

Analysis of the Implementation of a Tinkercad-Assisted Inquiry-Based Learning Model in Electrical Circuit Instruction

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Abstrak

The urgency of this study lies in addressing students' difficulties in understanding electrical circuits through an inquiry-based learning approach supported by Tinkercad. This study aimed to analyze the implementation of an inquiry learning model assisted by Tinkercad in teaching electrical circuit concepts at the senior high school level. The study employed a descriptive research design involving students and a physics teacher in a senior high school. Data were collected through classroom observations, student worksheets (LKPD), and teacher interviews. The implementation of the inquiry learning model was evaluated based on the achievement of each inquiry learning stage, while student worksheet results were used to assess learning outcomes related to conceptual understanding, process skills, analytical skills, conclusion drawing, and concept integration. The findings showed that all stages of the inquiry learning model were successfully implemented according to the planned procedures. Students demonstrated the highest level of engagement during the data collection stage through electrical circuit simulations using Tinkercad. The average student worksheet achievement reached 85%, categorized as very good. The highest score was obtained in conceptual understanding (91%), while the lowest score was found in conclusion-drawing skills (79%). Teacher interview results revealed positive perceptions of Tinkercad, particularly in its ability to visualize abstract electrical concepts, facilitate student exploration, and provide an alternative to conventional laboratory activities. Despite these positive findings, some students still required guidance in formulating hypotheses and drawing scientific conclusions. This study concludes that the integration of inquiry-based learning and Tinkercad can support the implementation of electrical circuit learning by providing a more interactive, exploratory, and student-centered learning environment. The findings contribute to the growing use of virtual laboratory technology in physics education, particularly in schools with limited laboratory facilities.

Kata Kunci: *Inquiry Learning, Tinkercad, Virtual Laboratory, Electrical Circuits, Physics Education.*

Introduction

Physics education plays an important role in developing students' scientific thinking skills, problem-solving abilities, and conceptual understanding. One of the physics topics that remains challenging for secondary school students is electric circuits because it involves abstract concepts that require visualization skills and an understanding of the relationships among current, voltage, and resistance within a system. Numerous studies have reported that students continue to experience difficulties in understanding fundamental electric circuit concepts and frequently develop misconceptions related to electric current flow, potential difference, and the characteristics of series and parallel circuits (Winarti et al., 2021; Riwayani

et al., 2025). These difficulties contribute to low conceptual understanding and limit students' ability to connect theoretical knowledge with real-world phenomena encountered in everyday life.

From a constructivist perspective, conceptual understanding cannot be acquired solely through the direct transfer of information from teachers to students; rather, it is actively constructed through learning experiences and interactions with the learning environment. Therefore, physics instruction requires learning environments that enable students to explore, observe, and test concepts independently. Along with the advancement of digital technology, virtual laboratories have emerged as a promising alternative for overcoming limitations in laboratory facilities while helping students visualize phenomena that are difficult to observe directly. Various studies have reported that virtual laboratories can improve conceptual understanding, science process skills, and student engagement in physics learning (Marín-Marín et al., 2024; Adhantoro et al., 2025). Furthermore, digital simulations allow students to conduct repeated experiments in a safe, flexible, and efficient manner without the risk of damaging laboratory equipment (Govender, 2025; Wang et al., 2024).

Despite the development of various instructional innovations, the teaching of electric circuits in schools still faces several challenges. Limited laboratory equipment, restricted laboratory time, and the predominance of teacher-centered instruction reduce students' opportunities to gain the investigative experiences necessary for developing deep conceptual understanding. As a result, students have fewer opportunities to conduct observations, test hypotheses, and analyze data directly. These conditions highlight the need for instructional approaches that integrate digital technology with student-centered scientific inquiry activities, ensuring that learning is not only focused on conceptual mastery but also on the development of scientific thinking and problem-solving skills.

