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The Implementation of the Fruit Battery Assisted Inquiry Model to Improve Students' Understanding of Science Concepts

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ABSTRAK

Penelitian ini dilatarbelakangi oleh rendahnya keaktifan dan pemahaman konsep IPAS siswa kelas V SD IT Muhammadiyah 06 Lhokseumawe pada materi rangkaian listrik sederhana akibat pembelajaran yang cenderung teoretis. Penelitian Tindakan Kelas (PTK) ini bertujuan meningkatkan kualitas proses dan hasil belajar siswa melalui penerapan model inkuiri terbimbing berbantuan media bio-baterai lemon. Subjek penelitian berjumlah 24 siswa. Data dikumpulkan melalui observasi aktivitas guru dan siswa serta tes tertulis di akhir setiap siklus. Hasil menunjukkan peningkatan signifikan kualitas proses, di mana aktivitas guru dan keaktifan siswa mencapai 100% (Sangat Baik) pada Siklus II. Peningkatan ini berdampak linear pada hasil belajar, ditandai kenaikan nilai rata-rata kelas dari 77,92 (Siklus I) menjadi 86,67 (Siklus II). Ketuntasan klasikal melonjak drastis dari 66,67% menjadi 91,67%, sehingga melampaui target keberhasilan (≥80%). Kesimpulannya, model inkuiri terbimbing dengan media bio-baterai lemon terbukti efektif mengoptimalkan keaktifan sekaligus menuntaskan pemahaman konsep IPAS siswa.

Kata Kunci: Inkuiri Terbimbing, Media Bio-Baterai, Rangkaian Listrik, Pemahaman Konsep IPAS, Penelitian Tindakan Kelas.

ABSTRACT

This study was motivated by the low levels of student engagement and conceptual understanding of science among fifth-grade students at SD IT Muhammadiyah 06 Lhokseumawe regarding simple electrical circuits, due to a teaching approach that tends to be theoretical. This Classroom Action Research (CAR) aims to improve the quality of the learning process and student outcomes through the application of a guided inquiry model supported by lemon bio-batteries. The research subjects consisted of 24 students. Data were collected through observations of teacher and student activities as well as written tests at the end of each cycle. The results showed a significant improvement in the quality of the learning process, with teacher activities and student engagement reaching 100% (Excellent) in Cycle II. This improvement had a linear impact on learning outcomes, marked by an increase in the class average score from 77.92 (Cycle I) to 86.67 (Cycle II). The class passing rate surged dramatically from 66.67% to 91.67%, thus exceeding the success target (≥80%). In conclusion, the guided inquiry model using lemon batteries proved effective in optimizing student engagement while ensuring their conceptual understanding of IPAS.

Keywords: Guided Inquiry, Bio-Battery Media, Electrical Circuits, Science Conceptual Understanding, Classroom Action Research.

A. INTRODUCTION

Learning is essentially a two-way communication process involving dynamic interaction among educators, learners, and learning resources within a learning environment (Djamaluddin, 2019). As a system, learning combines human elements, materials, facilities, and procedures that influence one another to achieve objectives optimally (Basir, 2017). The success of this educational system heavily depends on the effectiveness of organizing and transforming information from teachera as content providers to students as active recipients and processors of information so that the teaching-learning process can proceed effectively.

At the elementary school level, this essence of learning is now integrated into the Natural and Social Sciences (IPAS) subject through the Merdeka Curriculum, which emphasizes contextual and learner-centered learning (Kemendikbudristek, 2022). Science education no longer focuses on passive mastery of content but rather on developing scientific thinking skills and meaningful understanding through inquiry- based activities or hands-on investigations (National Research Council, 2012). However, when dealing with abstract concepts such as simple electrical circuits, students often face significant learning barriers because the concept of electric current is difficult to visualize without the support of concrete and contextual laboratory materials.

This low level of understanding of scientific concepts is reinforced by data from the 2022 PISA international assessment, in which Indonesian students' science literacy scores reached only 396 points, far below the OECD average of 485 points (OECD, 2023). This global empirical finding aligns with the actual challenges observed in the fifth-grade class at SD IT Muhammadiyah 06 Lhokseumawe, where students' average scores on daily quizzes on electrical circuits ranged only between 55 and 65, still falling below the established Minimum Competency Criteria (KKM) of 70. These low learning outcomes are driven by limited practical resources and the dominance of conventional lecture methods, leading students to tend to memorize verbal concepts without understanding the essence of the scientific process.

