

Original Article

Enhancing Science Concept Mastery through a Structured Inquiry Learning Model Integrated with Electronic Teaching Materials

Fitria Wahyu Wulansari¹ , Riva Ismawati^{1*} 

Abstract: Mastery of science concepts among eighth-grade students at SMPN 4 Magelang remains relatively low, as indicated by limited engagement in learning activities and assessment results below expected competency standards. This issue requires pedagogical intervention. This study aimed to enhance science concept mastery through a structured inquiry learning model integrated with electronic teaching materials. Collaborative classroom action research was conducted over three cycles with 32 students participating for six weeks. Concept-mastery tests based on Bloom's revised taxonomy were used as instruments, and data were analyzed using mean scores, achievement rates, and N-gain. Findings showed consistent improvement from Cycle I to Cycle III, with posttest scores increasing from 68 to 81, N-gain values rising from .44 to .69, and completion rates improving from 44% to 81%. The structured inquiry model facilitated students' conceptual understanding through systematic scientific procedures, while electronic teaching materials enhanced visualization and interactivity. These results demonstrate the effectiveness of combining structured inquiry with digital learning resources to strengthen students' comprehension and application of scientific concepts.

Keywords :

Structured inquiry; Electronic teaching materials; Concept mastery; Action Research; Science education



Author Affiliation:

¹ Faculty of Teacher Training and Education, Universitas Tidar, Indonesia

*Corresponding author(s):

Riva Ismawati, Universitas Tidar, Indonesia.

 rivaismawati@untidar.ac.id

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INTRODUCTION

The 21st century is marked by rapid globalization and technological advancement, requiring science education to integrate technology and e-learning tools that foster flexible, active, and analytically rich learning environments (Wu *et al.*, 2021; Asad *et al.*, 2021). Adaptive learning further enables personalized, technology-driven experiences that enhance engagement and effectiveness (Gligorea *et al.*, 2023). Grounded in constructivist principles, contemporary science education emphasizes active knowledge construction, reflection, and digital literacy as essential competencies for both students and teachers

(Puljak et al., 2020). Within this framework, inquiry-based learning remains one of the most effective approaches in science education (García, 2020), promoting questioning, data collection, analysis, and evidence-based reasoning aligned with broader scientific practices (Aditomo & Klieme, 2020; Manz et al., 2020; Strat et al., 2024). The integration of multimedia elements such as animations, narrated videos, and interactive texts supports conceptual understanding, prevents cognitive overload, and strengthens higher-order thinking, collaboration, and problem-solving skills (Hillmayr et al., 2020; Sutiani et al., 2021). Educational reforms further position inquiry as a core scientific practice from early schooling, encouraging experimentation, discussion, reflection, inductive reasoning, and self-regulated learning to apply scientific concepts to real-world contexts (Toma, 2022b; Oliver et al., 2021; Moote, 2020; Ernawati & Sujatmika, 2021; Forbes et al., 2020).

Studies at SMPN 4 Magelang reveal that eighth-grade students exhibit low mastery of science concepts, limited engagement, and suboptimal learning outcomes (Ardianti & Raida, 2022). These challenges highlight the need for instructional strategies that integrate inquiry-based learning and digital resources to strengthen conceptual understanding and 21st-century skills (Ismail, 2021). Inquiry-based learning fosters higher-order thinking by engaging students in constructing and evaluating scientific explanations through evidence and guided processes (Arifin et al., 2025; Toma, 2022a; Jong et al., 2021). In particular, structured inquiry situated within the intermediate levels of the inquiry continuum provides teacher-designed investigations with scaffolding that supports students in developing procedures, analyzing findings, and answering research questions, in contrast to the autonomy of open inquiry (Toma, 2022b). This approach promotes systematic scientific reasoning and more meaningful concept construction than traditional teacher-centered instruction.

Mastery of learning materials is fundamental to successful learning; however, low conceptual understanding may stem from difficulties with abstract concepts, limited readiness, minimal active participation, and conventional teaching approaches that lack interaction, feedback, and meaningful engagement (Samuelsson, 2021; Merta, 2021; Haleem et al., 2022). Effective learning environments promote creativity, active involvement, goal attainment, and positive classroom climates (Ikhsani et al., 2023). Inquiry-based science learning encourages students to actively design and conduct investigations to answer their own questions (Phang et al., 2020). yet its implementation may be constrained by school culture, professional support, resources, class size, assessment demands, and time limitations (Bansal & Ramnarain, 2021). Structured inquiry addresses these challenges by combining guided research questions and procedures with scaffolding, fostering critical thinking and evidence-based reasoning (Wang et al., 2022; Harun & Nurita, 2024). Therefore, structured inquiry represents a promising approach to improving junior high students' science learning outcomes.