One of the solutions widely recommended in the literature is the use of Tinkercad as a virtual laboratory for learning electric circuits. Tinkercad is a cloud-based platform that can be accessed free of charge without requiring the installation of specialized software, making it relatively easy for both teachers and students to use (Erdogan et al., 2025). The platform enables users to design, simulate, and test various electric circuits interactively through an environment that closely resembles a real laboratory setting. Previous studies have shown that the use of Tinkercad helps students understand electronics and electric circuit concepts through direct visualization, instant feedback, and a safer and more flexible exploration process (Kurmangaliyeva et al., 2025; Torres & Inga, 2025). In addition, simulation-based digital platforms have been found to enhance student engagement and support more contextualized learning experiences (Maspul, 2024; Govender, 2025).

To maximize the educational benefits of Tinkercad, an instructional model that actively engages students in knowledge construction is required. One such model is inquiry-based learning, which is grounded in constructivist theory. Inquiry learning positions students at the center of the learning process through activities such as formulating problems, developing hypotheses, conducting investigations, analyzing data, and drawing conclusions based on evidence. Recent studies have demonstrated that inquiry-based learning supported by virtual laboratories can improve conceptual understanding, critical thinking skills, and science process skills more effectively than conventional instruction (Doyan et al., 2025; Verawati et al., 2025). Furthermore, technology-supported inquiry approaches contribute to the development of twenty-first-century competencies, including collaboration, communication, creativity, and problem-solving skills (Govender, 2025; Zhang et al., 2024).

Several previous studies have reported the effectiveness of virtual laboratories and digital simulations in electronics and electric circuit education. The previous studied found that interactive web-based learning media can improve the quality of physics instruction through more representative visual presentations (Doyan et al., 2025). The previous studied demonstrated that digital simulations help students understand fundamental electronics concepts and improve their technical skills in designing electric circuits (Torres & Inga, 2025; Kurmangaliyeva et al., 2025). Other studies have also revealed that integrating digital technology into science education enhances learning motivation, digital literacy, and student engagement throughout the learning process (Marín-Marín et al., 2024; Adhantoro et al., 2025).

Nevertheless, most previous studies have focused on developing instructional media, examining the effectiveness of media on learning outcomes, or implementing virtual laboratories in general. Research specifically investigating the implementation of inquiry-based learning assisted by Tinkercad on electric circuit topics at the senior high school level remains relatively limited. Furthermore, only a few studies have simultaneously examined the implementation fidelity of inquiry learning syntax, students' responses to the learning process, and the relevance of Tinkercad as a supporting medium for physics instruction. Therefore, a research gap still exists and needs to be addressed to obtain a more comprehensive understanding of the implementation of Tinkercad-assisted inquiry learning in the context of electric circuit education at the secondary school level.

Based on the foregoing discussion, this study aims to: (1) describe the implementation of a Tinkercad-assisted inquiry learning model in teaching electric circuits at the senior high school level; (2) analyze students' worksheet achievement during the implementation of the learning model; and (3) explore teachers' responses regarding the use of Tinkercad in physics instruction.

The novelty of this study lies in integrating Tinkercad as a virtual simulation tool within an inquiry-based learning model for electrical circuit instruction, providing students with an interactive environment to explore, construct, test, and analyze circuits while developing conceptual understanding and scientific inquiry skills.

Method

Research Design

This study employed a quantitative descriptive research design aimed at describing the implementation of an inquiry-based learning model assisted by Tinkercad on the topic of electrical circuits in senior high school. The study focused on the implementation of inquiry learning syntax, students' worksheet (LKPD) achievement, and teachers' responses to the use of Tinkercad in physics learning.

A quantitative descriptive approach was selected because the study did not aim to examine the effect or effectiveness of a particular treatment. Instead, it sought to describe the implementation process and learning outcomes based on data collected during the instructional activities. Quantitative data were obtained from students' worksheet scores and classroom observations, which were analyzed using descriptive statistics in the form of percentages.