Learning difficulties in this area were identified through students' inability to transform information about electrical circuits from verbal form to visual form, such as circuit diagrams or graphs, and vice versa. In addition, students were unable to correlate the application of series and parallel circuit concepts with real-life examples, and often made repeated errors in classifying types of electrical circuits (series, parallel, and mixed). These weaknesses are exacerbated by students' inability to identify cause-and-effect relationships, distinguish characteristic equations in detail, and summarize electrical circuit material systematically.

To address this series of problems, a reconstruction of learning is needed through a model capable of directly stimulating science process skills (Astuti et al., 2025). The inquiry-based learning model is a relevant solution because it provides students with the opportunity to formulate problems, develop hypotheses, and draw conclusions independently (Sari et al., 2025). For this model to function optimally in electricity-related content, it requires support from concrete, eco-friendly media that are close to students' daily lives, such as bio-batteries or fruit batteries (Ningrum et al., 2025). The implementation of inquiry- based learning using fruit battery experiments has been proven to significantly boost students' learning motivation and understanding of electrical concepts (Akben, 2020). Based on these considerations, this study limits its scope to the application of the fruit battery-assisted inquiry model on simple electrical circuit material specifically for fifth-grade students at SD IT Muhammadiyah 06 Lhokseumawe.

Based on the above description of the conditions, gaps, and potential solutions, this study focuses on addressing the main issue of how the implementation of the fruit- battery-assisted inquiry model can improve fifth-grade students' conceptual understanding of science in the context of simple electrical circuits. Through this approach, the primary objective of this study is to describe and analyze in depth the effectiveness of implementing the fruit- battery-assisted inquiry model in improving fifth-grade

elementary school students' understanding of science concepts. The results of this study are expected to provide theoretical and practical alternative solutions to support the reconstruction of more meaningful science learning at the elementary level.

B. RESEARCH METHODOLOGY

This study is a Classroom Action Research (CAR) project conducted in a participatory and collaborative manner to enhance students' conceptual understanding through an innovative-progressive learning model (Trianto, 2018). This study was systematically designed into two cycles adopting Kurt Lewin's spiral model, where each cycle consists of four integrated stages: planning, implementation, observation, and reflection (Marzuki, 2022). The research subjects were 25 fifth-grade students at SD IT Muhammadiyah 06 Lhokseumawe during the odd semester of the 2025/2026 academic year.

Cycle I was conducted over three sessions, focusing on the topic of simple electrical circuits. The planning stage began with determining the subject matter, developing an inquiry-based teaching module, preparing bio-battery materials (lemons, zinc nails as anodes, and copper coins as cathodes), and designing an observation sheet. The implementation phase was divided into three sessions:

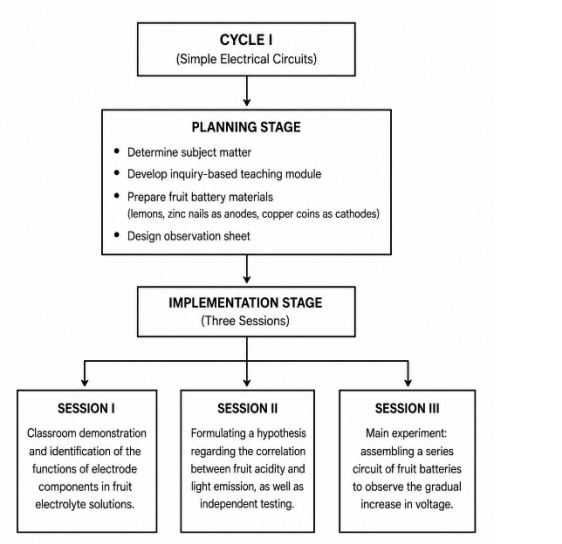


Figure 1. Flowchart of Cycle I Implementation in the Fruit Battery-Assisted Inquiry Learning Model

At the end of the third session, learning outcomes were evaluated through individual formative tests (Haris & Jihad, 2013). The observation phase was conducted twice (during the first and second sessions) by the researcher together with the classroom teacher as an observer to monitor instructional activities and student engagement (Sriwanto et al., 2015). The reflection phase was conducted at the end of the cycle to analyze students' technical and cognitive challenges as a basis for improvement if test results did not meet the established Minimum Passing Score (MPS) of 75.