Structured inquiry engages students in constructing knowledge through teacher-guided investigations that involve observing, questioning, collecting data, and drawing evidence-based conclusions, thereby fostering curiosity and critical thinking beyond rote memorization (Nugraha et al., 2021; Wang et al., 2022; Hulu et al., 2023; De Jong et al.,

2023; Gericke *et al.*, 2023). Although its implementation may face constraints such as time limitations and varying student readiness, structured inquiry has been shown to significantly enhance conceptual understanding, including in dynamic electricity topics (Ni'mah & Widodo, 2022; Husna & Minda, 2024). The integration of electronic teaching materials such as interactive simulations, multimedia content, and real-time feedback aligned with curriculum objectives further strengthens engagement and supports diverse learning needs (Susilawati *et al.*, 2023; Lawe *et al.*, 2021; Mukhibah & Widiansyah, 2024). Therefore, this study integrates structured inquiry with electronic teaching materials, aligning each inquiry stage with digital scaffolding and simulations. Unlike prior studies that applied inquiry learning or digital tools separately, this research examines their combined effect in enhancing conceptual understanding, meaningful reasoning, and measurable learning outcomes, contributing both theoretically and practically to science education innovation

METHOD

The study involved 32 eighth-grade students with diverse learning backgrounds. Concept mastery was measured using pretest and posttest assessments administered before and after implementing the structured inquiry model (Sari & Sukmawati, 2023). The instruments covered all levels of Bloom's taxonomy and were validated through expert review and pilot testing to ensure reliability and accuracy (Creswell, 2012; Njie & Asimiran, 2014). Data were analyzed using N-gain scores to determine improvement levels and interpreted based on established mastery criteria. Microsoft Excel was used for data organization and visualization, while triangulation of test results, classroom observations, and student worksheets enhanced validity. Conducted as classroom action research, the study followed three iterative cycles of planning, implementation, observation, and reflection, with each cycle refining the intervention until the predetermined mastery criteria were achieved. Student participation varied by attendance, but all present students completed the assessments. Figure 1 presents the procedural flow of the research cycles.

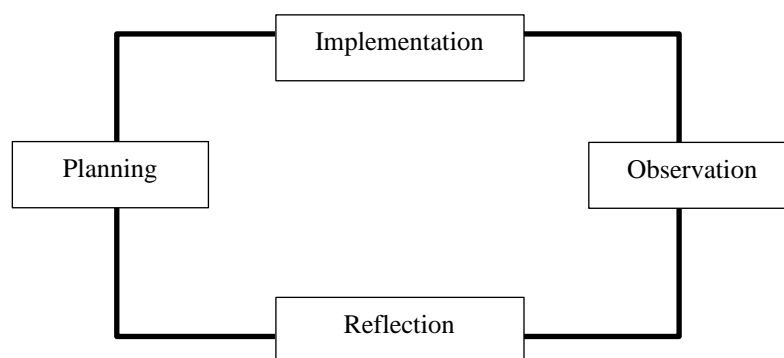


Figure 1 Classroom Action Research Chart

Each stage of the classroom action research

The classroom action research followed four cyclical stages: planning, implementation, observation, and reflection. During the planning stage, specific classroom learning problems were identified, and a structured inquiry model supported by electronic

teaching materials was selected. Instructional resources, including modules, worksheets, and digital materials aligned with inquiry syntax, were prepared alongside research instruments in the form of concept mastery tests covering Bloom's revised taxonomy levels C1–C5; C6 (Creating) was deliberately excluded due to time constraints, students' prior experience, and the study's focus on strengthening foundational conceptual understanding. In the implementation stage, learning activities were conducted according to the structured inquiry sequence pretest, intervention, and posttest emphasizing active participation, critical thinking, and knowledge construction. Observation was carried out throughout the process to document student engagement, interactions, and responses to inquiry tasks and electronic resources, providing qualitative data to complement quantitative test results. Reflection involved analyzing pretest–posttest outcomes using average scores and N-gain calculations, interpreting achievement levels based on predetermined mastery criteria, and integrating observational findings to refine subsequent cycles. Data reliability and validity were ensured through triangulation of test scores, student worksheets, and observation records, as well as consistency checks across cycles.

