

"The Effect of a Digital Comic-Assisted Guided Inquiry Learning Model on the Learning Outcomes and Critical Thinking Skills of Fourth-Grade Elementary School Students in Pulau Gebe District, Indonesia"

Pengaruh Penerapan Model Inkuiri Terbimbing Berbantuan Komik Digital Terhadap Hasil Belajar Dan Kemampuan Berpikir Kritis Siswa SD Negeri Kapaleo Kecamatan Pulau Gebe

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Abstract	Article Information
This study aimed to analyze the effect of implementing the Guided Inquiry learning model assisted by digital comics on the learning outcomes and critical thinking skills of fourth-grade students at SD Negeri Kapaleo, Pulau Gebe District. The study employed a quantitative approach using a quasi-experimental design with two groups: an experimental group receiving Guided Inquiry instruction supported by digital comics and a control group receiving Guided Inquiry instruction without digital comics. Prior to implementation, the digital comics were validated by experts in media, language, and subject matter, achieving a feasibility score of 96.05%, which was categorized as highly valid and suitable for instructional use. The research sample consisted of 40 students divided equally into the two groups. Data were collected through learning outcome tests and critical thinking skills tests and were analyzed using Analysis of Covariance (ANCOVA). The results revealed that the Guided Inquiry learning model assisted by digital comics had a significant positive effect on students' learning outcomes ($F = 5.072$, $p = 0.030$) and critical thinking skills ($F = 4.148$, $p = 0.049$). The mean learning outcome score in the experimental group increased from 44.06 to 77.34, while the mean critical thinking score improved from 39.19 to 69.85. These findings indicate that integrating the Guided Inquiry learning model with digital comic media enhances the effectiveness of science instruction for elementary school students.	Keywords: Guided Inquiry; Digital Comics; Learning Outcomes; Critical Thinking Skills; Elementary Science Education. Kata kunci: inkuiri terbimbing, komik digital, hasil belajar, berpikir kritis, IPA SD.
<i>Penelitian ini bertujuan untuk menganalisis pengaruh penerapan model pembelajaran Inkuiri Terbimbing berbantuan komik digital terhadap hasil belajar dan kemampuan berpikir kritis siswa kelas IV SD Negeri Kapaleo Kecamatan Pulau Gebe. Penelitian menggunakan pendekatan kuantitatif dengan desain eksperimen semu (quasi experimental) menggunakan dua kelompok, yaitu kelompok yang memperoleh pembelajaran Inkuiri Terbimbing berbantuan komik digital dan kelompok yang memperoleh pembelajaran Inkuiri Terbimbing tanpa komik digital. Sebelum digunakan dalam pembelajaran, komik digital divalidasi oleh ahli media, ahli bahasa, dan ahli materi dengan tingkat kelayakan sebesar 96,05% sehingga termasuk kategori sangat layak. Sampel penelitian terdiri atas 40 siswa yang dibagi menjadi dua kelompok. Data dikumpulkan melalui tes hasil belajar dan tes kemampuan berpikir kritis, kemudian dianalisis menggunakan Analisis Kovarians (ANCOVA). Hasil penelitian menunjukkan bahwa model pembelajaran Inkuiri Terbimbing berbantuan komik digital berpengaruh signifikan terhadap hasil belajar siswa ($F = 5,072$; $p = 0,030$) dan kemampuan berpikir kritis siswa ($F = 4,148$; $p = 0,049$). Rata-rata hasil belajar meningkat dari 44,06 menjadi 77,34 pada kelompok eksperimen, sedangkan kemampuan berpikir kritis meningkat dari 39,19 menjadi 69,85. Hasil Penelitian ini menunjukkan bahwa integrasi model Inkuiri Terbimbing dengan media komik digital mampu meningkatkan efektivitas pembelajaran IPA pada siswa sekolah dasar.</i>	History Manuscript : 18/04/2026 Revised : 28/04/2026 Accepted : 29/04/2026 Published : 30/04/2026

A. INTRODUCTION

Twenty-first century education requires learning systems that are capable of equipping students with higher-order thinking skills, problem-solving abilities, creativity, collaboration, and digital literacy to prepare them for the rapid advancement of science and technology (Partnership for 21st Century Learning [P21], 2019). Within this context, science education at the elementary school level plays a strategic role because it is intended not only to develop students' conceptual understanding but also to foster scientific skills through observation, inquiry, reasoning, and evidence-based decision-making (National Research Council, 2012). Student-centered science instruction is widely recognized as an effective approach for improving learning outcomes while simultaneously promoting critical thinking skills, which constitute one of the core competencies emphasized in the Merdeka Curriculum (Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia [MoECRT], 2022). Therefore, teachers are expected to design innovative instructional strategies by selecting learning models and instructional media that are aligned with the cognitive development characteristics of elementary school students (Nurdyansyah, 2019).

