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E-Comic-Based Mathematics Learning: Its Effect on Logical Reasoning and Motivation among Students in Urban and Rural Areas

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Abstract. *Many junior high school students perceive mathematics as a difficult subject due to the use of instructional techniques that are less engaging and limited in context. As technology continues to develop, digital media—including e-comics—have become innovative tools for enhancing students' motivation and logical–mathematical reasoning. This quasi-experimental study involved 100 eighth-grade students from both an urban school in Surabaya, the capital city of East Java Province, and a rural school in Jiwan–Madiun, one of the districts in East Java, using a pretest–posttest control group design, using a pretest–posttest control group design. The experimental and control group from each location as the samples. A questionnaire to measure the students' motivation and mathematics logical reasoning questions to assess logical-mathematical reasoning are the instrument. Statistical analysis included regression, Pearson correlation, and ANOVA test. The effect size ($R^2 = 0.466$) demonstrated the strength of the model. The results revealed that e-comic-based learning significantly improved students' motivation and logical-mathematical reasoning, with greater effects observed in urban schools. Furthermore, there was a moderately positive correlation between learning motivation and logical-mathematical reasoning abilities ($r = 0.587$). These findings suggest that integrating e-comics can effectively enhance learning outcomes while bridging urban-rural educational gaps.*

Keywords*: e-comic, learning motivation, logical reasoning, quasi-experiment, urban and rural students*

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Introduction

Students still regard mathematics as one of the most difficult subjects to learn in school (Chand et al., 2021). The abstract nature of mathematics has contributed to the perception that it is a challenging and complex subject throughout history (Uegatani et al., 2024). A positive relationship has been found between logical reasoning patterns and digital literacy skills among pre-service teachers, suggesting that students with stronger reasoning abilities tend to adapt better to digital learning environments (Alpian et al., 2022). The quick development of digital technology has prompted instructors all over the world to incorporate cutting-edge media to improve students' comprehension and motivation to learn (Ferreira et al., 2023; Zhang, 2025).

Learning media play a crucial role in fostering student engagement and active participation (Zhao et al., 2022). Due to their ability to combine textual content with visual narratives that support contextual learning, e-comics have become a compelling choice among digital learning media (Khotimah & Hidayat, 2022). Previous empirical research has shown that digital comics

can enhance students' mathematics engagement and comprehension through storytelling and visuals (Amin & Bahri, 2024; Manalo et al., 2024). However, most of this research focused on emotional or motivational outcomes rather than their influence on logical-mathematical reasoning skills, which are crucial for mathematical competence.

Logical reasoning is fundamental in the cognitive and academic development of students, facilitating problem solving and critical reasoning (Cedeño-Bailón et al., 2024). However, there remains a limited amount of research on the impact of e-comics on logical-mathematical reasoning, especially in junior high school mathematics. Although interactive media increased involvement, studies like Wijayanti et al. (2023) and Fuldiaratman and Minarni (2021) did not directly examine students' reasoning skills. This disparity emphasizes the necessity for empirical evidence linking e-comic-based learning to improving students' capacity for logical thought.

Furthermore, variations between urban and rural educational environments greatly shape how students engage with technology and learning media. Previous studies indicate that urban students often achieve higher mathematics scores due to better access to infrastructure, skilled teachers, and technological resources. As Apaza et al. (2024) explained the positive gap favouring urban students is explained by differences in school resources, teaching quality, and socioeconomic background. In contrast, research by Yahaya et al. (2025) highlights that rural schools still face persistent challenges such as limited facilities and lower student participation, primarily due to fewer contextualized learning experiences. These disparities suggest that the effectiveness of e-comics may vary across settings depending on cultural factors and the level of digital accessibility (Ahiaku et al., 2025). Nevertheless, only a few studies have explored the impact of digital learning interventions on Indonesian students across urban and rural contexts.

