Physics Communication
Volume 10 Issue 2 Year 2026 Pages 97-103

P-ISSN 2528-5971 | E-ISSN 2528-598X
https://journal.unnes.ac.id/journals/pc
https://doi.org/10.15294/pc.v10i2.58999

Comparative Effectiveness of Learning Cycle 5E-Based and Regular Worksheets on Conceptual Understanding of Current Electricity

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Abstract: Conceptual understanding of current electricity requires instructional materials that guide students systematically through exploration, explanation, application, and evaluation. This study compared the effectiveness of student worksheets that explicitly integrated the Learning Cycle 5E phases with that of regular worksheets in supporting junior high school students' conceptual understanding. A quasi-experimental nonequivalent control group design was employed with two intact ninth-grade classes, comprising 30 students in the experimental group and 30 in the control group. Both groups followed the same Learning Cycle 5E instructional sequence; the treatment differed only in the type of worksheet used. Conceptual understanding was measured using a 25-item three-tier multiple-choice test and analyzed using ANCOVA, partial eta squared, Hedges' g, and indicator-level analysis. After controlling for initial ability, the adjusted posttest mean of the experimental group was 54.17, compared with 32.64 for the control group. The difference was significant, $F(1, 57) = 44.324$, $p < .001$, with $\eta p^2 = .437$ and Hedges' $g = 1.10$, indicating a large between-group effect. Indicator-level analysis showed that the largest between-group difference occurred in interpreting, while summarizing remained the lowest-achieving indicator in the experimental group. Under the conditions of this study, worksheets that explicitly integrated the Learning Cycle 5E phases showed greater comparative effectiveness than regular worksheets in supporting conceptual understanding of current electricity.

Keywords: Effectiveness; Learning Cycle 5E; Current electricity; Student worksheets; Conceptual understanding

Submitted: 2025-07-13. **Revised:** 2026-08-19. **Accepted:** 2026-08-23.

Introduction

Conceptual understanding is a central outcome of physics learning because it enables students to interpret phenomena, explain relationships among concepts, and apply scientific knowledge across different situations. It involves more than recalling information; it includes the abilities to interpret, exemplify, classify, summarize, infer, compare, and explain concepts meaningfully (Wilson, 2016; Schaffernicht & Groesser, 2016). These abilities allow students to move beyond procedural or formula-based knowledge toward a coherent understanding of physical phenomena.

However, difficulties in conceptual understanding have been reported in electricity learning. Kaniawati et al. (2017) found that students' initial conceptual-understanding scores on direct-current electricity were 30.1 in the experimental group and 30.0 in the control group. Similarly, Nooritasari et al. (2019) reported relatively low conceptual-understanding scores for direct-current electric circuits across educational levels, with mean scores of 40.83 for junior high school students, 37.93 for senior high school students, and 43.14 for preservice physics teachers. These findings indicate that difficulties in understanding electrical concepts persist across educational levels.

These difficulties are particularly relevant to current electricity because students must relate circuit conditions, current flow, resistance, and component arrangements as parts of an interconnected system. In the present study, current electricity was limited to qualitative observations of open and closed circuits, series and parallel arrangements, and the function of resistors in limiting current. Understanding these concepts requires students to connect observable circuit behavior with relationships among components rather than consider each component separately. Nooritasari et al. (2019) identified difficulties in understanding current flow and the relationship between resistance and electric current. Consequently, instruction should provide opportunities for students to construct circuits, observe phenomena, compare results, and explain conceptual relationships based on evidence.

These learning requirements are consistent with the Learning Cycle 5E, which organizes instruction through the engage, explore, explain, elaborate, and evaluate phases. Engage activates prior knowledge through contextual phenomena, explore provides opportunities for investigation and observation, explain supports the construction of scientific explanations, elaborate extends concepts to new situations, and evaluate promotes reflection on learning outcomes (Bybee, 2015; Ruiz-Martín & Bybee, 2022). Through this sequence, students can progressively construct and reorganize conceptual understanding rather than receive concepts only through direct explanation (Varoglu et al., 2023; Ohst et al, 2014).

However, implementing the same instructional model does not necessarily mean that students receive the same level of learning support. The Learning Cycle 5E provides an instructional sequence, whereas student worksheets determine how that sequence is translated into concrete learning activities. Although both groups were taught using the Learning Cycle 5E model, the learning support provided through the worksheets differed. The experimental group used a developed worksheet that explicitly organized activities according to the engage, explore, explain, elaborate, and evaluate phases, whereas the control group used regular worksheets within the same 5E instructional sequence. Thus, the comparison in this study focused on whether differences in worksheet design were associated with differences in conceptual-understanding outcomes within the same instructional model.

Previous studies have examined the Learning Cycle 5E and worksheet-supported instruction using different research designs. Hidayati (2017) developed inquiry-based worksheets organized around the 5E learning cycle and reported improved conceptual mastery, whereas Parawangsa & Budiyanto (2022) implemented the Learning Cycle 5E with worksheet support and found improvement in conceptual understanding. Sutrisno & Nasir (2024) compared Learning Cycle 5E instruction with conventional instruction and reported stronger conceptual-understanding outcomes for the 5E group. However, because their study compared different instructional models, it did not isolate the contribution of worksheet design within the same 5E instructional framework. In contrast, Ridani & Arianingrum (2024) reported that Learning Cycle 5E-based worksheets rated as highly feasible did not produce a significant difference in chemistry literacy. Taken together, these findings indicate that the effectiveness of a 5E-based worksheet should be established empirically rather than inferred solely from its design or feasibility.