Despite educational policies promoting a shift toward more constructivist learning approaches, science instruction in elementary schools continues to be largely dominated by teacher-centered practices, in which students predominantly act as passive recipients of information rather than active constructors of knowledge (OECD, 2023). This instructional orientation limits students' engagement in the learning process and hinders the development of essential competencies, particularly critical thinking skills, which require active inquiry, reflection, and evidence-based reasoning (Facione, 2020). Insufficient student participation during classroom learning also contributes to lower academic achievement, especially in science topics that require strong conceptual understanding and the ability to visualize abstract scientific phenomena (Dakhi, 2020). Furthermore, empirical evidence suggests that instructional approaches primarily focused on content transmission are less effective in promoting deep conceptual understanding and higher-order thinking skills than learning environments that actively engage students in knowledge construction and scientific inquiry (Hattie, 2023).

One instructional approach that has been widely recognized as effective in addressing these challenges is the Guided Inquiry learning model. This model enables students to construct knowledge through a systematic process of scientific inquiry while receiving appropriate guidance from the teacher throughout each stage of learning, including problem identification, hypothesis formulation, data collection, data analysis, and conclusion drawing (Joyce et al., 2015). Such an approach is grounded in constructivist learning theory, which views learners as active participants who construct knowledge through meaningful learning experiences and social interaction (Vygotsky, 1978). A growing body of empirical research has demonstrated that Guided Inquiry significantly improves students' learning outcomes, science process skills, critical thinking skills, and problem-solving abilities compared with conventional teacher-centered instruction (Lazonder & Harmsen, 2016; Aras et al., 2024).

The effectiveness of an instructional model can be further enhanced when it is supported by learning media that accommodate the cognitive characteristics of elementary school students, who are generally in the concrete operational stage of development (Piaget, 1972). One promising instructional medium is digital comics, which integrate visual illustrations, narrative elements, and digital technology to present scientific concepts in a contextualized, engaging, and easily understandable manner (Khan et al., 2019). Previous studies have demonstrated that digital comics can enhance students' learning motivation, reading interest, conceptual understanding, and classroom engagement by providing a more interactive and meaningful learning experience

(Syahmi et al., 2022; Muhaimin et al., 2023). Beyond functioning as a medium for delivering instructional content, digital comics can also serve as a contextual learning resource that presents authentic scientific problems, thereby encouraging students to engage in systematic inquiry and evidence-based reasoning throughout the learning process (Evi, 2023).

Although numerous studies have investigated either the Guided Inquiry learning model or digital comics as instructional media, most have examined these approaches independently rather than integrating them into a unified instructional framework. Empirical studies that combine Guided Inquiry with digital comics to enhance elementary students' learning outcomes and critical thinking skills in science education remain limited, particularly in schools located in archipelagic regions where access to educational resources and learning facilities is often constrained (Aras et al., 2024; Putri et al., 2025). This limitation indicates a clear research gap regarding the integration of digital learning media with inquiry-based instruction to create more contextual, meaningful, and student-centered learning experiences. Furthermore, relatively few studies have examined the effectiveness of this integrated approach in teaching plant reproduction at the elementary school level. Consequently, further empirical evidence is needed to strengthen the development of technology-enhanced science learning models that not only improve students' academic achievement but also foster critical thinking skills through authentic scientific inquiry.

In response to these gaps, this study proposes a novel instructional approach by integrating the Guided Inquiry learning model with digital comics in teaching plant reproduction at the elementary school level. The novelty of this study lies not merely in the use of digital comics as instructional media, but in their systematic integration into each phase of the Guided Inquiry process to facilitate scientific inquiry through contextualized learning scenarios presented in a visual narrative format. This integration is expected to support students in developing a deeper conceptual understanding, actively constructing scientific knowledge, and enhancing their critical thinking skills through meaningful inquiry-based learning experiences. Accordingly, this study aims to evaluate the feasibility of the developed digital comics and to examine the effects of implementing the Guided Inquiry learning model supported by digital comics on the learning outcomes and critical thinking skills of fourth-grade students at SD Negeri Kapaleo, Pulau Gebe District, Indonesia.