Up in light of these factors, our work fills several research gaps. First, it extends earlier research that solely looked at engagement or enjoyment by examining the causal effects of e-comic-based learning on students' motivation and logical reasoning (Johar et al., 2023; Kusmaryono & Maharani, 2025; Yulaichah et al., 2024). Second, it offers a comparative analysis between rural and urban environments, shedding light on contextual equity in the efficacy of digital learning. Lastly, it adds to the body of knowledge by connecting motivation and logical-mathematical intelligence within an e-comic learning framework an intersection that has not received much attention in previous ICT-based interventions. Accordingly, this study seeks to answer the following research questions:

RQ-1: What is the impact of e-comics on junior high school students' motivation to learn mathematics in both urban and rural schools?

RQ-2: How are students' logical-mathematical reasoning skills in urban and rural schools affected by e-comic media?

RQ-3: After e-comic-based learning, is there a significant correlation between students' logical-mathematical reasoning ability and learning motivation?

By answering these research questions, this study aims to make a theoretical contribution by enriching the study of the relationship between digital media and the cognitive development of students. This research is expected to produce learning innovations that are fair, inclusive, and adaptable to various educational contexts in Indonesia. In addition, the findings of this study are expected to serve as a reference for educators in designing technology-based learning strategies that are relevant to the needs and characteristics of today's students.

Method

Research Design

This study employed a quasi-experimental design with a pretest-posttest control group approach. The design was selected because it allows for a comparison between experimental and control groups while considering contextual differences between urban and rural schools (Hermawan & Hariyanto, 2022). The quasi-experimental type was chosen due to the practical constraints in fully randomizing participants within school settings.

Four groups were formed as follows: (1) Urban Experimental Group (E_1): Students in urban schools taught using e-comic-based learning. (2) Urban Control Group (C_1): Students in urban schools taught using conventional learning methods. (3) Rural Experimental Group (E_2): Students in rural schools taught using e-comic-based learning. (4) Rural Control Group (C_2): Students in rural schools taught using conventional methods.

Examining treatment effects (using e-comics versus traditional instruction) and contextual effects (urban versus rural settings), as well as potential interaction effects, was made possible by the design. Mathematics logical reasoning and learning motivation were assessed prior to (pretest) and after (posttest) the intervention in order to track treatment-related changes. The experimental design of this study can be seen in Table 1.

Table 1. Experimental design of the study

School Location	Group Type	Treatment	Number of Students (n)	Description
Urban (SMPN 34 Surabaya)	Experimental Group	Received e-comic-based learning intervention	25	Students learned mathematics using e-comic media.
	Control Group	Received conventional (textbook-based) learning	25	Students learned through traditional methods without e-comics.
Rural (SMPN 1 Jiwan)	Experimental Group	Received e-comic-based learning intervention	25	Students learned mathematics using e-comic media.
	Control Group	Received conventional (textbook-based) learning	25	Students learned through traditional methods without e-comics.

Participants

Fifty students from an urban junior high school located in the capital of Surabaya city, and fifty students from a rural junior high school from located in Madiun (approximately 164 km from Surabaya), made up 100 participants in the study. One experimental class and one control class, each with about 25 pupils, were contributed by each school. Participants were eighth-grade students aged 13–14-years who followed the same Merdeka Curriculum and had comparable academic backgrounds. Purposive sampling was used to choose the schools based on several criteria: (1) comparable curriculum implementation, (2) availability of digital learning facilities (computers or tablets), (3) teacher readiness to integrate e-comic media, and (4) administrative approval from school authorities.

To ensure that the groups were equal in terms of students' academic ability and past mathematical achievement, mathematics teachers from both schools were consulted prior to the intervention. Pretest scores on motivation and logical thinking were statistically evaluated to ensure baseline comparability; the results showed no significant difference ($p > 0.05$) among the four groups, indicating that they were comparable before the beginning of the study. Class-level matching was employed to preserve equivalency even though full random assignment was not possible due to administrative constraints at the school. The following criteria were used to match the classes: (1) mean mathematics scores from the previous semester, (2) students' age and gender distribution, and (3) teachers' years experience.

