

Changes in Learning Outcomes Following the Use of Simple Electrical Circuit Teaching Aids Among Fifth-Grade Elementary Students

Bintang¹, Sinta Maria Dewi², Aang Solahudin Anwar³, Anggy Giri Prawiyogi⁴

^{1,2,3,4}Universitas Buana Perjuangan Karawang, Jawa Barat, Indonesia

Article Info

Article history:

Received 2026-09-14

Revised 2026-09-22

Accepted 2026-10-07

Keywords:

Electrical circuits

Elementary science

Learning outcomes

Pretest-posttest

Quantitative study

Teaching aid

ABSTRACT

Simple electrical circuits can be difficult for elementary students because abstract concepts may not be readily connected to observable components. However, limited evidence addresses learning outcomes associated with simple, tangible circuit teaching aids in elementary classrooms. This study examined changes in fifth-grade students' learning outcomes following instruction with a simple electrical circuit teaching aid. A quantitative, pre-experimental one-group pretest-posttest design involved 21 fifth-grade students. An achievement test on simple electrical circuits was administered before and after instruction. Descriptive statistics, the Shapiro-Wilk test, and a paired-samples t-test were used. Mean achievement increased from 39.29 (SD = 17.12) to 70.24 (SD = 11.72). The difference was statistically significant, $t(20) = -10.594$, $p < .001$, with a large standardized within-group change (Cohen's $d_z = 2.31$). The findings indicate substantial within-group improvement following the instructional experience. Because no control group was included, the improvement cannot be attributed exclusively to the teaching aid. The study provides preliminary classroom-level evidence for using simple, tangible circuit activities in elementary science learning. Future research should include larger samples, comparison groups, validated instruments, and stronger experimental designs.

This is an open-access article under the [CC BY-SA](#) license.



Corresponding Author:

Bintang

Primary School Teacher Education Study Program, Faculty of Teacher Training and Education, Universitas Buana Perjuangan Karawang, Karawang, Indonesia

Email: sd22.bintang@mhs.ubpkarang.ac.id

1. INTRODUCTION

Science learning in elementary school is expected to help children make sense of natural phenomena through observing, questioning, experimenting, reasoning, and communicating explanations. In the Indonesian elementary curriculum, science learning is integrated with broader scientific and contextual competencies that require students to connect concepts with observable phenomena rather than merely recall definitions [1]. This

orientation is particularly important for topics such as electrical circuits, in which students need to connect abstract scientific concepts with observable and manipulable phenomena.

Simple electrical circuits are one such topic. Students are expected to recognize the function of a power source, wires, switches, and lamps and to understand that the components must be connected in a suitable closed pathway for the circuit to operate. Research on children's ideas about electricity has repeatedly shown that learners may enter instruction with incomplete or alternative conceptions of how a circuit works [2]–[6]. Young children's ability to construct a working circuit is also not always identical to their ability to predict or explain why a circuit works, suggesting that practical experience and conceptual explanation need to be connected carefully [3]. These difficulties indicate that instruction on electrical circuits should provide opportunities for students to interact directly with circuit components while connecting their observations to scientific explanations.

When learners can manipulate actual components, they can observe the consequences of connecting or disconnecting parts of a circuit and compare successful and unsuccessful configurations. Studies involving elementary learners have shown that opportunities to work with real circuits can support conceptual understanding, especially when practical activities are combined with appropriate guidance [7], [8]. Jaakkola et al. reported that elementary students working with simulations and real circuits could develop stronger understanding when the learning environment provided meaningful opportunities to explore circuit behavior [8]. Thus, concrete circuit activities may provide a useful instructional context for helping students relate circuit components and their functions to observable outcomes.

However, the value of concrete representations should not be interpreted as a claim that physical objects automatically produce better learning. Research comparing concrete and abstract representations indicates that the learning benefit depends on how representations are designed and integrated with instruction [9]. In a study of elementary students learning about electric circuits through simulation, Jaakkola and Nurmi found that the nature of the representation and the level of instructional guidance affected students' conceptual development [9]. Accordingly, a simple teaching aid should be considered as part of an instructional sequence in which students observe, manipulate, test, and interpret circuit behavior rather than as an independent source of learning.