B. METHOD

Research Design

This study adopted a quantitative approach employing a quasi-experimental research design with a pretest–posttest non-equivalent control group design. This design was considered appropriate because it enabled the comparison of the effects of the Guided Inquiry learning model supported by digital comics on elementary students' learning outcomes and critical thinking skills while statistically controlling for differences in their initial abilities through pretest scores (Creswell & Creswell, 2018).

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experimental	O ₁	X ₁	O ₂
Control	O ₃	X ₂	O ₄

Note:

O₁ : represents the pretest administered to the experimental group.

O₂ : represents the posttest administered to the experimental group.

O₃ : represents the pretest administered to the control group.

O₄ : represents the posttest administered to the control group.

X₁ : represents the implementation of the Guided Inquiry learning model supported by digital comics.

X₂ : represents the implementation of the Guided Inquiry learning model.

Development of Digital Comic Media

The digital comic was developed using the ADDIE instructional design model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). During the analysis stage, a needs assessment was conducted to identify instructional requirements for teaching plant reproduction in elementary science. The design stage involved developing the storyboard, character designs, visual illustrations, and instructional content aligned with the Learning Outcomes (Capaian Pembelajaran) specified in the Merdeka Curriculum. The development stage resulted in a digital comic prototype, which was subsequently evaluated by experts in science content, instructional media, and language. Following revisions based on the experts' recommendations, the finalized digital comic was implemented in the experimental group during the instructional intervention. Finally, the evaluation stage focused on assessing both the feasibility of the developed digital comic and its effectiveness in improving students' learning outcomes and critical thinking skills.

Research Instruments

Three research instruments were employed in this study: (1) a digital comic validation checklist, (2) a multiple-choice achievement test to assess students' learning outcomes, and (3) an essay-based test designed to measure students' critical thinking skills based on Facione's (2020) critical thinking framework. Before data collection, all instruments were subjected to content validity evaluation by three expert validators with expertise in science education, instructional media, and educational assessment. The evaluation confirmed that all instruments possessed adequate content validity and were considered appropriate for use in the study.

Research Procedure

The study was conducted in several sequential stages. It began with the development and validation of the digital comic, followed by the selection of the experimental and control groups. Prior to the instructional intervention, both groups completed a pretest to assess their initial learning outcomes and critical thinking skills. The experimental group received instruction through the Guided Inquiry learning model supported by digital comics, whereas the control group was taught using the Guided Inquiry learning model without digital comic support. Upon completion of the instructional intervention, both groups completed a posttest to evaluate changes in learning outcomes and critical thinking skills following the implementation of the respective instructional treatments.

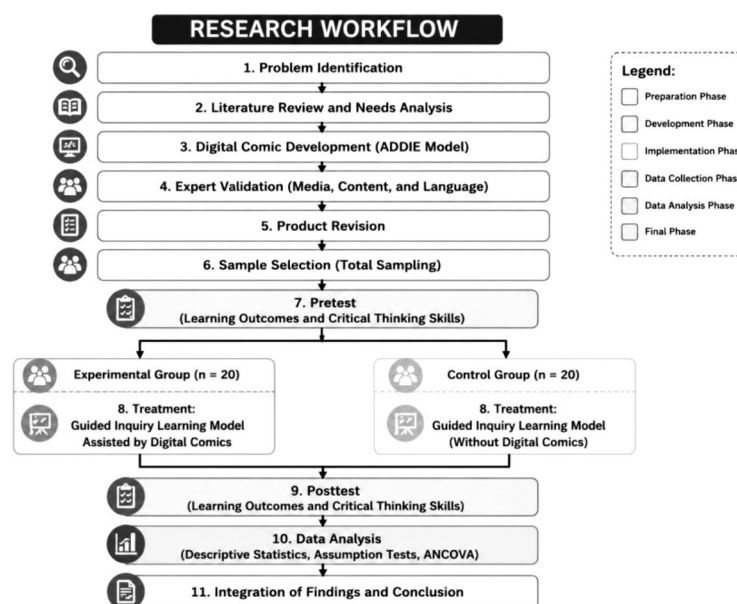


Figure 1. Research Procedure Flowchart

Data Collection

Data collection involved three main sources: the digital comic validation, the learning outcomes test, and the critical thinking skills test. The feasibility of the digital comic was evaluated by three expert validators who assessed the quality of its content, instructional media design, and language appropriateness. Students' learning outcomes and critical thinking skills were measured using pretest and posttest instruments administered to both the experimental and control groups before and after the instructional intervention.