Research Site and Time

The study was conducted at SMAN 11 Makassar during the second semester of the 2025/2026 academic year. The research site was selected purposively based on the suitability of the instructional content and the school's readiness to support the use of technology-based learning media. Data collection was carried out in April 2026 during the implementation of the electrical circuits unit for Grade XI students.

Research Participants

The participants consisted of 30 Grade XI students and one physics teacher from SMAN 11 Makassar. Participants were selected using purposive sampling based on the relevance of the instructional topic and students' involvement in the implementation of inquiry-based learning assisted by Tinkercad.

Data Collection Techniques

Observation

Observation was conducted to collect data regarding the implementation of the inquiry-based learning model assisted by Tinkercad during classroom instruction. Direct observations were carried out using an observation checklist developed according to the phases of the inquiry learning model. The observed aspects included problem orientation, hypothesis formulation, data collection through simulation activities, data analysis, and drawing conclusions. In addition, observation was used to monitor students' participation and engagement throughout the learning process.

Student Worksheets (LKPD)

Student worksheets (LKPD) were used to collect data on students' learning achievement after participating in inquiry-based learning assisted by Tinkercad. The worksheets were designed according to the stages of inquiry learning and served as an instrument for assessing students' conceptual understanding and learning skills throughout the instructional process.

Interview

Interviews were conducted with the physics teacher as supporting data to obtain information regarding the ease of using Tinkercad, its suitability for the instructional content, and its potential application in physics education.

Research Instruments

The research instruments consisted of observation sheets, student worksheets (LKPD), and interview guidelines.

Observation Sheet

The observation sheet was used to assess the implementation of the inquiry learning model, including problem orientation, hypothesis formulation, data collection, data analysis, and conclusion drawing. The observation results were used to describe the implementation process of the learning activities.

Student Worksheets (LKPD)

The worksheets were used to assess students' achievement during the learning activities. Assessment was based on the following indicators: conceptual understanding, process skills, analytical skills, ability to draw conclusions, and conceptual integration.

Interview Guidelines

The interview guidelines served as a reference for obtaining information from the physics teacher regarding the use of Tinkercad in physics instruction, the benefits of the learning media, and challenges encountered during the implementation process.

Instrument Validation

The research instruments were reviewed by two physics education lecturers and one physics teacher to ensure the alignment of the indicators with the research objectives. The validation results were used to revise and improve the instruments prior to data collection. The content validity of the instruments was evaluated by two physics education experts and one experienced physics teacher. The validation process focused on the relevance, clarity, and appropriateness of each indicator in relation to the research objectives. Based on the validators' evaluations, the instruments were categorized as valid and suitable for data collection after minor revisions.

Data Analysis Techniques

Data obtained from observations, student worksheets, and interviews were analyzed using descriptive analysis techniques. Observation data were used to describe the implementation of the inquiry-based learning model assisted by Tinkercad. Interview data served as supporting evidence to strengthen the findings obtained from observations and student worksheets. Student worksheet data were analyzed using descriptive statistics in the form of percentages, calculated using the following formula:

$$\text{Percentage} = (\text{Obtained Score} / \text{Maximum Score}) \times 100\%$$

The percentage scores were interpreted according to the criteria presented in Table 1.

Table 1. Interpretation Criteria of Achievement Percentage

Percentage (%)	Category
81–100	Excellent
61–80	Good
41–60	Fair
21–40	Poor
0–20	Very Poor

To enhance data credibility, methodological triangulation was employed by comparing the results obtained from observations, student worksheets, and interviews. This approach provided a more comprehensive understanding of the implementation of the Tinkercad-assisted inquiry learning model on the topic of electrical circuits in senior high school.

Result

Implementation of the Inquiry Learning Model Assisted by Tinkercad

The observation results indicate that the inquiry learning model assisted by Tinkercad could be implemented in accordance with the planned syntax. The learning activities began with the problem orientation stage by presenting contextual problems related to the

application of electrical circuits in daily life. At this stage, students showed interest in the problems presented and began relating them to their prior experiences. Next, students were guided to formulate hypotheses in groups based on the given problems. At this stage, some students still required teacher guidance in developing initial assumptions that were consistent with electrical circuit concepts. Nevertheless, group discussions proceeded quite well, and most students were able to express their opinions during the learning process.