One class from each school was randomly assigned to the experimental condition and another to the control condition after matching. This approach preserved ecological validity while allowing partial randomization and reducing potential selection bias. Thus, this design helps ensure that differences in outcomes are more likely to be due to treatment than to uncontrolled external factors.

Materials

Digital comics covering a variety of subjects, including Social Arithmetic, Linear Equation in One Variable, Reasoning, and Comparison, were used as learning resources. The ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) was used in the creation of this digital comic. To ensure that the storyline and problem contexts aligned with the learning objectives, curriculum standards and student characteristics were examined during the analysis phase. During the design phase, scripts, dialogues, and graphic sequences were developed to simulated real mathematical problem-solving situation that encourage logical reasoning.

Figure 1. Content and characters of digital comics with social arithmetic material

The e-comic was developed using Pixton and Canva, incorporating narrative text, graphic illustrations, and brief interactive challenges at the end of each part. To increase student engagement, motivational aspects were integrated through familiar characters, vibrant graphics, and context-based humor. In order to guarantee equitable access to technology, the e-comic was used in classrooms via tablets and computers provided by the school. Lastly, two media experts and two mathematics teachers provided expert validation during the assessment process, assessing readability, engagement, and content accuracy.

Before being implemented in the study, this e-comic was reviewed several experts and passed the validity, practicality, and effectiveness tests in classroom trials. This shows that the digital comics used meet the quality standards as a learning medium suitable for students to support the learning process. The following is an example of the mathematics e-comic illustration, along with the dialogue presented in Figure 1.

Instruments

Three instruments were utilized to collect data: a descriptive test (T-1), a learning motivation questionnaire (T-2B), and an interview guideline. Five open-ended questions measuring students' logical-mathematical reasoning skills were included in the descriptive test (pretest and posttest), which was organized according to logical-mathematical reasoning indicators. The learning motivation questionnaire (T-2B) consisted of 24 five-scale questions adapted from the Motivation Assessment Scale (Ferland et al., 2022) and was given after the learning process. The interview guideline was employed to capture how the mathematics

instructor in the experimental class felt about using e-comics in the classroom. Before being used, all instruments were validated and approved by media and material experts.

Mathematics Logical Thinking Test (Descriptive Test / T-1)

The descriptive test was developed to assess students' logical-mathematical reasoning ability based on indicators from Gardner's multiple intelligences theory (Morgan, 2021) and Bloom's revised cognitive taxonomy (Anderson & Krathwohl, 2001). The five open-ended items measured pattern recognition and generalization, numerical reasoning, deductive and inductive reasoning, classification, relational analysis, and logical problem-solving using mathematical operations. Each item required students to explain their logical-mathematical reasoning process, not only to compute answers. Example item:

> *A store gives a 10% discount on goods priced at Rp50,000. If a student buys 3 items, what is the total payment? Explain the reasoning steps used.*

Students' responses were evaluated using a 4-point analytic rubric (0 = incorrect or no response; 4 = complete and logical reasoning). Two mathematics education experts independently scored all responses, and the resulting inter-rater reliability (Cohen's $\kappa = 0.87$) indicated a high level of consistency. Validity and reliability: (a) Content validity: Reviewed by three experts (mathematics education, educational psychology, instructional design); CVI = 0.92 (very valid). (b) Construct validity: Confirmed via Exploratory Factor Analysis (KMO = 0.81; Bartlett's test $p < 0.001$). (c) Reliability: Cronbach's $\alpha = 0.84$, indicating good internal consistency.