Data Analysis

Data analysis was performed using IBM SPSS Statistics version 26. Descriptive statistics were first computed to summarize the characteristics of the data, including the mean, standard deviation, minimum, and maximum values. Before conducting the inferential analysis, the assumptions of normality and homogeneity of variance were evaluated using the Kolmogorov–Smirnov test and Levene's test, respectively. Subsequently, Analysis of Covariance (ANCOVA) was employed to examine the effects of the Guided Inquiry learning model supported by digital comics on students' learning outcomes and critical thinking skills while controlling for baseline differences through pretest scores as the covariate. Statistical significance was determined at the 5% significance level ($\alpha = 0.05$) (Field, 2020).

C. RESULTS AND DISCUSSION

Effect of the Guided Inquiry Learning Model Supported by Digital Comics on Learning Outcomes

The findings indicated that the Guided Inquiry learning model supported by digital comics had a significant positive effect on students' learning outcomes in the topic of plant reproduction. This was reflected in the improvement of the experimental group's mean score from 44.06 on the pretest to 77.34 on the posttest, whereas the control group's mean score increased from 43.28 to 73.44. The relatively similar pretest mean scores suggest that both groups had comparable initial levels of understanding before the instructional intervention. Following the intervention, the greater improvement observed in the experimental group indicates that integrating digital comics into the Guided Inquiry learning model contributed more effectively to students' conceptual understanding than the Guided Inquiry model implemented without digital comic support.



Figure 2. Comparison of Mean Pretest and Posttest Learning Outcome Scores Between the Experimental and Control Groups

ANCOVA revealed a statistically significant difference in learning outcomes between the experimental and control groups after controlling for students' pretest scores ($F = 5.072$, $p = 0.030$). The model explained 34.8% of the variance in learning outcomes (Adjusted $R^2 = 0.348$), indicating a moderate effect of the instructional intervention. Prior to conducting the inferential analysis, the assumptions of normality and homogeneity of variance were verified, confirming that the data met the assumptions required for ANCOVA. Therefore, the observed differences in learning outcomes can be interpreted as reflecting the effect of the Guided Inquiry learning model supported by digital comics rather than differences in students' initial abilities (Field, 2020).

Table 2. ANCOVA Results for the Effect of the Guided Inquiry Learning Model Supported by Digital Comics on Students' Learning Outcomes
Tests of Between-Subjects Effects

Dependent Variable:Postes Hasil Belajar

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	567.706 ^a	2	283.853	11.412	.000
Intercept	3300.886	1	3300.886	132.710	.000
Pretes Hasil Belajar	415.098	1	415.098	16.689	.000
Model Pembelajaran	126.155	1	126.155	5.072	.030
Error	920.297	37	24.873		
Total	228850.672	40			
Corrected Total	1488.002	39			

a. R Squared = .382 (Adjusted R Squared = .348)

The improvement in students' learning outcomes indicates that integrating digital comics into the Guided Inquiry learning model enhanced the effectiveness of the instructional process. Rather than functioning solely as a medium for content delivery, the digital comic served as a learning resource that enabled students to understand the context of the problem before engaging in scientific inquiry. Through the use of visual illustrations, dialogues, and narrative sequences, the digital comic facilitated students' initial conceptual understanding of plant reproduction, thereby supporting more systematic problem identification, hypothesis formulation, and information gathering during the inquiry process. These findings are consistent with Mayer's Cognitive Theory of Multimedia Learning, which posits that information presented through integrated verbal and visual representations promotes more effective cognitive processing and facilitates the construction of coherent mental representations than text-based instruction alone (Mayer, 2021). Consequently, students were better able to organize new information, relate it to their prior knowledge, and construct scientific concepts more effectively throughout the learning process.

The observed improvement in students' learning outcomes was also associated with the quality of the instructional media developed in this study. The digital comic achieved an overall feasibility score of 96.05%, which was classified as highly feasible, indicating that its content, language, and media design met the required standards for classroom implementation. This high level of feasibility suggests that the digital comic was pedagogically appropriate and capable of supporting the implementation of the Guided Inquiry learning model by providing scientifically accurate, age-appropriate, and well-structured learning materials. As a result, the instructional media effectively facilitated students' conceptual understanding and supported the learning process throughout the inquiry activities.