Table 1 presents the criteria for calculating the Normalized Gain (N-gain), which is used to evaluate the improvement in students' concept mastery after the implementation of instructional interventions. These criteria are essential for interpreting the extent to which the learning process contributes to students' progress. Higher N-gain values indicate greater improvement compared to their initial performance.

Table 1 N-Gain Criteria

N-gain Score	Interpretation
$0.70 < g < 1.00$	High
$0.30 < g < 0.70$	Moderate
$0.00 < g < 0.30$	Low
$g = 0.00$	No improvement
$-1.00 < g < 0.00$	Decline in performance

As shown in Table 1, the N-gain value is used to classify the level of improvement in students' learning outcomes following the instructional activities. A value categorized as *High* indicates that the intervention has produced substantial gains in concept mastery. A *Moderate* category suggests a reasonable level of improvement, though still leaving room for further enhancement. Meanwhile, a *Low* category reflects minimal progress. An N-gain of zero means no observable improvement, whereas a negative value signifies a decline in students' performance compared to the initial assessment. These criteria serve as a basis for assessing the effectiveness of each cycle of the conducted action research.

RESULT AND DISCUSSION

To evaluate the effectiveness of the learning intervention, students' concept mastery was assessed through pretests and posttests administered in each learning cycle. These assessments served to measure the initial level of understanding and the extent of improvement after the instructional treatment. By comparing the results obtained before and after each cycle, researchers were able to observe the progression of students' cognitive achievement as well as identify areas that required further refinement in

subsequent cycles. Table 2 presents the detailed results of the pretests and posttests, illustrating changes in concept mastery across the entire action research process.

Table 2. Recapitulation of Pretest and Posttest Results in Each Cycle

Data	Cycle 1		Cycle 2		Cycle 3	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Total score	1,163	1,840	1,278.7	2,336	1,026.7	2,188
Number of Students	27	27	31	31	27	27
Students Achieving Mastery	1	12	1	18	1	22
Mean Score	43	68	41.2	75	38	81
N-gain	0.44 (moderate)		0.57 (moderate)		0.69 (moderate)	
Completion Rate	3.7%	44%	3.2%	58%	3.7%	81%

Table 2 presents the development of students' learning outcomes from Cycle I to Cycle III. The average pretest scores show a fluctuating downward trend, from 43 in Cycle I to 41.2 in Cycle II and further down to 38 in Cycle III. This fluctuation indicates that students' initial abilities were not stable across cycles, which may be influenced by external factors such as differences in student readiness, variations in the number of students in each cycle, and the timing of the pretest administration. Since the pretest was conducted prior to the learning intervention, these variations do not reflect the impact of the instructional model but rather the uncontrolled conditions of students' initial knowledge. Despite this, the posttest scores consistently increased from 68 in Cycle I to 75 in Cycle II and reached 81 in Cycle III, accompanied by a substantial rise in learning mastery from 44% to 81%. These results demonstrate that the actions implemented were effective in improving students' conceptual understanding. The improvement is further supported by the upward trend in N-Gain scores, which increased from 0.44 in Cycle I to 0.57 in Cycle II and 0.69 in Cycle III, all of which fall within the medium category. This pattern suggests that the structured inquiry learning model supported by electronic teaching materials progressively enhanced students' conceptual understanding across the learning cycles.. This, problems in inquiry serve as puzzles with explicit clues that must be solved through investigation and reasoning (Hasmira, 2023).

According to Trianah (2021), inquiry-based learning allows students to actively engage with relevant concepts and principles, gaining real-world experience through experimentation and independently constructing knowledge. In structured inquiry, students are guided to find information through experimental activities supported by problem statements, research tools, and learning resources. They are responsible for completing tasks according to established protocols and for making inferences through observing, questioning, reasoning, concluding, and communicating (Handriani *et al.*, 2015). Generally, structured inquiry activities help students understand scientific concepts through systematic, step-by-step procedures. These findings align with Christofer and

Irawati (2022), who reported that inquiry-based learning effectively enhances conceptual understanding among grade XI students, supported by adequate information and communication technology resources. Triannah (2021) also demonstrated that the use of inquiry-based student worksheets significantly improves science concept mastery. In line with these findings, the structured inquiry model further offers several advantages, including the development of students' argumentation skills, the acquisition of new information relevant to everyday knowledge, the enhancement of systematic data analysis abilities, and the encouragement of both collaborative and independent learning (Susilawati *et al.*, 2023).