Hands-on learning is also consistent with broader evidence from science education. Meta-analytic research has reported positive relationships between innovative teaching approaches and student achievement, although the magnitude of effects varies across approaches and contexts [10]. Research on control-of-variables instruction further indicates that demonstrations and opportunities to engage with evidence can support scientific reasoning and achievement [11]. Similarly, syntheses of inquiry-based science instruction have found positive effects when inquiry is structured appropriately and when learners receive adequate guidance [12], [13]. A meta-analysis of hands-on science practices found evidence of benefits for science achievement, while also emphasizing that the instructional context matters [14]. A broader review of physical manipulatives likewise found that such materials are used widely with young learners and can support learning in science as well as other domains, although the evidence is heterogeneous and methodological limitations remain [15]. Taken together, these findings suggest that concrete teaching aids can create

productive opportunities for learning, but their contribution should be examined within specific subject matter and classroom contexts.

Simple electrical circuit teaching aids may therefore provide a bridge between scientific representation and direct experience. Students can identify the components, connect them, operate a switch, observe whether a lamp lights, and compare alternative configurations. Such activity potentially makes the relationship among components more salient than verbal explanation alone. This is especially relevant when students are still developing the ability to reason about unseen processes such as current flow. Research on circuit misconceptions has shown that learners can retain non-scientific explanations even after instruction [4], [6], [16]. Practical experiences that are explicitly connected to explanations may therefore provide teachers with an opportunity to address students' difficulties while also supporting measurable learning outcomes.

The present study focuses on learning outcomes rather than on students' conceptual explanations or attitudes. This focus is consistent with a substantial body of educational research in which achievement tests are used to examine whether an instructional intervention is accompanied by measurable improvement. Meta-analyses of science interventions generally indicate that active and guided learning can contribute to achievement, but the outcomes depend on the intervention and assessment used [10], [12], [17]. Nevertheless, previous research has more often examined broader instructional approaches, simulations, inquiry, or manipulatives, leaving less empirical evidence on the learning outcomes associated with a simple, tangible electrical circuit teaching aid in an elementary classroom. Consequently, examining pretest and posttest performance provides a useful initial evaluation of whether students demonstrate higher achievement after experiencing instruction with the circuit teaching aid.

The study also responds to a practical need in elementary science instruction. Teachers may require instructional media that are relatively simple, tangible, and directly aligned with the concept being taught. Unlike representations that remain on a screen or in a textbook, a physical circuit can be handled by students and immediately tested. Recent research on multimedia and physical representations reinforces the importance of matching instructional representation to learning goals rather than assuming that a particular medium is universally superior [18]–[20]. Within this context, the originality of the present study lies in examining a simple physical electrical circuit teaching aid as a directly manipulable instructional medium and evaluating its associated learning outcomes among fifth-grade elementary students. The study therefore addresses a specific classroom-level empirical gap rather than claiming that physical teaching aids are generally superior to other forms of representation.

Against this background, the purpose of this study was to examine whether fifth-grade students' learning outcomes differed before and after instruction using a simple electrical circuit teaching aid. The study employed a one-group pretest-posttest design with 21 students. The research question was: Is there a statistically significant difference between students' learning outcomes before and after learning with the simple electrical circuit teaching aid? The corresponding hypothesis was that students would demonstrate significantly higher learning outcomes after the instructional experience than before it.

Because the design did not include a control group, the study interprets any observed difference as evidence of improvement following the instructional experience rather than definitive proof that the teaching aid alone caused the improvement.

The study is expected to contribute empirical evidence concerning the use of a simple, tangible teaching aid for elementary electrical circuit instruction. Practically, the findings may provide teachers with information about the potential use of a directly manipulable circuit model as part of guided science learning. More broadly, the study contributes to the discussion of how concrete instructional representations can be examined within specific elementary science contexts without assuming that the medium itself is sufficient to produce learning.

2. METHOD

2.1. Research Design

This study used a quantitative pre-experimental approach with a one-group pretest-posttest design. The design was selected to compare students' learning outcomes at two measurement points: before the instructional treatment and after the treatment. The same students completed both measurements, allowing the analysis to focus on within-participant change. The study was conducted as an initial classroom-level evaluation of a simple electrical circuit teaching aid rather than as a controlled experiment.

The design can be represented as O_1-X-O_2 , where O_1 represents the pretest, X represents learning activities using the simple electrical circuit teaching aid, and O_2 represents the posttest. The design is appropriate for an initial classroom evaluation because it allows the researchers to document whether achievement changes after the learning experience. At the same time, it does not provide the level of experimental control required to rule out alternative explanations such as testing effects, maturation, history, or changes associated with repeated exposure to the material. Accordingly, the design was used to examine changes in students' learning outcomes following the instructional experience, while causal interpretations were treated cautiously.