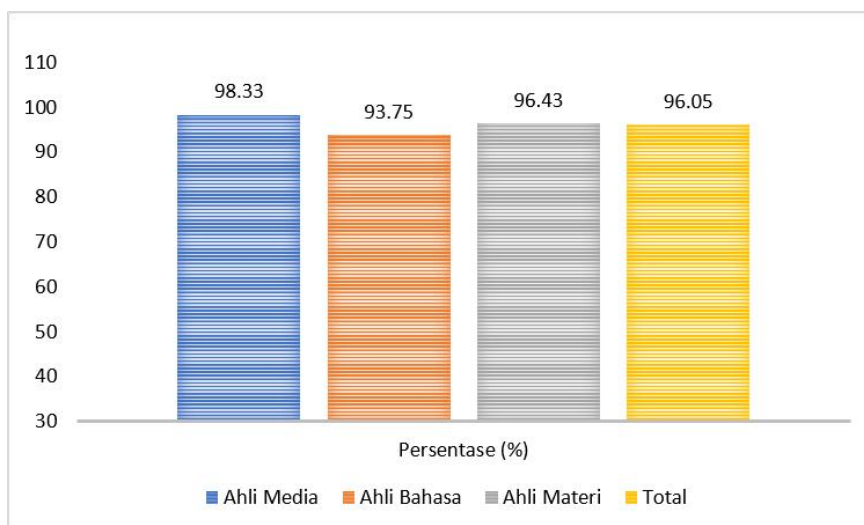


Figure 3. Percentage Scores of the Digital Comic Validation for the Plant Reproduction Topic

The high feasibility of the developed instructional media indicates that the digital comic provided clear, accurate, and pedagogically appropriate representations of scientific concepts that were well aligned with the cognitive characteristics of elementary school students. Consequently, the improvement in students' learning outcomes cannot be attributed solely to the Guided Inquiry learning model but also to the quality of the instructional media, which had undergone a rigorous expert validation process prior to classroom implementation. The validated digital comic enabled students to access contextualized scientific information in a structured and meaningful manner, thereby facilitating conceptual understanding throughout the inquiry activities. These findings are consistent with those reported by Syahmi et al. (2022), who demonstrated that digital comics designed according to learners' developmental characteristics significantly enhanced students' conceptual understanding of science by presenting learning materials in a contextualized, engaging, and easily comprehensible format.

The greater improvement in learning outcomes observed in the experimental group further suggests that the digital comic functioned as a cognitive bridge between students' prior knowledge and the scientific concepts introduced during instruction. During the orientation phase, students were introduced to contextual scientific problems through the narrative and visual representations presented in the digital comic. Subsequently, during the inquiry phase, they examined and verified the information by formulating hypotheses, collecting evidence, and drawing conclusions based on the results of their investigations. This instructional sequence enabled students to actively construct scientific knowledge through inquiry rather than passively receiving information from the teacher. Such findings are consistent with those reported by Arantika et al. (2019), who argued that the effectiveness of Guided Inquiry lies in providing learners with structured opportunities to discover scientific concepts through guided investigation. When this inquiry process is supported by appropriate instructional media, students are better able to connect prior knowledge with new scientific concepts, resulting in more meaningful learning experiences and improved learning outcomes.

The findings further suggest that the superior learning outcomes achieved by the experimental group were not solely attributable to the use of digital comics as instructional media, but rather to their systematic integration into each phase of the Guided Inquiry learning model. In

this study, the digital comic provided a meaningful learning context through authentic scientific scenarios, while the Guided Inquiry model engaged students in exploring, analyzing, and validating scientific concepts within that context. The complementary roles of the instructional media and the inquiry process created a coherent learning environment that promoted active knowledge construction rather than passive information acquisition. This pedagogical synergy may explain why the instructional intervention remained statistically significant even after students' pretest scores were controlled using Analysis of Covariance (ANCOVA). These findings are consistent with the meta-analysis conducted by Lazonder and Harmsen (2016), which concluded that guided inquiry produces significantly greater learning gains than unguided inquiry because appropriate instructional guidance enables students to conduct scientific investigations more effectively while minimizing cognitive overload.