The success of the learning process was also supported by the use of interactive and contextual electronic teaching materials, which presented the content through text, graphics, and videos, helping students better understand abstract concepts. Previous studies have shown that such electronic materials can enhance learning efficiency and accommodate diverse learning styles, including visual, auditory, and kinesthetic (Mazid *et al.*, 2025). In addition, Mayasari *et al.* (2022) reported that electronic teaching materials significantly improve students' learning outcomes and conceptual understanding. In this study, the contribution of these materials to learning effectiveness became increasingly evident through the activities and performance improvements observed in each cycle.

The contribution of these materials was clearly reflected in the progressive developments across the learning cycles. In the first cycle, the electronic teaching materials supported students in understanding basic concepts through visual displays and videos, enabling them to follow experimental procedures more easily, although guidance was still needed. In the second cycle, improvements appeared in students' ability to complete tasks more independently, indicating that the interactive presentation of the material successfully strengthened their conceptual understanding. By the third cycle, students were able to apply the concepts accurately in problem-solving activities and demonstrated consistent improvement in their performance.

Cycle I began with a planning stage, which involved the creation of learning tools such as teaching modules, student workbooks, and electronic teaching materials in the form of flipbooks. The learning tools were created using the Structured Inquiry model syntax. Then, they were validated by four science teachers at SMPN 4 Magelang, which served as the research site, to ensure the content's suitability, alignment with the learning objectives, and relevance to the student characteristics. During the implementation phase, the therapy is administered to students utilizing the Structured Inquiry Model and electronic teaching resources like flipbooks. Flipbooks have the advantage of incorporating multiple multimedia components, making them an appealing, interactive learning medium that can boost students' willingness to learn. The visual and acoustic aspects also enhance memory, improving learning outcomes (Rahayu *et al.*, 2021). Using a flip book as a learning resource allows students to better understand the topic. Flipbooks are easy to keep and may be accessed on various electronic devices, allowing students to learn anytime and anywhere (Rini *et al.*, 2021).

The flipbook provides interactive information such as text, graphics, animations, videos, and sounds, and it also includes student workbooks in the form of worksheets.

These worksheets include questions that help students observe, evaluate, and develop conclusions based on the findings of experiments and the topics covered in the flipbook. Following group discussions, students complete their assignments alone. This aligns with (Ariyani *et al.*, 2021), who indicated that reference exams are classified into three groups in student workbooks. First, practice questions that may be answered in groups or during discussions with peers. Second, group practice questions are utilized to determine how effectively pupils grasp the content that has been covered. Third, individual assignments are offered to encourage pupils to be active, self-sufficient, and creative in gaining and expanding their cognitive abilities.

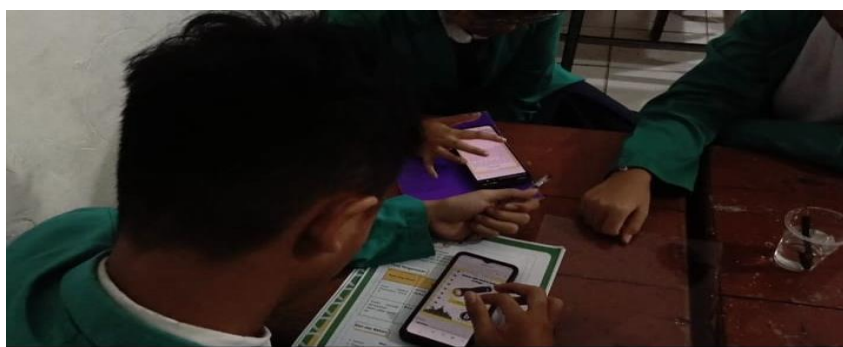


Figure 1. Students interacting with the flipbook

Interaction with the flipbook involves students actively engaging with the electronic teaching material by navigating through text, graphics, animations, videos, and audio elements. This process allows students to explore concepts at their own pace, revisit sections as needed, and connect visual or multimedia content with theoretical knowledge. During interaction, students not only receive information but also participate in inquiry-based activities such as observing experiments, answering embedded questions, and making notes, which foster deeper understanding and retention of scientific concepts. This active engagement promotes independent learning, critical thinking, and the development of problem-solving skills, aligning with the goals of structured inquiry-based learning.