Cycle II was designed as a learning reconstruction based on the reflections from Cycle I and was also conducted over three sessions, with an in-depth exploration of series and parallel circuits. The planning phase focused on enriching the Teaching Module scenarios and revalidating supporting experimental tools. The implementation phase was divided into three sessions:

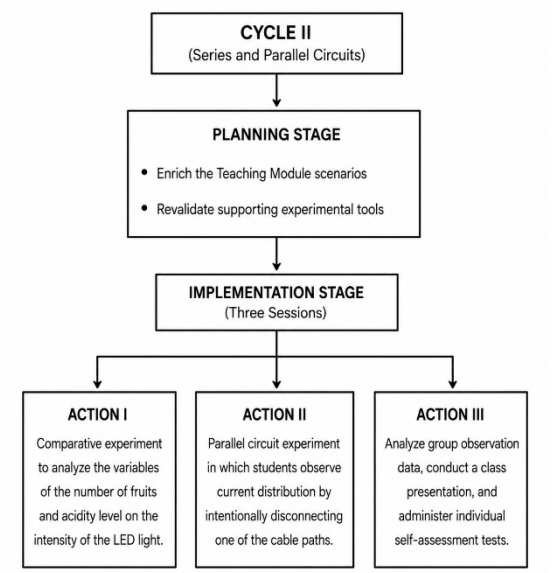


Figure 2. Flowchart of Cycle II Implementation in the Fruit Battery-Assisted Inquiry Learning Model

The observation phase was conducted twice during the first and second sessions using a systematic observation guide in collaboration with the classroom teacher and peers. The final reflection stage was conducted to synthesize all of the students' cognitive achievements, if the indicators of classical learning mastery were met, the

action cycle was declared complete. Data analysis in this classroom action research followed a process that involved reviewing all the data, reducing the data through categorization or classification, and drawing conclusions or conducting final verification. The success of the teacher's instructional activities and the students' active learning responses were calculated using the Average Score Percentage (AS) formula as follows:

$$AS = \frac{\text{Total Score}}{\text{Maximum Score}} \times 100\ \%$$

The results of the calculation of the average percentage score from the observation sheet were then interpreted in terms of the classification of the level of success of the intervention to determine whether the learning process was proceeding according to the scenario or required corrective action in the next cycle. Based on this assessment formula, the classification of the level of success of the intervention is presented in Table 1.

Table 1. Action Success Criteria Indicators

Scale Criteria	Qualification
90% ≤ AS ≤ 100%	Excellent
80% ≤ AS < 90%	Good
70% ≤ AS < 80%	Fair
60% ≤ AS < 70%	Poor
0% ≤ AS < 60%	Very Poor

Based on the scale criteria in Table 1, the success rate of both the teacher's instructional process and the students' activities must reach at least the "Good" category or achieve a percentage of ≥ 80%. On the other hand, the test result data were analyzed using the classical learning completeness indicator. A class is declared to have achieved classical completeness if at least ≥ 80% of the total number of students in the class successfully obtain a score equal to or above the Minimum Completeness Criteria (KKM) set by the school, which is 75. The formula for processing classical completeness data is as follows:

$$KKM = \frac{\text{Number of Students Who Complete Learning}}{\text{Total Number of Students}} \times 100\%$$

RESULTS AND DISCUSSION

Description of Cycle I

The Classroom Action Research (CAR) conducted in Class V of SD IT Muhammadiyah 06 Lhokseumawe aimed to improve students' conceptual understanding of science, specifically on the topic of simple electrical circuits. This study was completed in two sequential cycles, each consisting of three meetings that integrated a guided inquiry learning model with alternative bio-battery media made from lemons. To measure the effectiveness of the instructional process managed by the researcher and observed by the classroom teacher, data regarding the teacher's instructional activities and students' learning engagement were collected periodically during the first and second meetings of each cycle. The recapitulation of these process observation results is comprehensively presented in Table 2.