From a constructivist perspective, the findings of this study suggest that meaningful knowledge is more effectively constructed when students actively engage in the learning process and participate in authentic learning experiences. In the present study, the digital comic provided an initial learning experience through contextualized visual representations, whereas the Guided Inquiry learning model enabled students to examine, refine, and reconstruct their conceptual understanding through systematic scientific inquiry. The interaction between the digital comic and the inquiry-based learning process promoted active knowledge construction by encouraging students to relate new information to their prior knowledge, critically evaluate evidence, and formulate conclusions based on scientific investigation. Consequently, learning extended beyond the acquisition of conceptual knowledge to include stronger knowledge retention, as students developed their understanding through direct learning experiences rather than passive information reception. These findings are consistent with the constructivist learning perspective proposed by Hmelo-Silver et al. (2007), which emphasizes that meaningful learning is achieved when learners actively construct conceptual understanding through inquiry, collaboration, and authentic problem-solving experiences.

The findings of this study have important implications for science education, suggesting that effective instruction depends not only on the selection of an appropriate instructional model but also on the use of learning media that effectively support each stage of the instructional process. Integrating digital comics into the Guided Inquiry learning model created a more contextualized and engaging learning environment, enabling students to participate more actively throughout the inquiry process and resulting in greater improvements in learning outcomes than Guided Inquiry instruction implemented without digital comic support. These findings indicate that the effectiveness of inquiry-based learning can be enhanced when instructional media are deliberately designed to facilitate students' active engagement in scientific investigation rather than merely serving as tools for content delivery. Therefore, the development of digital learning media for elementary science education should emphasize their integration into inquiry-based instructional practices, allowing them to function as an essential component of the instructional strategy that supports meaningful knowledge construction and promotes students' conceptual understanding.

Effect of the Guided Inquiry Learning Model Supported by Digital Comics on Students' Critical Thinking Skills

Critical thinking is a fundamental competency that develops through learning experiences that engage students in identifying problems, evaluating evidence, analyzing information, and drawing conclusions based on empirical findings. In the present study, students' critical thinking skills improved in both the experimental and control groups; however, the improvement was more pronounced among students who participated in the Guided Inquiry learning model supported by digital comics. This finding indicates that integrating digital comics into the Guided Inquiry learning process provided a more effective learning environment for fostering higher-order thinking skills than the Guided Inquiry model implemented without digital comic support. The results of the Analysis of Covariance (ANCOVA) further confirmed that the instructional intervention had a statistically significant effect on students' critical thinking skills ($F = 4.148$, $p = 0.049$) after controlling for pretest scores as the covariate. Moreover, the model explained 70.3% of the variance in students' critical thinking skills (Adjusted $R^2 = 0.703$), suggesting that a substantial proportion of the observed improvement was attributable to the instructional approach implemented in this study.

Table 3. ANCOVA Results for the Effect of the Guided Inquiry Learning Model Supported by Digital Comics on Students' Critical Thinking Skills

Tests of Between-Subjects Effects

Dependent Variable: Posttest Critical Thinking Skills

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2724.771 ^a	2	1362.385	47.207	.000
Intercept	2857.848	1	2857.848	99.024	.000
Pretes Berpikir Kritis	2596.965	1	2596.965	89.985	.000
Model Pembelajaran	119.710	1	119.710	4.148	.049
Error	1067.823	37	28.860		
Total	189092.750	40			
Corrected Total	3792.594	39			

a. R Squared = .718 (Adjusted R Squared = .703)

The adjusted coefficient of determination indicates that the instructional intervention accounted for a greater proportion of the variance in students' critical thinking skills than their baseline abilities. Furthermore, the assumptions of normality and homogeneity of variance were confirmed prior to conducting the inferential analysis, demonstrating that the dataset satisfied the statistical requirements for Analysis of Covariance (ANCOVA). Accordingly, the significant effect identified through ANCOVA can be interpreted with confidence as reflecting the effectiveness of the Guided Inquiry learning model supported by digital comics, rather than differences in students' initial levels of critical thinking (Field, 2020).

Students' critical thinking skills improved in both the experimental and control groups following the instructional intervention. However, the improvement was greater among students who learned through the Guided Inquiry learning model supported by digital comics than among those who experienced the Guided Inquiry model without digital comic support. Specifically, the mean critical thinking score of the experimental group increased from 39.19 on the pretest to

69.85 on the posttest, whereas the control group showed an increase from 39.05 to 66.28. The relatively similar pretest scores indicate that both groups had comparable baseline critical thinking abilities prior to the intervention. In contrast, the larger gain observed in the experimental group suggests that the integration of digital comics into the Guided Inquiry learning process provided additional instructional support that enhanced students' critical thinking development beyond that achieved through the Guided Inquiry model alone.