Learning Motivation Questionnaire (T-2B)

Students' motivation toward mathematics learning was measured using a 24-item Likert-scale questionnaire (1 = strongly disagree to 5 = strongly agree). The instrument was adapted and contextualized from the Motivation Assessment Scale (Ferland et al., 2022) and the Mathematics Learning Motivation Inventory (Doño & Mangila, 2021). It measured four key dimensions: (a) Intrinsic motivation (e.g., curiosity, enjoyment of math activities), (b) Extrinsic motivation (e.g., teacher encouragement, peer recognition), (c) Effort and persistence, and (d) Self-efficacy in mathematics. Example items:

> *I feel more interested in mathematics when the learning uses comic stories.*
> *Even when mathematics problems are difficult, I try to finish them.*
> *The visuals and stories in e-comics make me more motivated to learn.*

Validation and reliability procedures: (a) The questionnaire was reviewed by two psychologists and one mathematics education expert; CVI = 0.89. (b) Pilot-tested with 30 students outside the main sample to ensure clarity and cultural relevance. (c) EFA confirmed

four components explaining 67.4% of variance. (d) Cronbach's $\alpha = 0.91$, indicating excellent reliability across all dimensions.

Interview Guideline

Following the intervention, semi-structured interviews with mathematics teachers from the experimental groups were carried out. The interview guideline consisted of eight open-ended questions intended to investigate teachers' perspectives and experiences with the incorporation of e-comic-based learning. Examples of these questions included:

> *How do you perceive students' engagement and participation during e-comic learning?*
> *What challenges did you face when using e-comic media in mathematics teaching?*
> *In your opinion, how does this media affect students' logical reasoning and motivation?*

This analysis was used by researchers to identify teachers' thought patterns and real experiences during the learning process. The results of these interviews were then used to strengthen the interpretation of the research results and provide in-depth insights into the effectiveness and acceptance of the use of digital comics in the context of mathematics learning. Teacher responses were recorded, transcribed, and thematically analyzed to support the quantitative findings.

Data Analysis Techniques

Data were analyzed using SPSS version 26. Preliminary assumption testing included normality (Kolmogorov–Smirnov), homogeneity (Levene's test), and linearity, all of which were satisfied ($p > 0.05$). Inferential tests included: (1) Paired-samples t-test to measure pretest–posttest improvement within each group. (2) Two-way ANOVA (2 × 2 factorial design) to examine effects of media and school location. (3) ANCOVA when pretest differences appeared. (4) Pearson correlation to analyze the relationship between motivation and logical-mathematical reasoning.

Effect sizes were reported using Cohen's d and partial η^2. The results showed medium to large effects ($\eta^2 = 0.27–0.46$), indicating that the use of e-comics had a substantial impact on students' motivation and logical reasoning skills. These findings reinforce the evidence that the integration of interactive digital media in learning can significantly improve student engagement and conceptual understanding.

Procedure

The experimental groups received e-comic-based instruction throughout a four-week intervention (8 meetings, 80 minutes each), while the control groups received traditional instruction. SMPN 34 Surabaya, an urban school, and SMPN 1 Jiwan, Madiun, a rural school, were purposefully chosen. Both schools use the same Merdeka Curriculum and have instructors with comparable experience (8–12 years). Pretests conducted prior to the intervention revealed no discernible variation initial motivation or ability ($p > 0.05$). The ADDIE stages, which consisted of introduction, learning through digital comics (social arithmetic, linear equations, ratio), and reflection, were followed when learning using e-comics. The same material was used in control classes, but without the use of comics. A fidelity-of-implementation rate of 93.7% was attained based on classroom observations.