2.2. Participants and Sampling

The study involved 21 fifth-grade elementary school students. The participants represented the students who took part in the classroom instructional activities and completed both the pretest and posttest. The study therefore focused on a single group of fifth-grade students rather than a comparison or control group.

The participants were treated as an intact classroom group, and all 21 students who participated in the instructional activities were included in the analysis. Because the study was conducted at the classroom level, the findings are interpreted within the context of the participating students rather than as representative of fifth-grade students more broadly.

2.3. Instructional Treatment

The instructional treatment used a simple electrical circuit teaching aid consisting of the basic components required to demonstrate a functioning circuit. The learning activities were organized around the relationships among a power source, connecting wires, a switch,

and a lamp. Students were provided with opportunities to observe the components, connect them, operate the switch, and observe the resulting condition of the lamp. The central instructional purpose was to make the relationship among circuit components directly observable and manipulable.

The teaching aid was used as part of classroom instruction rather than as an isolated object. The teacher introduced the components and their functions, guided students in assembling the circuit, and directed attention to the observable consequences of different connections. This approach is consistent with evidence that hands-on learning is more meaningful when learners receive instructional support and opportunities to interpret the evidence generated through activity [13], [14].

The instructional activities were implemented through teacher-guided demonstrations and student interaction with the circuit components. Students observed the function of the power source, wires, switch, and lamp, connected the components, operated the switch, and observed whether the lamp operated. The teaching aid was therefore integrated into the instructional process to connect students' direct observations with the targeted electrical circuit concepts.

2.4. Research Instrument and Data Collection

Student achievement was measured using a learning outcome test addressing the simple electrical circuit material taught during the intervention. The same assessment framework was administered as a pretest and a posttest so that the researchers could compare achievement before and after instruction. The pretest was administered before students received the treatment, whereas the posttest was administered after the instructional activities had been completed.

The available study record reports the resulting scores and statistical analyses but does not provide a separate item-level validity or reliability analysis for the test. Therefore, the present article does not claim a specific reliability coefficient or validity index that was not reported in the original study. The outcome measure is therefore interpreted as the achievement test used by the researchers to assess students' mastery of the targeted simple electrical circuit material.

Because the same assessment framework was used at both measurement points, the possibility of a testing effect should be acknowledged. Students may have become more familiar with the test content through the pretest, meaning that some change in posttest performance could be associated with repeated exposure to the assessment rather than solely with the instructional experience.

2.5. Data Collection Procedure

Data collection consisted of three main stages. First, students completed the pretest before the instructional treatment. Second, the teacher conducted learning activities using the simple electrical circuit teaching aid, including observation, circuit assembly, switch operation, and observation of the resulting lamp condition. Third, students completed the posttest after the instructional activities had been completed.

The pretest and posttest scores were recorded for each student and subsequently paired for statistical analysis. The same group of 21 students participated in both measurement points, allowing the researchers to examine within-participant changes in learning outcomes.

2.6. Ethical Considerations

Because the participants were elementary-school students, the research was conducted with attention to participant confidentiality and voluntary participation. Students' identities were not reported in the analysis or presentation of the findings, and the results were presented in aggregated form. Institutional and parental or guardian permission should be reported if such documentation was obtained as part of the original study.

2.7. Data Analysis

Descriptive statistics were used to summarize the pretest and posttest scores, including the mean, standard deviation, median, minimum, maximum, and range. The Shapiro-Wilk test was used to examine distributional assumptions. The reported analysis also included Levene's test for homogeneity of variance. Although homogeneity is not a principal assumption for a paired-samples t-test, it is retained in the results because it was part of the original statistical analysis.

Because the pretest and posttest were obtained from the same students, the main inferential analysis was a paired-samples t-test. The significance level was set at $\alpha = .05$. A significance value below .05 was interpreted as evidence of a statistically significant difference between the pretest and posttest scores. The direction of change was interpreted from the mean scores and the mean difference, rather than from the negative sign of the t statistic, because the statistical software calculated the difference as pretest minus posttest. The analysis therefore focused on whether students' mean learning outcomes differed significantly between the pretest and posttest. Given the absence of a control group, a statistically significant difference was interpreted as evidence of improvement following the instructional experience rather than definitive evidence that the teaching aid alone caused the improvement.