Table 2. Recapitulation of Process Observation Scores (Teacher and Students)

Cycle & Meeting	Obcerved Aspect	Presentage	Category
Cycle I			
Meeting 1	Teacher's Activities	90.63%	Excellent
	Students'	70.00%	Fair
	Engagement		
Meeting 2	Teacher's Activities	93.75%	Excellent
	Students' Engagement		
Cycle II			
Meeting 1	Teacher's Activities	96.88%	Excellent
	Students'	90.00%	Excellent
Meeting 2	Engagement	100.00%	Excellent
	Teacher's Activities		
	Students'		

Colleagues (Moleong, 2006).

To ensure the validity of the data collected in the field, the researcher employed three verification techniques: meticulous observation, triangulation (comparing test results, observations, and research subjects), and peer review or discussion of the process with colleagues (Moleong, 2006).

Based on the empirical data recorded in Table 1, a significant upward trend in the quality of the learning process is evident from Cycle I to Cycle II. At the beginning of the intervention (Cycle I, Meeting 1), the teacher's instructional delivery was already rated as "Excellent" (90.63%). However, the students' active 70.00%, falling into the "Fair" category. This initial barrier occurred because the students were unaccustomed to the syntax of the inquiry model, which demands independent critical thinking; they tended to remain passive and experienced technical confusion when identifying the anode (zinc nail) and cathode (copper coin) on the lemons. This condition began to improve in the second meeting through more intensive scaffolding, where student engagement rose to 85.00% (Good).

Description of Cycle II

Entering Cycle II, the researcher reconstructed the instructional strategies based on the reflections from the previous cycle. Consequently, in the first meeting of Cycle II, student engagement surged to 90.00% (Excellent) and reached an optimal score of 100.00% in the second meeting. This dramatic increase took place because the students had fully mastered the mechanism of scientific inquiry. The utilization of concrete bio-battery media proved empirically successful in transforming the classroom atmosphere into a highly interactive environment.

Students demonstrated high levels of critical reasoning during the comparative experiments and parallel circuit testing; they were even able to analyze the distribution of electrical current independently when one of the cable paths was intentionally disconnected. This optimization of the process directly and linearly impacted the students' cognitive learning outcomes, the data for which are displayed in Table 3.

Table 3. Distribution of Students' Conceptual Understanding

Classical Mastery Status	Not Achieved (≥80%)	Achieved

(Source: Processed Research Data, 2026)

Discussion

The implementation of the guided inquiry learning model assisted by lemon-based bio-battery media demonstrated a positive impact on students' conceptual understanding of simple electrical circuits. The improvement observed in this study was not only reflected in students' learning outcomes but also in the quality of the learning process throughout the two action research cycles. The findings indicate that the learning activities designed through guided inquiry enabled students to actively construct knowledge through direct experience and experimentation.

During Cycle I, students were introduced to the concepts of simple electrical circuits through demonstrations and guided investigations using lemon-based bio-batteries. Although the teacher's instructional activities were categorized as excellent, student engagement during the first meeting remained relatively low. Many students were unfamiliar with the inquiry learning process and tended to rely on teacher explanations rather than independently exploring scientific phenomena. Difficulties were also observed when students attempted to identify the functions of the zinc nail as the anode and the copper coin as the cathode. Furthermore, several students experienced misconceptions regarding the relationship between electric current, voltage, and the brightness of the LED bulb. As a result, some groups required intensive guidance during the experimental activities. These findings indicate that elementary school students need adequate scaffolding when they first engage in inquiry-based learning activities.

The challenges encountered in Cycle I became important reflection materials for improving the implementation of Cycle II. Based on the evaluation results, the researcher redesigned the learning activities by providing clearer instructions, strengthening group discussions, and

increasing opportunities for students to compare experimental results. In Cycle II, students conducted comparative investigations to analyze the effects of fruit acidity and the number of fruits on electrical energy production. Students were also involved in parallel circuit experiments that required them to observe changes in current distribution when one of the cable paths was intentionally disconnected. Through these activities, students were encouraged to analyze evidence, formulate explanations, and draw conclusions independently.