The data collection stage was carried out through electrical circuit simulations using Tinkercad. Students designed series and parallel circuits and then observed changes in current and voltage occurring within the circuits. Based on the observation results, this stage demonstrated the highest level of student engagement compared to the other stages. Most students actively experimented with various circuit configurations and discussed the simulation results they obtained. The results of the observation of the implementation of the inquiry learning model syntax are presented in Table 2.

Table 2. Implementation of the Inquiry Learning Model Syntax Assisted by Tinkercad

Inquiry Stage	Category	Observation Findings
Problem Orientation	Appropriate	Students showed interest in the problems presented
Hypothesis Formulation	Appropriate	Some students still required teacher guidance
Data Collection	Highly Appropriate	Students actively conducted simulations using Tinkercad
Data Analysis	Appropriate	Group discussions proceeded quite well
Drawing Conclusions	Highly Appropriate	Most students were able to draw conclusions from the learning activities

Based on Table 2, all learning syntax stages were implemented successfully. The data collection and conclusion-drawing stages were categorized as highly appropriate, while the hypothesis formulation and data analysis stages still required teacher assistance in several groups. These findings indicate that the use of Tinkercad can support the implementation of inquiry learning, particularly in concept exploration and investigation activities.

Results of Students' Worksheet (LKPD) Completion

The assessment of the student worksheets (LKPD) was conducted to determine student achievement on five learning indicators, namely conceptual understanding, process skills, analytical ability, conclusion-drawing ability, and concept integration.

Table 3. Results of Students' Worksheet (LKPD) Assessment

No.	Indicator	Percentage	Category
1	Conceptual Understanding	91%	Very Good
2	Process Skills	87%	Very Good
3	Analytical Ability	83%	Very Good
4	Drawing Conclusions	79%	Good
5	Concept Integration	85%	Very Good
	Average	85%	Very Good

Based on Table 3, the average student worksheet achievement was 85%, which falls into the very good category. However, there were variations in achievement across indicators. The conceptual understanding indicator obtained the highest percentage (91%), while the conclusion-drawing indicator obtained the lowest percentage (79%).

The high achievement in the conceptual understanding indicator indicates that most students were able to explain the concepts of series and parallel circuits after conducting simulations using Tinkercad. In addition, the process skills indicator also obtained a high

percentage (87%), indicating that students were able to use simulations to conduct observations and collect the data required for learning.

For the analytical ability and concept integration indicators, most students were able to relate simulation results to the theoretical concepts they had learned. Nevertheless, several students still experienced difficulties in interpreting the simulation results in greater depth. This condition was reflected in the conclusion-drawing indicator, which obtained the lowest percentage among all indicators. These findings suggest that some students still require guidance in formulating conclusions based on the observational data they have obtained. Overall, the worksheet results indicate that students were able to follow the stages of inquiry learning and effectively utilize Tinkercad as a medium for exploring electrical circuit concepts. However, the ability to formulate scientific conclusions still requires attention in future learning implementations.

Teacher Responses to the Use of Tinkercad

The interview results indicate that teachers provided positive responses toward the use of Tinkercad in electrical circuit learning. According to the teachers, the platform helps visualize concepts that are difficult to observe directly through conventional learning, thereby making it easier for students to understand the relationships among components within an electrical circuit. The teacher stated: *"Tinkercad helps students understand electrical circuits because they can directly observe changes in current and voltage when components in the circuit are modified."*

In addition to supporting concept visualization, teachers also considered Tinkercad relatively easy for students to use after receiving initial explanations regarding the available features. However, during the initial stages of implementation, several students still required assistance in operating the simulations and interpreting the results they obtained. Teachers also stated that Tinkercad has the potential to become an alternative learning tool that supports physics laboratory activities, particularly in schools with limited laboratory facilities. Therefore, Tinkercad can be utilized as a supporting medium to facilitate the implementation of inquiry-based learning in electrical circuit topics.