Figure 2. Collaborating in groups to solve practice questions, enhancing their understanding of the topic

In Figure 2, students are seen working collaboratively in small groups to complete practice questions provided in the electronic teaching materials. This group interaction

encourages discussion, exchange of ideas, and collective problem-solving, which helps students clarify misconceptions and deepen their understanding of the concepts. Collaborative learning also fosters communication skills, critical thinking, and the ability to reason collectively, enabling students to apply theoretical knowledge to practical tasks. By engaging in these activities, students are not only reinforcing individual understanding but also developing social and cognitive skills essential for effective learning.

Observations conducted by the researchers and teachers focused on students' learning activities, their participation in discussions, and their responses to the use of flipbooks within the inquiry learning sequence. In Cycle I, the multimedia features in the flipbook supported the problem-orientation and hypothesis-formulation stages, and students were able to collect and test data through simple experiments on the properties of light. However, many students still required substantial guidance during the hypothesis-testing and conclusion-drawing stages, indicating that these phases demanded higher-order cognitive skills and were not yet optimally supported. A technical obstacle also emerged: students struggled to complete the electronic worksheets because they had to switch back and forth between the flipbook and a separate worksheet tab, which disrupted their concentration and reduced productivity.

In Cycle II, revisions were implemented to address the problems identified in Cycle I, particularly students' diminished concentration due to switching between the flipbook and a separate worksheet, as well as their limited independence during hypothesis testing and conclusion drawing. The revised learning tools were validated by four science teachers at SMPN 4 Magelang to ensure their appropriateness and alignment with the learning objectives. The primary improvement involved integrating the teaching materials and the electronic worksheet into a single liveworksheet, thereby streamlining the digital workflow while maintaining the multimedia strengths of the flipbook. The liveworksheet incorporated interactive videos, animations, images, and automatically assessed tasks, features that are characteristic of effective e-worksheets and support both engagement and efficient evaluation (Rumasoreng *et al.*, 2023). Observations in Cycle II showed that the integrated format enhanced students' focus, facilitated smoother hypothesis development and data testing, and increased their independence in completing inquiry tasks. Overall, these adjustments yielded clear pedagogical improvements, demonstrating that a unified, multimedia-supported e-worksheet can significantly strengthen the effectiveness of inquiry-based learning.

In Cycle III, lesson planning continued using electronic teaching materials embedded within the e-worksheets, which had proven more effective based on the previous cycles. The worksheet activities were designed to support students in constructing their understanding through guided inquiry, as the structured tasks encouraged active participation, independent reasoning, and access to information that stimulated higher-order thinking (Celik *et al.*, 2022). Adjustments to the material were made to strengthen students' conceptual grasp of plate tectonics, and the revised learning tools were revalidated by four science teachers at SMPN 4 Magelang to ensure their alignment with learning objectives and contextual needs. Using the Structured Inquiry model, the concept of tectonic plates was presented through explanatory texts and videos that visually depicted

plate movements, enabling deeper engagement with the phenomena. Students identified various types of plates and their movements, then communicated their findings through group presentations. These stages presentation, scientific argumentation, and reflection formed part of the hypothesis-testing and conclusion-drawing phases, requiring students to think critically and evaluate observational evidence. As a result of these actions, the strategies employed in Cycle III enhanced students' inquiry skills, critical thinking, and conceptual understanding more effectively compared to previous cycles.

The observation focused on students' participation in discussions, the development of critical thinking during presentations, and the assessment of observational data. Reflections in Cycle III indicated that students had adapted well to the learning model and the integrated e-worksheets. Compared to earlier cycles, evidence of improvement was observed in students' performance: they could not only recall and comprehend the material but also apply, analyze, and evaluate information from the electronic teaching resources more independently. The design of the e-worksheets integrating multimedia elements, interactive tasks, and guided inquiry steps explicitly facilitated higher-order thinking skills and strengthened conceptual mastery by providing structured opportunities for reasoning, problem-solving, and reflection. This transition from flipbooks to e-worksheets enhanced learning efficiency, improved access to instructional features, and supported deeper engagement with the content. Figure 3 illustrates the appearance of the electronic teaching materials used.