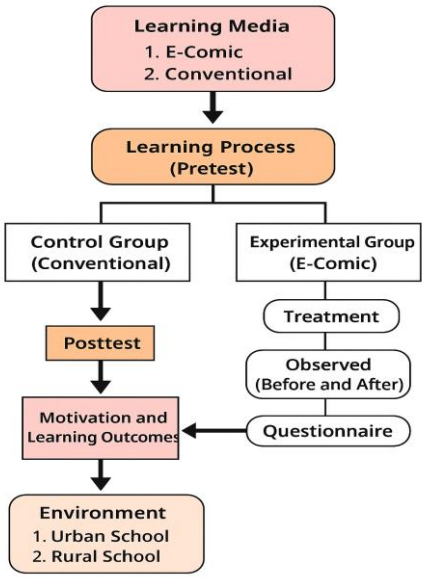

Figure 2. Research procedure

Ethical Considerations

This study complied with ethical research standards in educational contexts. Ethical approval was obtained from the Research Ethics Committee of Universitas Negeri Surabaya (Approval No. 034/UNESA/ETK/2025) prior to data collection. Before participation, researchers: (a) Informed school principals, teachers, students, and parents about the research objectives, procedures, and confidentiality of data; (b) Obtained written consent from school authorities and informed assent from students; (c) Ensured that participation was voluntary, and students could withdraw at any time without penalty; and (d) Guaranteed that collected data would be used solely for academic purposes and reported anonymously.

Results and Discussion

Students from urban schools (SMPN 34 Surabaya) in the experimental group that used e-comic media had an average motivation score of 126.8 (SD = 9.5) and an average logical-mathematical reasoning score of 84.6 (SD = 7.3). Students from rural schools (SMPN 1 Jiwan) in the same group obtained slightly lower averages, with a motivation score of 121.5 (SD = 10.2) and a logical-mathematical reasoning score of 79.8 (SD = 8.1). These differences in averages show that although both groups benefited from the use of digital comics, urban school students tended to show higher levels of motivation and reasoning ability than rural school students.

Students in the control group, on the other hand, who used traditional instruction without e-comics, scored lower overall. In contrast to the rural control group, which displayed averages of 105.6 (SD = 10.8) for motivation score and 70.4 (SD = 9.2) for logical-mathematical reasoning score, the urban control group had an average of 107.3 (SD = 11.1) for motivation score and 73.9 (SD = 8.6) for logical-mathematical reasoning score. These results indicate a clear pattern where students who learned using e-comics consistently demonstrated higher motivation and better logical reasoning abilities than those in the control groups. Furthermore, students in urban schools tended to perform slightly better than those in rural schools on both variables, suggesting that access to digital tools and prior exposure to visual media might influence learning engagement and performance.

The Kolmogorov-Smirnov test was used to test for normality. Students' motivation and logical-mathematical reasoning test results indicate a normal distribution. This indicates that the data meets the assumptions required for further parametric testing, thereby ensuring the reliability of subsequent inferential analysis.

Table 2. Normality test for baseline analysis: Urban and rural schools

Variables	Urban and rural schools	Kolmogorov-Smirnov[a]			Shapiro-Wilk
		Statistic	Df	Sig.	Statistic
Experimental motivation	SMPN 34 Surabaya	.200	25	.011	.886
	SMPN 1 Jiwan	.171	25	.057	.918
Control motivation	SMPN 34 Surabaya	.147	25	.172	.928
	SMPN 1 Jiwan	.135	25	.200*	.937
Experimental logical reasoning	SMPN 34 Surabaya	.154	25	.129	.952
	SMPN 1 Jiwan	.195	25	.015	.946
Control logical reasoning	SMPN 34 Surabaya	.194	25	.016	.944
	SMPN 1 Jiwan	.187	25	.025	.927

All the sig. values obtained were greater than 0.05, as shown in Table 2. These findings suggest that the data originates from a population is normally distributed. Therefore, it can be concluded that the sample data sufficiently met the characteristics of the population, allowing for valid comparisons between groups in further analysis.