Discussion

Implementation of the Inquiry Learning Model Assisted by Tinkercad

The observation results showed that all stages of the inquiry learning model assisted by Tinkercad were implemented according to the planned procedures. These findings indicate that Tinkercad can be utilized as a medium that supports the implementation of inquiry-based learning, particularly during the exploration and investigation of electrical circuit concepts. This finding is consistent with previous studies reporting that Tinkercad has the potential to support investigation-based learning in electrical circuit topics through virtual experimental activities.

The high level of student engagement observed during the simulation activities may be attributed to the interactive nature of Tinkercad. Unlike conventional instruction, virtual simulations allow students to manipulate circuit components, observe immediate changes in electrical variables, and test multiple configurations without the constraints of physical laboratory resources. This interactive experience may facilitate active knowledge construction and increase students' motivation to participate in inquiry activities. The successful implementation of the learning model can be explained through constructivist theory, which emphasizes that knowledge is actively constructed through learning experiences and interactions with the learning environment. In this study, Tinkercad functioned as a virtual

learning environment that enabled students to independently explore, observe, and test concepts. Virtual simulations allowed students to visualize phenomena that are difficult to observe directly, thereby facilitating the process of knowledge construction. Previous studies have also stated that virtual technology can assist in visualizing electrical concepts that cannot be directly observed, and that virtual environments can enhance the quality of learning experiences in electrical circuit topics.

During the data collection stage, students demonstrated high engagement while conducting series and parallel circuit simulations using Tinkercad. This condition suggests that the use of virtual simulations provides students with opportunities to conduct investigations without being constrained by the availability of laboratory equipment. This finding is supported by previous studied, who stated that Tinkercad can serve as a flexible and accessible alternative for dynamic electricity laboratory activities (Maspul, 2024). Furthermore, Virtual laboratories in dynamic electricity topics can support students' exploration and data collection activities (Saputri et al., 2023; Budiarti et al., 2025).

Nevertheless, some students still required guidance during the hypothesis formulation and conclusion-drawing stages. This condition indicates that scientific thinking skills do not develop automatically through the use of technology alone but require adequate teacher guidance. This finding is consistent with the previous studied, who emphasized that the success of inquiry-based learning is strongly influenced by the scaffolding provided by teachers throughout the investigation process (Antonio & Prudente, 2024). Similarly, inquiry learning supported by digital simulations still requires teacher assistance to help students perform analysis and reasoning optimally (Manurung & Simamora, 2025).

Students' Worksheet (LKPD) Achievement

The results of the worksheet assessment indicated that students achieved an average score of 85%, which falls into the very good category. The highest percentage was obtained for the conceptual understanding indicator (91%), whereas the conclusion-drawing indicator achieved the lowest percentage (79%). This variation suggests that students found it relatively easier to understand concepts and conduct observations than to formulate generalizations based on the data they collected.

The high achievement in conceptual understanding indicates that Tinkercad simulations helped students visualize the relationships among current, voltage, and resistance in electrical circuits. Visualization is one of the primary advantages of virtual laboratories because it allows students to observe phenomena that are difficult to see directly in conventional laboratory activities. Previous studies have stated that digital visualization helps students understand abstract electrical principles, and that Tinkercad-based electrical circuit simulations help students understand the relationships among electrical components through more concrete visual representations.

The high achievement in process skills indicates that students were able to conduct observations, collect data, and interpret simulation results effectively. This finding is consistent with the previous studied, who demonstrated that virtual laboratories can support students' science process skills through exploration and investigation activities (Fitria & Purnomo, 2025). Similar findings have also been reported, namely that the integration of virtual laboratories into inquiry-based learning can enhance student engagement in scientific investigation processes.