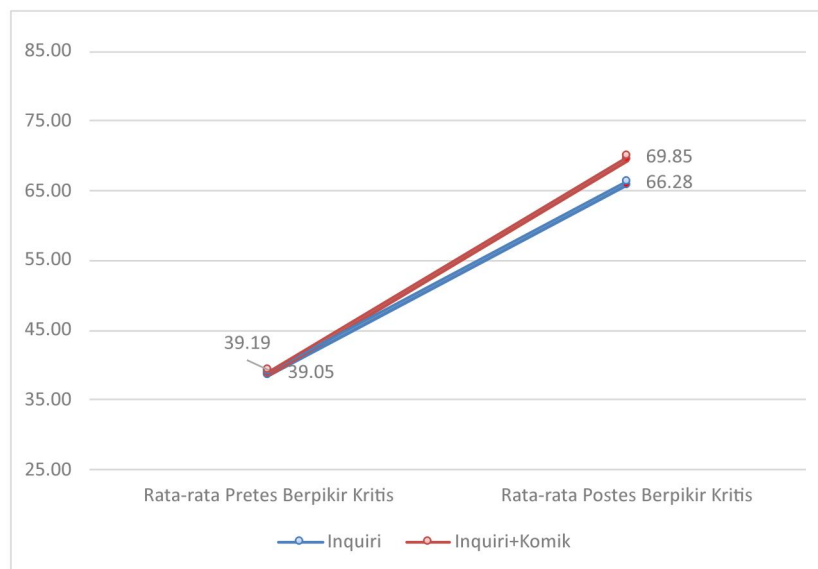


Figure 4. Comparison of Mean Pretest and Posttest Critical Thinking Scores Between the Experimental and Control Groups

The minimal difference in the pretest scores suggests that the experimental and control groups were comparable in terms of their initial critical thinking abilities before the instructional intervention. Establishing baseline equivalence is particularly important in quasi-experimental research because it strengthens the validity of the comparison between groups and allows the observed posttest differences to be interpreted primarily as the effect of the instructional treatment rather than as a consequence of pre-existing differences. Consequently, the pretest–posttest design employed in this study provides a more robust basis for evaluating the effectiveness of the Guided Inquiry learning model supported by digital comics in enhancing students' critical thinking skills.

The observed improvement in students' critical thinking skills can be attributed to the fundamental characteristics of the Guided Inquiry learning model, which positions students as active participants in the construction of scientific knowledge. Throughout the learning process, students were engaged in identifying problems, formulating hypotheses, gathering relevant information, evaluating evidence, and drawing conclusions based on the results of their investigations. These inquiry activities required students to continuously employ analytical reasoning, reflective thinking, and evidence-based decision-making, thereby fostering the development of critical thinking as an integral component of the learning process rather than as an isolated cognitive skill. The findings of this study are consistent with the meta-analysis conducted by Lazonder and Harmsen (2016), which demonstrated that guided inquiry is more effective than unguided inquiry in promoting higher-order thinking skills because structured

instructional guidance enables students to conduct scientific investigations more systematically while reducing unnecessary cognitive demands.

The difference in critical thinking performance between the experimental and control groups suggests that scientific inquiry becomes more effective when students receive appropriate support in understanding the context of the problems under investigation. In the present study, the digital comic provided this contextual support by presenting plant reproduction phenomena through visual illustrations and narrative sequences that closely reflected students' everyday experiences. Such contextualized visual representations enabled students to establish causal relationships and develop an initial conceptual understanding before engaging in the inquiry process. Consequently, students devoted less cognitive effort to interpreting the problem itself and were able to focus more on analyzing information, evaluating alternative explanations, and constructing evidence-based arguments throughout the investigation. These findings are in line with those reported by Özdemir (2017), who demonstrated that contextual visual representations enhance students' reasoning by facilitating the integration of new information with their existing knowledge structures.