The Impact of E-Comic Media on Students' Motivation

Before analyzing the statistical results, it is important to highlight a descriptive overview of student motivation in various school contexts. Descriptive statistics provide an initial understanding of how digital comics influence student enthusiasm and engagement in learning mathematics. This overview also aims to illustrate patterns of comparison in motivation between students in urban and rural schools before and after the implementation of digital comic-based learning. The following findings are derived from the research that was conducted using SPSS software:

Model Summary

Table 3. Model summary of regression analysis of e-comic media on the students' motivation

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.683[a]	.466	.455	10.627

The model summary in the output of linear regression shows how strongly the independent variable (free) and the dependent variable (bound) are related. Based on the calculation in the summary model, the results show that R = 0.683, indicating a strong correlation between the independent variables (group and school location) and students' learning motivation. The value of R^2 = 0.466 means that 46.6% of the variation in learning motivation can be explained by the variables group (experimental vs. control) and school location (urban vs. rural). This relatively high R^2 value indicates that the model has good predictive strength.

ANOVA (Model Significance Test)

Table 4. ANOVA test results of e-comic media on students' learning motivation

Model		Sum of Squares	df	Mean Square	F	Sig.
1.	Regression	9565.160	2	4782.580	42.349	<,001[b]
	Residual	10954.400	97	112.932		
	Total	20519.560	99			

a. Dependent Variable: E-Comic Learning on Learning Motivation
b. Predictors: (constant), Group, Urban and Rural Schools.

Based on the ANOVA calculation Table 4, it is obtained that F = 42.349 with sig. <0,001. This result means the regression model as a whole is significant. So, there is a joint influence between groups and school location on learning motivation.

Coefficients (Significance Test of Each Variable)

Table 5. Analysis of coefficients of e-comic media on students' motivation

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1.	(Constant)	126.400	6.887		18.353	<,001
	Urban and Rular Schools	.160	3.006	.005	.053	.958
	Group	-19.480	2.603	-.680	-7.484	<,001

a. Dependent Variable: E-Comic Learning on Learning Motivation

From Table 5, it can be interpreted that Group variable (Experiment vs Control) has B = -19.480, t = -7.484 and p <0.001. This means that the group has a significant effect on learning motivation, and the negative value means that if label 1 = experiment, and 2 = control, the control group has an average motivation lower than the control by 19.480 points. Meanwhile, the effect of school location (urban vs. rural) is not statistically significant, as shown by B = 0.160, t = 0.053, p = 0.958. This result suggests that school location does not influence learning motivation; in other words, students' motivation levels do not differ significantly between urban and rural schools within this model. From research findings presented above, it can be seen that there is an positive effect of learning using e-comic media on the learning motivation of junior high school students.

The Impact of E-Comic Media on Students' Logical-Mathematical Reasoning

To gain a deeper understanding of how digital media supports the development of higher-order thinking skills, an additional analysis was conducted that focused on students' logical-mathematical reasoning abilities. This study aimed to determine the extent to which the integration of digital comics affects students' logical reasoning performance in various school environments. The impact of e-comic media in instruction on students' logical-mathematical reasoning was analyzed using SPSS software, the following results are obtained:

Model Summary

Table 6. Model summary of results of analysis on e-comic media on students logical-mathematical reasoning

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.683[a]	.466	.455	10.627

a. Predictors: (Constant), Experimental Control, Location schools

According to Table 6, the experiment/control and school location variables account for 27% of the variation in on students logical-mathematical reasoning, with a R Square value of

0.270. Other factors outside of this model have an impact on the remaining 73%. It can be concluded that although the use of digital comics and the school context play a significant role, students' reasoning abilities are also influenced by additional variables such as teaching quality, learning environment, and individual differences among students.

ANOVA

Table 7. ANOVA test results of e-comic media on junior high school students' students logical-mathematical reasoning

No.	Model	Sum of Squares	df	Mean Square	F	Sig.
1.	Regression	5330.513	2	2665.257	17.948	<,001[b]
	Residual	14404.219	97	148.497		
	Total	19734.732	99			

a. Dependent Variabel: logical-mathematical reasoning
b. Predictors: (constant), Experimental Control, Location schools

Based on Table 7, the analysis shows that school location has a significant effect on logical-mathematical reasoning, where students in rural schools scored 11.02 points lower than those in urban schools ($p < 0.001$). In addition, the group effect is also significant, with students in the control group scoring 9.58 points lower than those who learned using e-comic media ($p < 0.001$). These findings indicate that e-comic–based learning has a positive and substantial impact on students' logical-mathematical reasoning, particularly in urban settings where access to digital tools and technological support is generally stronger.