3. RESULTS

3.1. Descriptive Statistics

This section presents the descriptive and inferential findings concerning changes in students' learning outcomes between the pretest and posttest. The analysis focuses on the within-group change following instruction using the simple electrical circuit teaching aid.

The descriptive results show a clear increase in students' achievement after the instructional treatment. The mean pretest score was 39.29, whereas the mean posttest score was 70.24. The mean gain was therefore 30.95 points. The minimum score increased from 8 to 50, and the maximum score increased from 75 to 92. The standard deviation decreased from 17.118 to 11.721, indicating that the posttest scores were less dispersed than the pretest scores.

Table 1. Descriptive Statistics of Pretest and Posttest Scores

Statistic	Pretest	Posttest
N	21	21
Mean	39.29	70.24
Std. Deviation	17.118	11.721
Std. Error Mean	3.735	2.558
Median	42.00	67.00
Minimum	8	50
Maximum	75	92
Range	67	42
Variance	293.014	137.390
95% CI of Mean	31.49–47.08	64.90–75.57

As shown in Table 1, the mean score increased by 30.95 points from the pretest to the posttest, while score variability decreased. The reduction in the standard deviation from 17.118 to 11.721 indicates that the posttest scores were more concentrated around the mean than the pretest scores. Descriptively, these results indicate substantial improvement in measured achievement following the instructional experience.

The descriptive increase should nevertheless be interpreted within the one-group pretest-posttest design. Because the same students completed both assessments and no comparison group was included, the observed gain cannot be attributed exclusively to the teaching aid.

3.2. Normality Test

The Shapiro-Wilk test was used because the study included 21 students. The pretest produced a Shapiro-Wilk significance value of .898, while the posttest produced a value of .180. Both values exceed .05, indicating that the available data do not provide sufficient evidence of a significant departure from normality.

Table 2. Shapiro-Wilk Normality Test

Measure	Statistic	df	Sig.
Pretest	0.978	21	0.898
Posttest	0.936	21	0.180

The normality results do not indicate a significant departure from normality for either measurement. However, because the principal inferential analysis was a paired-samples *t*-test, the most directly relevant assumption concerns the distribution of the paired difference scores rather than the separate pretest and posttest distributions. Thus, the reported normality results provide supporting information, but they should not be treated as a complete assessment of the paired-test assumption.

3.3. Paired-Samples Comparison

The paired-samples statistics confirm the descriptive increase. The pretest mean was 39.29 (SD = 17.118), compared with 70.24 (SD = 11.721) for the posttest. The mean difference calculated by the software was -30.952 because the subtraction was performed as pretest minus posttest. When expressed as improvement from pretest to posttest, the mean change was +30.952 points.

Table 3. Paired-Samples Statistics

Measurement	Mean	N	Std. Deviation	Std. Error Mean
Pretest	39.29	21	17.118	3.735
Posttest	70.24	21	11.721	2.558

The correlation between pretest and posttest scores was .626 and statistically significant ($p = .002$). This correlation indicates a moderate positive association between students' scores across the two measurement points, but it does not provide evidence of an instructional effect and is not central to the hypothesis test.

Table 4. Paired-Samples Correlation

Pair	N	Correlation	Sig. (2-tailed)
Pretest–Posttest	21	0.626	0.002

The principal hypothesis test produced $t(20) = -10.594$ with $p < .001$. The 95% confidence interval for the mean difference (pretest minus posttest) ranged from -37.047 to -24.858. Because the interval does not include zero and the significance value is below .05, the null hypothesis of no mean difference is rejected.

Table 5. Paired-Samples t-Test

Pair	Mean Difference	Std. Deviation	Std. Error Mean	95% CI Lower	95% CI Upper	t	df	Sig.
Pretest – Posttest	-30.952	13.388	2.922	-37.047	-24.858	-10.594	20	<0.001

The paired-samples t-test therefore indicated a statistically significant difference between pretest and posttest scores, with higher scores observed after the instructional experience. The standardized within-participant effect size, calculated as Cohen's ($d_z = \frac{t}{\sqrt{n}}$), was approximately 2.31 in absolute value. This represents a large standardized within-group change. However, the magnitude should be interpreted cautiously because the study did not include a control group and the effect may partly reflect baseline performance, repeated testing, or other factors associated with the pre-experimental design.