The development of students' critical thinking skills in this study was fostered through the interaction between inquiry activities and scientific discussion. Throughout the discussion sessions, students were not only encouraged to present their answers but were also required to justify their reasoning, compare the evidence they had collected, and critically evaluate the arguments presented by their peers. Such learning activities promoted evidence-based argumentation by encouraging students to formulate conclusions grounded in empirical evidence rather than unsupported assumptions. This pattern of instruction is consistent with Facione's (1990) conceptualization of critical thinking, which encompasses the abilities to interpret information, analyze arguments, evaluate evidence, draw reasoned inferences, and provide logical explanations. The continuous engagement of students in these cognitive processes throughout each phase of the Guided Inquiry learning model contributed to the development of critical thinking as an integral outcome of the learning experience.

The findings of this study further indicate that the improvement in students' critical thinking skills was not merely attributable to the use of digital comics as instructional media, but rather to the manner in which the media were systematically integrated into each phase of the Guided Inquiry learning model. In the present study, the digital comic functioned as an instructional scaffold by introducing contextual scientific problems, whereas the Guided Inquiry model engaged students in investigating, validating, and explaining those problems through a structured process of scientific inquiry. This complementary interaction between the instructional media and the inquiry process created a learning environment that encouraged students to construct evidence-based explanations and engage in higher-order cognitive processes throughout the lesson. Such integration distinguishes the present study from many previous investigations, which have generally examined the effectiveness of either instructional media or inquiry-based learning as separate interventions. Consistent with the findings of Dobber et al. (2017), inquiry-based instruction exerts a greater influence on students' critical thinking when learners receive adequate instructional support during the inquiry process. The present findings extend this evidence by demonstrating that such support can be effectively provided through digital instructional media specifically designed to facilitate students' thinking processes, rather than functioning solely as a means of delivering instructional content.

From a constructivist perspective, the improvement in students' critical thinking skills observed in this study can be understood as a consequence of their active engagement in constructing knowledge through meaningful learning experiences. Rather than acquiring knowledge through passive information reception, students developed their understanding by testing hypotheses, comparing evidence, and revising their initial conceptions based on empirical findings generated during the inquiry process. Such learning experiences encouraged students to adopt more reflective, analytical, and systematic approaches to problem solving, thereby fostering the development of critical thinking as an integral component of scientific inquiry. These findings are consistent with the constructivist perspective advanced by Hmelo-Silver et al. (2007), who argued that inquiry-based learning provides an environment in which students actively construct knowledge while simultaneously developing higher-order thinking skills through structured investigative activities.

The findings of this study have important implications for science education, suggesting that the development of students' critical thinking skills requires instructional approaches that extend beyond the acquisition of conceptual knowledge by providing opportunities for learners to explore, question, and verify information independently. The present study demonstrates that systematically integrating digital comics into each phase of the Guided Inquiry learning model creates such a learning environment by encouraging students to construct evidence-based arguments through active engagement in scientific inquiry. Consequently, the contribution of this study lies not merely in the use of digital comics as instructional media, but in demonstrating that their systematic integration within the Guided Inquiry learning process strengthens scientific reasoning and promotes greater improvements in students' critical thinking skills than the implementation of the Guided Inquiry model without digital comic support. These findings provide empirical evidence that instructional media can function not only as tools for presenting learning content but also as pedagogical scaffolds that facilitate inquiry-based learning and support the development of higher-order thinking skills in elementary science education.

D. CONCLUSION

The findings of this study demonstrate that the developed digital comic achieved a very high level of feasibility, with an overall validation score of 96.05%, indicating that it is suitable for use as an instructional medium in teaching plant reproduction at the elementary school level. Furthermore, the implementation of the Guided Inquiry learning model supported by digital comics had a statistically significant positive effect on both students' learning outcomes and critical thinking skills among fourth-grade students at SD Negeri Kapaleo, Pulau Gebe District. These findings were evidenced by the greater improvements in the experimental group's mean posttest scores compared with those of the control group and were further supported by the results of the Analysis of Covariance (ANCOVA), which revealed significant effects on learning outcomes ($p = 0.030$) and critical thinking skills ($p = 0.049$). The integration of digital comics into each phase of the Guided Inquiry learning model created a more active, contextualized, and meaningful learning environment that enabled students not only to develop a deeper conceptual understanding of science but also to strengthen their critical thinking skills through systematic scientific inquiry. These findings provide empirical evidence that the effectiveness of inquiry-based science instruction can be enhanced when instructional media are deliberately integrated into the inquiry process rather than used solely as tools for content delivery. Therefore, the Guided Inquiry learning model supported by digital comics may be recommended as an effective

instructional alternative for improving the quality of science education in elementary schools, particularly in educational settings with characteristics similar to those of the present study.

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