The learning process in Cycle II showed substantial improvement compared to Cycle I. Students became more confident in conducting experiments and were more actively involved in discussions and presentations. They demonstrated better scientific reasoning skills by explaining why differences in circuit configurations affected LED brightness. The use of concrete bio-battery media helped students visualize abstract electrical concepts that were previously difficult to understand through conventional explanations alone. According to Abdullah (2025), science learning media play an important role in helping elementary school students understand abstract concepts by providing concrete and meaningful learning experiences. The findings of the present study support this view, as students showed greater conceptual understanding after directly observing electrical phenomena through bio-battery experiments.

The improvement in students' learning engagement is also consistent with the characteristics of guided inquiry learning. Dani et al. (2021) reported that guided inquiry learning can enhance students' motivation and creativity because learners are actively involved in investigating problems and constructing their own understanding. Similarly, Akben (2020) found that inquiry-based learning significantly improves students' achievement in science education by encouraging active participation throughout the learning process. In the present study, students gradually became more independent in conducting investigations and analyzing experimental results, particularly during Cycle II.

From a theoretical perspective, the findings can be explained through constructivist learning theory. Bada (2015) argues that knowledge is constructed through learners' active interaction with their environment rather than passively received from teachers. Likewise, Dewey (1997) emphasizes that meaningful learning occurs when students engage in direct experiences that allow them to connect theory with practice. The lemon-based bio-battery activities provided opportunities for students to experience scientific concepts firsthand, thereby facilitating deeper conceptual understanding. The effectiveness of guided inquiry observed in this study is also supported by previous studies. Gultom and Sinuraya (2016) found that inquiry-based learning improves students' critical thinking and learning outcomes because learners actively participate in problem-solving activities. Guritno et al. (2015) further reported that guided inquiry contributes positively to science process skills and scientific attitudes. In addition, Djawadi (2016) explained that inquiry-oriented science learning encourages students to investigate, analyze, and conclude scientific phenomena independently. These findings are in line with the results of the present study, where students demonstrated improved engagement, scientific reasoning, and conceptual mastery after participating in inquiry-based bio-battery experiments.

The use of fruit batteries as learning media also contributed significantly to students' learning experiences. Demirci (2019) found that fruit battery experiments positively affect students' science achievement and learning motivation because they transform abstract electrical concepts into observable phenomena. Similar conditions were observed in this study, where students became more enthusiastic and actively engaged when they witnessed LED bulbs lighting up through the electrical energy generated by lemons. This direct experience helped reduce misconceptions and facilitated a better understanding of electrical circuit concepts.

Overall, the differences between Cycle I and Cycle II demonstrate that the continuous improvement of learning strategies through reflection is essential in classroom action research. The integration of guided inquiry

learning and lemon-based bio-battery media successfully transformed students from passive recipients of information into active participants in the learning process. As a result, students' engagement, scientific reasoning, and conceptual understanding improved substantially, leading to the achievement of the predetermined success indicators.

CONCLUSION

The implementation of the guided inquiry learning model assisted by fruit battery media effectively improved fifth-grade students' understanding of science concepts on simple electrical circuits at SD IT Muhammadiyah 06 Lhokseumawe. The improvements observed across the two classroom action research cycles indicate that guided inquiry encouraged students to actively investigate, analyze experimental results, and construct scientific knowledge through direct experience. Furthermore, the use of fruit battery media helped transform abstract concepts into concrete learning experiences, thereby enhancing students' engagement, scientific reasoning, and conceptual understanding. Therefore, integrating guided inquiry with fruit battery media is an effective strategy for improving elementary students' science learning outcomes and conceptual understanding.

This study is not without limitations. The research was conducted within a single classroom at one elementary school with a relatively small number of subjects, so the findings cannot yet be generalized to broader populations or different school contexts. In addition, the implementation was limited to two cycles focusing solely on the topic of simple electrical circuits, which restricts insight into the long-term retention of students' conceptual understanding beyond the research period. The bio-battery medium used was also limited to lemons, without comparing it to other fruit or organic materials that may yield different levels of effectiveness. Based on these limitations, future researchers are encouraged to expand the scope of the study to larger and more diverse samples across multiple schools, extend the number of cycles or include a delayed post-test to examine the retention of students' conceptual understanding over time, and explore other bio-battery materials or additional science topics to enrich the application of the guided inquiry model. Further studies are also recommended to examine the influence of guided inquiry combined with bio-battery media on other learning outcomes, such as students' scientific attitudes and higher-order thinking skills.

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