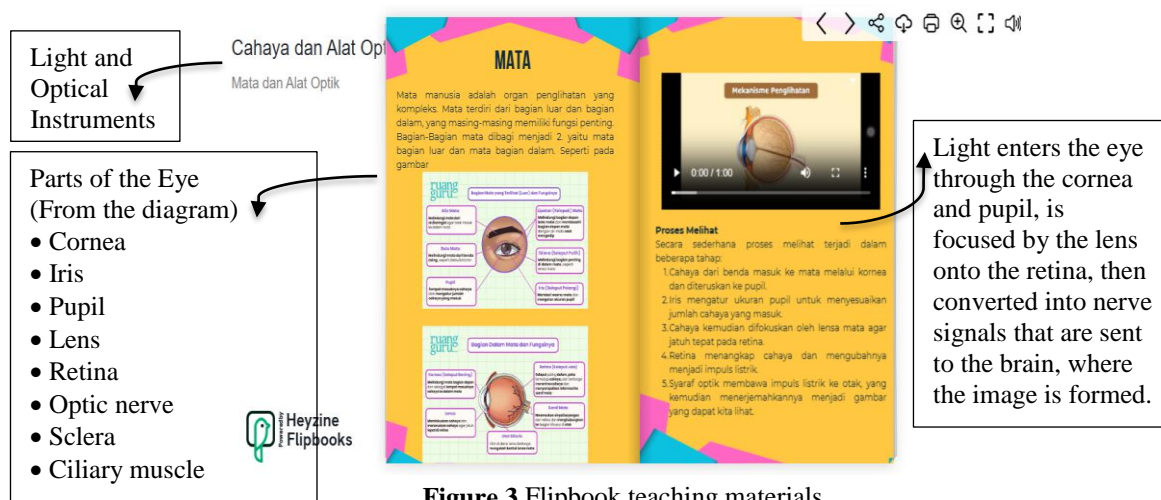


Figure 3 Flipbook teaching materials

The flipbook serves as interactive electronic teaching material, presenting science concepts through a combination of text, images, animations, videos, and audio. It is designed to facilitate students' understanding both visually and practically, while supporting independent and inquiry-based learning. In addition, the flipbook is structured according to the stages of structured inquiry, guiding students through observing phenomena, formulating questions, conducting simple investigations, analyzing data, and drawing evidence-based conclusions. Interactive features such as embedded quizzes, simulations, and reflective prompts provide immediate feedback and scaffolding, helping students monitor their own understanding. By integrating multimedia elements in a

coherent and systematic format, the flipbook not only enhances engagement and motivation but also reduces cognitive overload, accommodates diverse learning styles, and promotes deeper conceptual mastery and critical thinking skills.

Layers of the Earth

1. Crust
The crust is the outermost layer of the Earth's surface and has a thickness of approximately 5–70 km.

2. Mantle
The mantle is located beneath the crust and has a thickness of about 2,900 km.

- **Outer Core**
The outer core is located at a depth of about 2,900–5,150 km below the Earth's surface and is composed of molten iron and nickel.
- **Inner Core**
The inner core is located at a depth of about 5,150–6,371 km below the Earth's surface and is composed of solid iron and nickel.

Figure 4. The worksheet display teaching materials

The Earth consists of four main layers: the crust, mantle, outer core, and inner core. The crust is the thin, outermost layer where living organisms reside, with a thickness ranging from about 5 to 70 km. Beneath it lies the mantle, the thickest layer, extending to a depth of approximately 2,900 km and composed mainly of semi-molten rock that influences tectonic movement. Below the mantle is the outer core, a liquid layer rich in iron and nickel that generates the Earth's magnetic field. At the center is the inner core, a solid sphere primarily made of iron and nickel, characterized by extremely high temperatures and pressure.

Collecting Data

Tools and Materials

Procedure: Work in Groups!

Conduct the experiment according to the steps below. Write down the results of your observations and discuss them with your group

Results of Observations and Discussion

Write the results of your observations and the conclusions obtained after conducting the experiment.

