamrin et al., 2024; Toheri et al., 2020). The visual representation of transformation processes also helps students understand spatial relationships more effectively. This is particularly important in geometry transformation, where visualization plays a key role in conceptual understanding. In addition, the sequential structure of the comic supports step-by-step reasoning, allowing students to follow the logic of each transformation. The improvement in reasoning ability suggests that the comic successfully integrates cognitive and visual elements. Therefore, the educational fantasy comic can be considered an effective medium for enhancing students' mathematical reasoning.

Beyond cognitive outcomes, this study also demonstrates a significant improvement in students' self-esteem after using the educational fantasy comic. The narrative structure and positive character representation create a supportive learning environment that encourages students to participate actively. Students are exposed to characters who demonstrate confidence, persistence, and problem-solving skills, which serve as role models. This contributes to the development of students' confidence in their own abilities. Compared to conventional learning environments, which

may induce anxiety, the comic-based approach provides a more relaxed and enjoyable atmosphere. This finding is consistent with research highlighting the importance of affective factors in mathematics learning. The integration of motivational dialogue within the comic reinforces positive attitudes toward learning. In addition, successful problem-solving experiences within the comic contribute to students' sense of achievement. However, this study has several limitations, including a relatively small sample size and a focus limited to geometry transformation. Future research is recommended to expand the application of educational comics to other mathematical topics and to integrate digital technology for broader implementation. Overall, the findings suggest that educational fantasy comics offer a promising approach for enhancing both cognitive and affective aspects of mathematics learning.

Implications

The findings of this study have important implications for mathematics education, particularly in the development of innovative instructional media that integrate cognitive and affective dimensions. The use of educational fantasy comics demonstrates that narrative-based visual media can effectively support students' understanding of abstract mathematical concepts. This suggests that teachers should consider incorporating storytelling and visual representation into mathematics instruction to enhance conceptual clarity. The integration of contextual problems within a narrative framework also implies that learning should be designed to promote active engagement and reasoning rather than passive memorization. In addition, the improvement in students' self-esteem indicates that instructional media should not only focus on academic achievement but also on students' emotional and psychological development. Therefore, educators are encouraged to create learning environments that are supportive, engaging, and confidence-building. The results also imply that curriculum developers can integrate visual-narrative learning approaches into mathematics teaching materials to improve overall learning quality. Furthermore, the practicality of the developed comic suggests that such media can be easily implemented without requiring significant changes to existing teaching practices. This highlights the potential for scalable application in different educational contexts. The findings also provide a basis for integrating interdisciplinary approaches, combining elements of art, storytelling, and mathematics. In terms of educational policy, the results support the need for promoting innovative and student-centered learning strategies in schools. Finally, this study contributes to the advancement of research on instructional media by demonstrating that educational fantasy comics can serve as an effective tool for enhancing both mathematical reasoning and students' self-esteem.

Limitations and Suggestions for Future Research

This study has several limitations that should be acknowledged when interpreting the findings. First, the sample size was relatively small and limited to a single school, which may restrict the generalizability of the results to broader educational contexts. Second, the participants were drawn from a specific grade level, so the applicability of the findings to other age groups or educational levels remains uncertain. Third, the study focused only on geometry transformation material, which limits the scope of the findings to a particular topic in mathematics. Fourth, the duration of the implementation was relatively short, making it difficult to assess the long-term impact of the educational fantasy comic on students' learning outcomes. Fifth, the study relied primarily on quantitative measures, which may not fully capture the depth of students' learning experiences and perceptions. Sixth, although the instruments used were reliable, self-reported data such as questionnaires may be influenced by subjective bias. Seventh, the study did not include a detailed analysis of individual differences, such as learning styles or prior knowledge, which may affect learning outcomes. Based on these limitations, future research is recommended to involve larger and more diverse samples across different schools and educational levels. In addition, further

studies could explore the application of educational fantasy comics in other mathematical topics to examine their broader effectiveness. Longitudinal research is also needed to investigate the sustainability of the learning improvements over time. Moreover, integrating qualitative methods such as interviews and classroom observations could provide deeper insights into students' learning processes. Finally, future studies are encouraged to develop digital or interactive versions of educational comics to enhance accessibility and adapt to the demands of technology-based learning environments.

CONCLUSION

This study concludes that the educational fantasy comic developed for geometry transformation learning is a valid, practical, and effective instructional medium. The validation results indicate that the comic meets the required standards in terms of content accuracy, structural organization, and language appropriateness. The practicality findings show that the comic is easy to use, engaging, and well accepted by both students and teachers in classroom settings. The effectiveness analysis demonstrates that the use of the educational fantasy comic significantly improves students' mathematical reasoning compared to conventional learning methods. In addition, the comic contributes to enhancing students' self-esteem by creating a supportive and enjoyable learning environment. The integration of narrative storytelling and visual representation enables students to better understand abstract mathematical concepts. The use of contextual problems within the comic encourages active learning and promotes higher-order thinking skills. Furthermore, the presence of positive characters and motivational elements supports students' confidence and persistence in learning mathematics. These findings indicate that combining cognitive and affective approaches in instructional design can lead to more meaningful learning outcomes. The study also highlights the importance of using innovative and student-centered learning media in mathematics education. Overall, the educational fantasy comic offers an alternative teaching strategy that can enhance both conceptual understanding and emotional engagement. Therefore, this study provides evidence that educational fantasy comics can be effectively implemented to improve the quality of mathematics learning, particularly in geometry transformation topics.

AUTHOR CONTRIBUTIONS STATEMENT

Wanda Nugroho Yanuarto conceptualized and designed the study, led the development of the educational fantasy comic, and conducted the data analysis related to mathematical reasoning and self-esteem outcomes. Faizal Abdul Hafizh contributed to the instructional design of the comic, supported data collection and implementation in the classroom, and assisted in interpreting the research findings. Both authors collaboratively developed the research framework, contributed to writing and revising the manuscript, critically reviewed the content for intellectual accuracy, and approved the final version of the manuscript.

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