Overall, the results provide evidence of a statistically significant within-group improvement in students' measured learning outcomes following instruction with the simple electrical circuit teaching aid. The results do not, however, establish that the teaching aid alone caused the observed improvement.

4. DISCUSSION

4.1. Interpretation of the Main Finding

The central finding is that students achieved substantially higher scores after learning with the simple electrical circuit teaching aid. The mean increased by 30.95 points, and the paired-samples t-test indicated that the change was statistically significant. The finding is consistent with the broader literature suggesting that active and inquiry-oriented science

learning can support academic achievement when learning activities are appropriately structured [10]–[14].

The magnitude of the observed standardized change was also large (Cohen's $(d_z) \approx 2.31$). However, this value represents a within-group standardized change and should not be interpreted as evidence of a causal treatment effect. The large change may reflect the low baseline performance, close alignment between the instructional content and assessment, repeated exposure to related test material, or other classroom factors occurring between the two measurements. Thus, the result is best interpreted as evidence of substantial improvement in measured achievement rather than as an isolated estimate of the effect of the teaching aid.

4.2. Concrete Representation and Guided Learning

One plausible explanation is that the teaching aid provides a concrete representation of relationships that are otherwise difficult for elementary students to observe. Electrical current itself is not directly visible, while the operation of a circuit can be inferred from observable outcomes such as a lamp turning on or remaining off. Research on children's understanding of circuits has documented difficulties in connecting circuit configurations with explanations of how a circuit functions [2]–[4]. A physical circuit allows students to manipulate the relevant components and observe immediate outcomes, potentially making the conceptual relationships more accessible.

The importance of concrete experience is supported by research on representations in science learning. Jaakkola and colleagues found that elementary students' understanding of electric circuits was influenced by the learning environment and by the relationship between simulations and real circuits [8], [9]. Their work does not imply that physical materials are always superior; rather, it suggests that representation and instructional support interact. The present finding is consistent with this perspective because the teaching aid was integrated into teacher-guided activities involving observation, manipulation, and interpretation rather than being used as a passive display.

The result also accords with research on hands-on science. Caglak's meta-analysis reported positive effects associated with hands-on science practices, while Byrne et al.'s scoping review showed that physical manipulatives can support learning in science and other domains, although evidence across studies is mixed [14], [15]. The present study extends this literature at a classroom level by documenting a substantial pretest-posttest improvement in a specific elementary electrical circuit learning context. It does not, however, establish that the physical teaching aid would outperform other instructional representations.

4.3. Guided Activity and Observable Evidence

Another relevant explanation concerns inquiry and guided activity. When students connect a battery, wire, switch, and lamp, they can formulate simple predictions, test connections, observe outcomes, and revise their understanding. Such processes resemble basic inquiry practices. Meta-analytic research has found that inquiry-based instruction can improve student outcomes, particularly when learners receive appropriate guidance [12], [13]. In the present study, these processes provide a plausible instructional explanation for

the observed improvement, but inquiry skills themselves were not directly measured. Therefore, the findings should not be interpreted as evidence that students' scientific reasoning or inquiry competence necessarily improved.

The result is also compatible with findings from broader science-intervention research. Savelsbergh et al. found positive achievement effects for innovative science and mathematics teaching, while Schwichow et al. found that instructional approaches involving demonstrations and cognitive conflict can influence science achievement [10], [11]. In the present context, the response of the lamp to different circuit arrangements provided an observable outcome that could be connected to the instructional explanation of circuit operation.

Recent literature continues to emphasize the importance of high-quality science experiences in the early grades. A 2026 meta-analysis reported that classroom-based science interventions were associated with stronger science achievement in early childhood settings [21]. Another 2026 meta-analysis found that science activities can promote scientific literacy when learning opportunities are appropriately designed [22]. Although these studies involve younger learners and broader intervention categories than the present study, they reinforce the general importance of providing structured science experiences rather than relying exclusively on verbal transmission.

4.4. Alternative Explanations and Methodological Limitations

The finding should not be overstated. The one-group pretest-posttest design is vulnerable to internal-validity threats. Students may improve because they have seen similar questions during the pretest, because they become more familiar with the material through repeated exposure, or because of other classroom experiences occurring between the two measurements. These possibilities are particularly important given the large observed standardized change. Without a comparison group, the study cannot determine how much of the improvement would have occurred in the absence of the teaching aid.