Figure 5 LKPD (Students Worksheet) contained in electronic teaching materials

The student worksheets (LKPD) embedded in the electronic teaching materials contain tasks, questions, and experimental guidelines for students to complete. They are designed to enhance critical thinking, creativity, and independence in learning science concepts. In digital format, students can conduct observations, experiments, and problem-solving exercises interactively, following the structured inquiry-based learning model.

Table 3 presents the normalized gain (N-gain) scores for each cognitive level across the three cycles.

Table 3 N-gain Results for Each Cycle

Data	N-gain					
	Cycle I		Cycle II		Cycle III	
C1	0,4	Moderate	0,6	Moderate	0,1	Low
C2	0,3	Low	0,7	High	0,6	Moderate
C3	0,4	Moderate	0,8	High	0,7	High
C4	0,2	Low	0,5	Moderate	0,6	Moderate
C5	0,07	Low	0,1	Low	0,2	Low

Table 3 presents the normalized gain (N-gain) scores for each cognitive level across the three cycles. Students' abilities in aspects C2 to C5 showed continuous improvement from Cycle I to Cycle III, indicating increased proficiency in applying, analyzing, evaluating, and creating knowledge. Mastery of aspect C1 (remembering) increased from an N-gain of 0.4 (moderate) in Cycle I to 0.6 (moderate) in Cycle II but declined to 0.1 (low) in Cycle III. This decrease does not indicate a loss of recall ability; rather, the pretest scores in Cycle III were already high, leaving limited room for quantitative improvement. The observed improvements in C2–C5 were supported by the structured inquiry learning model assisted by electronic teaching materials. This approach guided students through problem-oriented tasks that encouraged critical thinking, reasoning, and evidence-based discussion. The integration of multimedia resources and interactive questions in the electronic materials provided opportunities for students to engage actively with the content, promoting higher-order cognitive skills (Diyana & Pebriana, 2022; Ramayani & Amalia, 2022; Saputra *et al.*, 2023). For C1 development, the problem-oriented syntax encouraged students to retrieve prior knowledge through guiding questions, images, and videos, ensuring that foundational recall supported more complex reasoning tasks (Agustina *et al.*, 2025; Sibiya & Mtshali, 2025).

Teachers facilitated activities such as observing phenomena, recording key information, and addressing factual questions, enabling students to access foundational knowledge (Ferdinand-james *et al.*, 2024; Nuraini *et al.*, 2025; Saputra *et al.*, 2025). While teachers guided the learning process with structured prompts and procedures, students were encouraged to construct explanations independently based on the evidence they gathered. Furthermore, integrating electronic teaching materials supported the concurrent development of both lower-level (C1) and higher-order cognitive skills, demonstrating how interactive digital resources can enhance the continuum of thinking processes in structured inquiry learning .

Electronic teaching materials served as crucial resources in supporting students' mastery of C1–C3 cognitive aspects. For C1 (remembering), these materials facilitated recall through multimedia content such as images, videos, and animations, which helped clarify abstract concepts that are difficult to convey via text alone (Handoyo *et al.*, 2024). The benefits of electronic teaching materials engaging multimedia, ease of distribution, and interactive features enhanced students' motivation and retention, laying a strong

foundation for higher-order cognitive skills. The C2 aspect (understanding) showed an N-gain increase from 0.3 (low) in Cycle I to 0.7 (high) in Cycle II, then slightly decreased to 0.6 (moderate) in Cycle III due to already high pretest scores. The improvement in C2 reflects the effectiveness of the problem formulation and hypothesis stages, where students actively connected observed phenomena, explained interrelationships among concepts, and developed tentative hypotheses (Trisnani *et al.*, 2024). Electronic teaching materials supported this stage by providing structured guidance, visualizations, and interactive prompts, enabling students to comprehend complex concepts and link them to real-world contexts. For C3 (applying), N-gain improved from 0.4 (moderate) in Cycle I to 0.8 (high) in Cycle II, with a slight decline to 0.7 (high) in Cycle III. During the data collection phase, students applied concepts in practical experiments guided by the electronic materials. The integration of real-life contexts, structured instructions, and interactive features such as simulations facilitated the transfer of knowledge to practical situations, promoted applied thinking skills, and encouraged independent exploration. Overall, the progression from C1 to C3 demonstrates a cumulative conceptual development, where foundational recall and understanding supported the effective application of knowledge. The design of electronic teaching materials combining multimedia, interactive tasks, and scaffolded guidance systematically facilitated higher-order cognitive skills while ensuring engagement and comprehension across all stages of learning.