Coefficients

Table 8. Coefficient analysis results of e-comic media on students' logical-mathematical reasoning

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1.	(Constant)	83.311	5.312		15.684	<,001
	Location Schools	-11.021	2.437	-.392	-4.522	<,001
	Experiment-Control	-9.579	2.437	-.341	-3.930	<,001

a. Dependent Variable: Students' Logical-Mathematical Reasoning

From Table 8, the regression results can be summarized as follows. First, the constant value of 83.311 indicates that students from urban schools who are in the control group have a predicted initial logical-mathematical reasoning score of 83.311. Second, the school location variable (coded as City = 0, Village = 1) shows a significant negative coefficient of –11.021 ($p < 0.001$), meaning that students from rural schools tend to score 11.021 points lower than their urban counterparts when placed in the same treatment condition. Third, the group variable (Experiment = 1, Control = 2) also shows a significant negative coefficient of –9.579 ($p < 0.001$), indicating that students in the control group scored 9.579 points lower than those in the experimental group

using e-comic media. Taken together, these results show that the regression model is significant, demonstrating that both school location and the type of instruction influence students' logical-mathematical reasoning. Learning with e-comics contributes positively and significantly to improving students' performance, and students from urban schools tend to achieve higher logical-mathematical reasoning than those from rural settings.

The Relationship between Learning Motivation and Mathematical Logical Reasoning Ability After Following Learning Using E-Comics

Furthermore, it was analyzed to find out the relationship between learning motivation and logical- mathematical reasoning ability after participating in learning using e-comics, especially in the experimental and control group by using Pearson correlation analysis that showed in Table 9. This analysis aims to determine the extent to which high levels of learning motivation are related to improvements in logical-mathematical reasoning abilities in students. These correlation findings provide additional support for the idea that affective factors, such as motivation, play an important role in influencing students' cognitive outcomes in mathematics learning using digital comics.

Table 9. Analysis results of the relationship between learning motivation and logical-mathematical reasoning after e-comic-based learning

		Motivation	Logical- Mathematical Reasoning
Motivation	Pearson Correlation	1	.587**
	Sig. (2-tailed)		<,001
	N	44	44
Logical-Mathematical Reasoning	Pearson Correlation	.587**	1
	Sig. (2-tailed)	<,001	
	N	44	44

The significance value (p) <0.001 indicates that the association is statistically significant because it is significantly smaller than $\alpha = 0.05$. The Spearman correlation (ρ) = 0.587 included in the moderate to strong category. Therefore, it can be said that students who use e-comic media to learn have a significant and positive relationship between their learning motivation and their logical-mathematical reasoning outcomes. In other words, the higher the students' learning motivation, the better their logical-mathematical reasoning performance. This demonstrates how motivation plays a significant role in e-comic-based mathematics learning performance in both urban and rural school contexts.

The results of this study indicate that the use of e-comic media has a significant positive effect on students' learning motivation and logical-mathematical reasoning abilities, regardless of school location (Farhan et al., 2024; Safitri et al., 2024). To ensure that the observed effects were attributable to the e-comic intervention rather than external factors, several potential

confounders were carefully controlled. First, by adopting the same lesson plans and instructional tempo in both experimental and control classrooms, the teacher's effect was reduced. Second, statistical analysis confirmed pre-test equality by showing no significant difference in baseline performance between groups ($p = 0.467$). Third, in order to account for disparities in digital access, all students used devices provided by the school, which reduced bias related to unequal technology ownership or experience. These methodological controls boost the study's internal validity and provide additional confidence that the improvements in motivation and reasoning are mostly due to the e-comic-based learning intervention.