However, the conclusion-drawing indicator obtained a lower percentage than the other indicators. This result suggests that some students still experienced difficulties in connecting their observations with the underlying scientific principles. A similar condition was reported by previous studies, who found that higher-order thinking skills, particularly synthesis and conclusion drawing, remain challenging in inquiry-based learning environments (Arifin et al., 2025). The another study also emphasized that conclusion-drawing skills represent a component of higher-order thinking that requires continuous practice and development (Antonio & Prudente, 2024). Overall, the worksheet results indicate that students were able to follow the stages of inquiry learning and effectively utilize Tinkercad as a tool for exploring electrical circuit concepts. These findings support previous studies demonstrating that the use of Tinkercad can create a more interactive learning experience and encourage active student engagement in technology-based learning.

Teacher Responses to the Use of Tinkercad

The interview results revealed that teachers responded positively to the use of Tinkercad in electrical circuit learning. Teachers believed that the platform helped visualize concepts that are difficult to observe directly and facilitated students' understanding of the relationships among components within an electrical circuit. This finding aligns with previous studies stating that virtual technology can improve the visualization of electrical concepts and thereby facilitate the learning process. Teachers also considered Tinkercad relatively easy for students to use after receiving initial guidance regarding its available features. This finding is supported by previous reports indicating that Tinkercad possesses a high level of usability and is easy to implement in technology-based learning activities.

Furthermore, teachers viewed Tinkercad as a potential alternative learning tool when physical laboratory facilities are limited. This finding is consistent with the previous study, who stated that Tinkercad can serve as an alternative medium for dynamic electricity laboratory activities in schools (Masputi, 2024). Virtual laboratories can provide a solution to limited laboratory facilities without reducing students' opportunities to engage in investigative activities. Overall, the findings indicate that the integration of the inquiry learning model and Tinkercad can support the implementation of electrical circuit learning by providing a learning environment that is more interactive, exploratory, and student-centered. These findings reinforce recent studies demonstrating that virtual laboratories can serve as an effective alternative for supporting physics learning in the digital era. From a theoretical perspective, the findings support the constructivist view that meaningful learning occurs when students actively construct knowledge through exploration and interaction with learning environments. The integration of inquiry learning and virtual laboratory technology provided opportunities for students to investigate, test ideas, and refine their understanding based on evidence generated during the learning process.

Conclusion

This study examined the implementation of an inquiry learning model assisted by Tinkercad in teaching electrical circuits. The findings showed that all stages of the inquiry model were successfully implemented, with students actively participating in exploration and investigation activities through virtual simulations. The student worksheet results indicated a very good level of achievement, particularly in conceptual understanding and process skills. Teachers also responded positively to the use of Tinkercad, highlighting its effectiveness in visualizing abstract electrical concepts and supporting learning in schools with limited

laboratory facilities. However, this study was conducted in only one school and focused on implementation, student performance, and teacher responses. Therefore, the findings cannot be generalized broadly and do not provide evidence of the model's effectiveness in improving learning outcomes. Despite these limitations, the study demonstrates that Tinkercad can support inquiry-based physics learning and provide an alternative virtual laboratory environment for electrical circuit instruction. This study has several limitations.

First, the research was conducted in only one school with a relatively small number of participants, limiting the generalizability of the findings. Second, the study focused on describing the implementation process rather than measuring the effectiveness of the instructional model through experimental comparison. Third, student responses were not collected directly through questionnaires or interviews. Therefore, future studies are needed to provide broader empirical evidence regarding the effectiveness of Tinkercad-assisted inquiry learning. Future studies should involve larger samples and experimental research designs to evaluate the effectiveness of inquiry learning assisted by Tinkercad on students' conceptual understanding, critical thinking, and science process skills. Further research is also recommended to explore the use of Tinkercad in other physics topics and in combination with different learning models. Additionally, teachers should provide sufficient guidance during inquiry activities to help students develop stronger analytical and conclusion-drawing skills.

Acknowledgment

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