The absence of a control group is particularly important because the posttest mean increased considerably. Without a comparison condition, it is impossible to determine whether a conventional lesson without the teaching aid would have produced a similar improvement. Future studies should therefore use a quasi-experimental or randomized design with a comparison group and, where feasible, include delayed posttests to examine retention. Such studies could also compare physical teaching aids with diagrams, simulations, or combinations of physical and digital representations, building on previous research on circuit learning [7]–[9].

Measurement quality represents another important limitation. The present study reports achievement scores but does not provide item-level validity evidence or a reliability coefficient for the achievement test. Consequently, the extent to which the instrument consistently and adequately measured the intended learning outcomes cannot be established from the available evidence. This limitation is particularly relevant when interpreting the large pretest-posttest change because measurement characteristics may influence the magnitude of observed differences. Future research should report the number and format of

items, content-validation procedures, reliability estimates, scoring procedures, and alignment between test items and learning objectives.

The role of representation is particularly important when considering students who may hold alternative conceptions. Studies have shown that misconceptions about electric circuits can persist and can involve assumptions about current, components, and circuit configurations [4], [6], [16]. More recent work has also examined students' mental models of electricity and found that learning activities that require students to construct and explore representations can shift the sophistication of those models [24]. These findings provide a conceptual basis for using physical circuit activities to elicit and discuss students' ideas, but the present study did not directly measure changes in misconceptions or mental models.

4.5. Implications for Elementary Science Teaching

The present findings have practical implications for elementary science teaching. A simple circuit teaching aid does not require students to master advanced mathematics or abstract electrical theory before engaging with the concept. Students can begin with observable relationships among components and gradually connect those observations to conceptual explanations. For classroom practice, the findings suggest that a simple physical circuit can be incorporated into guided instruction as a means of providing students with direct opportunities to observe and manipulate circuit components.

The result should also be considered alongside research on instructional media more generally. Mayer's review of multimedia learning emphasizes that learning outcomes depend on how instructional materials direct attention and support cognitive processing [19]. Cromley and Chen's recent meta-analysis likewise shows that multimedia effects vary according to learning outcomes, design principles, learner characteristics, and academic domains [20]. Although the present intervention was physical rather than multimedia-based, these findings reinforce the broader principle that instructional effectiveness depends on how a representation is aligned with the learning objective and instructional process.

The present findings should therefore not be interpreted as establishing that physical teaching aids are inherently more effective than diagrams, simulations, or other instructional media. Instead, they indicate that a simple circuit teaching aid can be meaningfully integrated into elementary science instruction and accompanied by measurable improvement in achievement.

4.6. Overall Interpretation and Future Research

Overall, the findings provide classroom-level evidence of a statistically significant increase in fifth-grade students' measured learning outcomes following instruction with a simple electrical circuit teaching aid. The improvement was substantial in descriptive terms and statistically significant, with a large within-group standardized change. The strongest conclusion supported by the design is therefore that students performed better on the achievement measure after the instructional experience.

Recent classroom research on the application of concrete teaching aids to simple electrical circuits also indicates their potential relevance to improving elementary science learning outcomes [29]. In addition, research identifying misconceptions among elementary

students in electrical circuit topics highlights the importance of providing learning experiences that connect direct observation with appropriate conceptual explanations [30].

Nevertheless, the evidence does not establish a unique causal effect of the teaching aid because the study lacked a control group, and the achievement instrument did not have documented item-level validity and reliability evidence in the available study record. These limitations should be considered when interpreting the large standardized change. Future research should employ stronger experimental or quasi-experimental designs, include a comparison condition, establish the psychometric quality of the achievement instrument, and examine whether learning gains are retained over time. Comparative studies could also investigate physical circuit teaching aids alongside diagrams, simulations, or blended representations to determine how different forms of representation support elementary students' learning of electrical circuits.

5. CONCLUSION

This study examined changes in fifth-grade students' learning outcomes following instruction using a simple electrical circuit teaching aid. The results showed a statistically significant increase in students' achievement, with the mean score increasing from 39.29 on the pretest to 70.24 on the posttest. The finding indicates a substantial within-group improvement following the instructional experience, but the one-group pretest-posttest design does not permit the improvement to be attributed exclusively to the teaching aid.

As a practical implication, the teaching aid may provide a concrete instructional context in which students can observe and manipulate electrical circuit components and relate these observations to the concepts being taught. This interpretation should be regarded as a plausible instructional explanation rather than a directly measured outcome, because the study assessed learning achievement rather than students' conceptual processes or mental models.