The study's findings are consistent with past research emphasizing the potential of digital visual media for education. Yulaichah et al. (2024) found that digital comics greatly enhance student students' critical thinking skills and creativity in mathematics through realistic mathematics. Similarly, Li et al. (2024) discovered that gamified visual media increase intrinsic motivation and maintain students' focus, particularly in courses that call for abstract reasoning. The present results provide credence to the theory that visual storytelling enhances the emotional appeal and relevance of abstract concepts, hence fostering meaningful learning (Chaabi & Younes, 2025).

Interestingly, this study differs from Zhao et al. (2022) conclusions that the digital gap severely hindered rural students' learning outcomes. The current study also found that while the absolute scores of rural pupils were slightly lower than those of their urban counterparts, the relative growth of both groups was similar (Mohammadpour & Yón, 2024). This suggests that when technology access is equitable, e-comic media can offer comparable cognitive and motivational advantages in a range of educational contexts (Apostolou & Linardatos, 2023; Yousofi et al., 2025). These findings imply that equitable access to digital resources can mitigate the impact of location-based learning disparities.

The statistics reveal a consistent tendency across all groupings. Schools in rural regions are clearly lacking in these areas, whereas schools in cities have sufficient libraries, labs, computer classes, and other amenities (Shambare & Jita, 2025). However, rural students demonstrated similar relative improvements in learning outcomes and motivation (around +18 points in motivation improvement), indicating that e-comics effectively foster comprehension and engagement regardless of digital background (Farhan et al., 2024). This bolsters the notion that e-comics can bridge contextual gaps and serve as an inclusive learning medium when access conditions are standardized (Belda-Medina, 2024; López-Prados & Saez-de-Adana, 2023; Matuk et al., 2021).

When taken as a whole, these findings show the educational advantages of including e-comics into math classes. The media's combination of visual narrative, interactivity, and

contextual relevance appears to enhance both the cognitive and emotive aspects of learning. Future implementations should therefore focus on ensuring equitable access to technology and teacher preparation in addition to integrating digital comics, as these factors collectively determine the longevity and scalability of such innovative teaching approaches.

Conclusion

This study shows that junior high school students' enthusiasm and logical-mathematical reasoning abilities are significantly improved by using e-comics as a teaching tool in both urban and rural settings. This research demonstrates that the use of e-comics as an instructional medium significantly enhances junior high school students' enthusiasm and logical-mathematical reasoning skills in both urban and rural contexts. E-comics effectively boost student engagement, create a more enjoyable learning experience, and facilitate better comprehension of mathematical concepts. Moreover, a strong and significant correlation was identified between learning motivation and logical reasoning, indicating that motivated learners tend to achieve better cognitive performance in mathematics. These findings reinforce the idea that digital visual learning resources can serve as powerful tools to foster both motivation and conceptual understanding at the same time. However, certain limitations should be noted. First, the sample was limited to two schools within one province, which may not accurately represent the diversity of educational settings or access to digital tools in other regions.

These findings allow for the formulation of several helpful recommendations. Teachers are encouraged to use e-comics as auxiliary media in their mathematics lessons to boost student engagement and conceptual understanding. Teachers should be trained in digital pedagogy and media production techniques so they can adapt e-comics to their own classroom needs. Governments must ensure equitable access to digital infrastructure, especially in remote schools, to reduce learning disparities and enable the successful implementation of interactive learning media across regions. Longitudinal studies could be carried out in the future to assess the long-term impacts of e-comic-based learning on students' capacity for critical and creative thought. In order to determine which modes best improve certain cognitive areas, future research may also compare e-comics with other digital media formats, such as gamified platforms or augmented reality. Increasing the sample size to encompass a wider range of subjects and grade levels would further improve the findings' generalizability and aid in the creation of inclusive, interesting, and technologically enabled learning models for a variety of educational contexts.

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