A consistent increase in N-gain was observed in C4 (analyzing), rising from 0.2 (low) in Cycle I to 0.5 (moderate) in Cycle II and 0.6 (moderate) in Cycle III. This improvement was supported by hypothesis-testing activities within the structured inquiry model, where students compared observations with predictions, evaluated data against theory, and identified patterns and cause-effect relationships. The use of electronic teaching materials further strengthened analytical skills by providing structured information, clear data visualizations, interactive graphs, tables, and guided analysis steps that facilitated systematic reasoning (Kafi, 2023). Well-designed digital materials not only enhance engagement but also improve analytical abilities and learning outcomes (Nida *et al.*, 2021), making it an effective and interactive solution to support the development of higher-level thinking in the world of education (Banda & Nzabahimana, 2021).

The C5 aspect (evaluating) showed only a small increase, with the N-gain rising from 0.07 (low) in Cycle I to 0.1 (low) in Cycle II, and reaching 0.2 (low) in Cycle III. This limited improvement indicates that the evaluative stage in structured inquiry where students assess the logic of their experimental results, relate the findings to the initial hypothesis, and consider the strengths and weaknesses of the investigation process remains challenging. Developing evaluative thinking requires not only cognitive ability but also the formation of reflective habits, which typically emerge through long-term practice. This finding aligns with Azizah *et al.* (2019), who emphasize that higher-order thinking skills must be cultivated consistently and systematically. Although the electronic teaching materials included reflection prompts intended to support this skill, students tended to focus more on the concrete and procedural parts of the experiment, reducing opportunities for deeper engagement with evaluative tasks. This suggests that the issue is not merely the presence of evaluative elements in the learning resources, but the limited intensity and

scaffolding of reflective thinking activities. To strengthen the development of C5, pedagogical strategies such as structured class discussions, guided peer assessment, and reflective journals are needed so that students can internalize evaluative habits and move beyond surface-level reflection.

The N-gain in C5 (evaluating) was lower than in C1 (remembering) and C3 (applying) because evaluation requires not only content understanding but also the ability to compare, critique, and make evidence-based judgments skills associated with early critical and reflective thinking development. Although the quantitative increase in C5 was modest, students' evaluating skills improved consistently across cycles. Overall, the findings indicate that the structured inquiry model supported by electronic teaching materials progressively enhanced conceptual mastery across cognitive levels C1–C5. These results are consistent with Ni'mah and Widodo (2022), who found structured inquiry effective in strengthening sub-concept understanding, who highlighted the role of digital-based materials in supporting conceptual comprehension. Despite these benefits, the study acknowledges limitations, especially the limited time period, which may limit the optimal development of students' higher-order cognitive skills for the better and more focused

CONCLUSION

The structured inquiry learning model supported by electronic teaching materials has been proven effective in improving students' mastery of science concepts. This is evident from the increase in learning completeness across each cycle, rising from 44% in Cycle I to 58% in Cycle II, and reaching 81% in Cycle III. These improvements are also reflected in the N-gain scores for each cognitive indicator. The N-gain values for C1 (remembering) and C2 (understanding) were relatively high in Cycles I and II, although a slight decrease in C1 during Cycle III occurred due to the already high initial pretest scores. Indicators C3 (applying) and C4 (analyzing) showed consistent progress through Cycle III, and although the increase in C5 (evaluating) remained relatively low, the trend still indicates students' growing engagement and familiarity with the structured inquiry process. In conclusion, the implementation of the structured inquiry learning model assisted by electronic teaching materials can enhance students' mastery of science concepts in a gradual and sustainable manner. These findings hold important pedagogical implications, suggesting that structured inquiry can serve as an effective framework for promoting active learning and higher-order thinking skills. Future research is recommended to extend the implementation period, integrate a wider range of digital resources, and explore the model's potential across different subjects and learning environments. Teachers are encouraged to refine each stage of the inquiry process to strengthen higher-order thinking skills. Effective scaffolding and meaningful investigative tasks enhance students' analytical and reflective abilities. Clear guidance in evaluating evidence promotes systematic reasoning and deeper conceptual understanding. Continuous reflection on instruction supports optimal and sustainable cognitive development.

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