The study provides preliminary classroom-level evidence of improved measured achievement following instruction with a simple electrical circuit teaching aid. Future research should use validated and reliable assessment instruments, report standardized effect sizes with appropriate confidence intervals, include larger samples and comparison groups, and employ quasi-experimental or randomized designs. Delayed posttests should also be considered to determine whether observed learning gains are retained over time. These approaches would provide stronger evidence for evaluating the contribution of simple electrical circuit teaching aids to elementary science learning.

REFERENCES

- [1] Badan Standar, Kurikulum, dan Asesmen Pendidikan, "Capaian pembelajaran mata pelajaran Ilmu Pengetahuan Alam dan Sosial (IPAS) fase A–fase C untuk SD/MI/Program Paket A," Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia, 2022.
 - [2] D. P. Shepardson, "The nature of fourth graders' understandings of electric circuits," *Science Education*, vol. 78, no. 5, pp. 489–514, 1994, doi: 10.1002/sce.3730780505.
 - [3] E. B. Glauert, "How young children understand electric circuits: Prediction, explanation and exploration," *International Journal of Science Education*, vol. 31, no. 8, pp. 1025–1047, 2009, doi: 10.1080/09500690802101950.
 - [4] S. Sencar, "Factors mediating the effect of gender on ninth-grade Turkish students' misconceptions
-

- concerning electric circuits,” *Journal of Research in Science Teaching*, vol. 41, no. 6, pp. 603–616, 2004, doi: 10.1002/tea.20016.
- [5] J.-W. Lin, “Do skilled elementary teachers hold scientific conceptions and can they accurately predict the type and source of students’ preconceptions of electric circuits?” *International Journal of Science and Mathematics Education*, 2015, doi: 10.1007/s10763-015-9635-4.
- [6] C. Preston, “Effect of a diagram on primary students’ understanding about electric circuits,” *Research in Science Education*, vol. 49, no. 3, 2019, doi: 10.1007/s11165-017-9662-y.
- [7] Z. C. Zacharia, “Comparing and combining real and virtual experimentation: An effort to enhance students’ conceptual understanding of electric circuits,” *Journal of Computer Assisted Learning*, vol. 23, no. 2, pp. 120–132, 2007, doi: 10.1111/j.1365-2729.2006.00215.x.
- [8] T. Jaakkola, S. Nurmi, and K. Veermans, “A comparison of students’ conceptual understanding of electric circuits in simulation only and simulation-laboratory contexts,” *Journal of Research in Science Teaching*, vol. 48, no. 1, pp. 71–93, 2011, doi: 10.1002/tea.20386.
- [9] T. Jaakkola, K. Nurmi, and S. Veermans, “Effects of abstract and concrete simulation elements on science learning,” *Journal of Computer Assisted Learning*, vol. 31, no. 4, pp. 300–313, 2015, doi: 10.1111/jcal.12089.
- [10] E. R. Savelsbergh, G. T. Prins, C. Rietbergen, S. Fechner, B. E. Vaessen, J. M. Draijer, and A. Bakker, “Effects of innovative science and mathematics teaching on student attitudes and achievement: A meta-analytic study,” *Educational Research Review*, vol. 19, pp. 158–172, 2016, doi: 10.1016/j.edurev.2016.07.003.
- [11] M. Schwichow, S. Croker, C. Zimmerman, T. Höffler, and H. Härtig, “Teaching the control-of-variables strategy: A meta-analysis,” *Developmental Review*, vol. 39, pp. 37–63, 2016, doi: 10.1016/j.dr.2015.12.001.
- [12] D. D. Minner, A. J. Levy, and J. Century, “Inquiry-based science instruction—What is it and does it matter? Results from a research synthesis years 1984 to 2002,” *Journal of Research in Science Teaching*, vol. 47, no. 4, pp. 474–496, 2010, doi: 10.1002/tea.20347.
- [13] A. W. Lazonder and R. Harmsen, “Meta-analysis of inquiry-based learning: Effects of guidance,” *Review of Educational Research*, vol. 86, no. 3, pp. 681–718, 2016, doi: 10.3102/0034654315627366.
- [14] S. Caglak, “Does hands-on science practices make an impact on achievement in science? A meta-analysis,” *Journal of Education in Science, Environment and Health*, vol. 3, no. 1, pp. 69–87, 2017, doi: 10.21891/jeseh.275708.
- [15] E. M. Byrne, H. Jensen, B. S. Thomsen, and P. G. Ramchandani, “Educational interventions involving physical manipulatives for improving children’s learning and development: A scoping review,” *Review of Education*, vol. 11, no. 2, e3400, 2023, doi: 10.1002/rev3.3400.
- [16] J.-J. Dupin and S. Johsua, “Conceptions of French pupils concerning electric circuits: Structure and evolution,” *Journal of Research in Science Teaching*, vol. 24, no. 9, pp. 791–806, 1987, doi: 10.1002/tea.3660240903.
- [17] K. J. Carbonneau, S. C. Marley, and J. P. Selig, “A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives,” *Journal of Educational Psychology*, vol. 105, no. 2, pp. 380–400, 2013, doi: 10.1037/a0031084.
- [18] C. Lafay, C. St-Pierre, and M.-P. Pagani, “Effects of interventions with manipulatives on immediate learning, maintenance, and transfer in children with mathematics learning disabilities: A systematic review,” *Education Research International*, 2019, Art. no. 2142948, doi: 10.1155/2019/2142948.
- [19] R. E. Mayer, “Using multimedia for e-learning,” *Journal of Computer Assisted Learning*, vol. 33, no. 5, pp. 403–423, 2017, doi: 10.1111/jcal.12197.
- [20] J. G. Cromley and R. Chen, “A meta-analysis of Richard Mayer’s multimedia learning research: Searching for boundary conditions of design principles across multiple media types,” *Educational Research Review*, vol. 49, Art. no. 100730, 2025, doi: 10.1016/j.edurev.2025.100730.
- [21] K. Lynch, C. A. Asher, A. W. Gotwals, and J. Settlage, “The effects of early childhood science educational interventions on children’s science achievement: A meta-analysis of classroom-based studies,” *The Elementary School Journal*, vol. 126, no. 3, pp. 501–534, 2026, doi: 10.1086/739369.
- [22] M. Gangal, M. Çalık, and Y. Ozturk, “Effectiveness of early childhood science activities in promoting scientific literacy: A meta-analysis study,” *Science & Education*, 2026, doi: 10.1007/s11191-026-00748-2.
- [23] G. Estrella, J. Au, S. M. Jaeggi, and P. Collins, “Is inquiry science instruction effective for English language learners? A meta-analytic review,” *AERA Open*, vol. 4, no. 2, pp. 1–23, 2018, doi: 10.1177/2332858418767402.
- [24] J. Saba and S. T. Levy, “Identifying aspects of complex and technological systems in the mental models of students who constructed computational models of electric circuits,” *Journal of Research in Science Teaching*, 2023, doi: 10.1002/tea.21814.

- [25] P. J. Garnett and D. F. Treagust, "Conceptual difficulties experienced by senior high school students of electrochemistry: Electric circuits and oxidation-reduction equations," *Journal of Research in Science Teaching*, vol. 29, no. 2, pp. 121–142, 1992, doi: 10.1002/tea.3660290204.
 - [26] J. A. Wilson, "Inquiry-based science instruction for students with disabilities: A systematic and meta-analytic review," *Science Education*, vol. 110, no. 2, pp. 639–653, 2026, doi: 10.1002/sce.70029.
 - [27] E. Ryanda and A. Khoiri, "Animated video learning improves elementary students electrical circuit understanding," *Academia Open*, vol. 11, no. 1, 2026, doi: 10.21070/acopen.11.2026.13826.
 - [28] A. P. Wahyoerie and Z. Zulherman, "The influence of the problem-based learning model assisted by PhET simulation on simple electric material on elementary school students' conceptual understanding," *Journal of Educational Sciences*, vol. 10, no. 8, pp. 467–479, 2026, doi: 10.31258/jes.10.8.p.467-479.
 - [29] R. Hartono, "Application of concrete props in improving science learning results: Simple electricity circuit material at elementary school," *Social, Humanities, and Educational Studies: Conference Series*, vol. 3, no. 4, 2020, doi: 10.20961/shes.v3i4.54401.
 - [30] R. Maulana, S. Anggoro, and R. D. Purwandari, "Identification of electrical circuit material science misconceptions in class VI SD UMP students," *Proceedings Series on Social Sciences & Humanities*, vol. 12, pp. 397–401, 2023, doi: 10.30595/pssh.v12i.826.
-