A systematic review by Agustiana et al. (2025) further showed that research on Learning Cycle 5E-based science materials has predominantly focused on product validation, whereas relatively few studies have examined their effectiveness in relation to student outcomes. More importantly, previous studies have rarely compared a worksheet that explicitly operationalizes the 5E phases with regular worksheets while holding the instructional model constant across groups. Such a comparison is useful for examining whether differences in worksheet organization are associated with additional differences in student outcomes when the Learning Cycle 5E model is held constant across groups. In addition, comparative effectiveness should not be evaluated solely from mean differences or statistical significance; initial ability and the magnitude of the between-group effect should also be considered.

Accordingly, this study aimed to compare the effectiveness of student worksheets that explicitly operationalized the Learning Cycle 5E phases with regular worksheets in supporting junior high school students' conceptual understanding of current electricity, while both groups followed the same 5E instructional sequence. Comparative effectiveness was examined by controlling for initial conceptual understanding, estimating the magnitude of the between-group effect, and describing posttest achievement across the seven conceptual-understanding indicators.

Methods

This study employed a quantitative approach with a quasi-experimental nonequivalent control group design. It was conducted with ninth-grade students at SMP Negeri 1 Japara, Kuningan Regency, West Java, Indonesia. Purposive sampling was used to select class IX.B as the experimental group and class IX.A as the control group, with 30 students in each group. The classes were selected because they were taught by the same teacher, followed the same curriculum, and had relatively comparable academic characteristics. Both groups completed a pretest before instruction and a posttest after the intervention to measure conceptual understanding of current electricity.

Both groups followed the same Learning Cycle 5E instructional sequence: engage, explore, explain, elaborate, and evaluate. The learning content, objectives, time allocation, teacher, and assessment instrument were held constant across groups. The experimental group used the developed Learning Cycle 5E-based worksheet, whereas the control group used regular worksheets within the same Learning Cycle 5E instructional model. Thus, the principal treatment difference was the type and structure of the worksheet used.

The experimental group used worksheets that explicitly integrated activities for each Learning Cycle 5E phase. These worksheets included contextual phenomena, prediction questions, investigation procedures, observation tables, guiding questions, concept-application tasks, and evaluations. The control group used regular worksheets within the same 5E instructional sequence, but the activities were not explicitly organized according to the five phases. The implementation comprised five meetings: one pretest meeting, three instructional meetings, and one posttest meeting. Each instructional meeting lasted 2 × 30 minutes and covered, respectively, open and closed circuits, series and parallel circuits, and the function of resistors in electric circuits.

Conceptual understanding was measured using a 25-item three-tier multiple-choice test. The primary conceptual-understanding score was determined from the first two tiers, requiring both the selected answer and its justification to be correct, whereas the confidence tier was not included in the primary score because misconception diagnosis was beyond the scope of this study. Three-tier multiple-choice formats are useful in electric-circuit research because they provide information about students' selected answers, the reasoning underlying those answers, and their confidence in those responses (Peşman & Eryılmaz, 2010). In the present study, however, the instrument was used as a reasoned conceptual-understanding test rather than as a diagnostic misconception test. The instrument covered the indicators of interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining. A score of 1 was assigned only when both the answer and its justification were correct; all other response combinations received a score of 0. The instrument obtained a mean Aiken's V index of .859. Although this value did not reach the critical value of .92 used in the validation procedure, the instrument was revised based on expert feedback before implementation. The final 25-item instrument demonstrated a KR-20 reliability coefficient of .926, indicating very high internal consistency.

Data analysis began with descriptive statistics, including the mean, standard deviation, minimum score, and maximum score. Comparative effectiveness was examined using ANCOVA, with posttest conceptual-understanding score as the dependent variable, worksheet type as the fixed factor, and pretest score as the covariate. This analysis compared posttest outcomes after adjusting for initial conceptual understanding. Before conducting ANCOVA, the linear relationship between pretest and posttest scores, residual normality, homogeneity of variance, and homogeneity of regression slopes were examined. ANCOVA results were reported using adjusted posttest means, the F statistic, degrees of freedom, p values, and partial eta squared. The significance level was set at $\alpha = .05$.

The magnitude of the between-group difference was estimated using Hedges' g with a 95% confidence interval. Posttest achievement was also examined descriptively across the seven conceptual-understanding indicators to identify patterns of relative strength and areas requiring further reinforcement.

Results and Discussion

Descriptive statistics for the conceptual-understanding scores of both groups are presented in Table 1.

Table 1. Descriptive Statistics of Conceptual Understanding Scores

Group	Test	N	Mean	SD	Minimum	Maximum
Control	Pretest	30	25.28	14.88	4.17	58.33
	Posttest	30	33.33	17.54	4.17	83.33
Experimental	Pretest	30	23.75	14.15	4.17	62.50
	Posttest	30	53.47	18.64	20.83	87.50

Table 1 shows that the two groups had relatively similar mean pretest scores, whereas their posttest scores differed more clearly. The experimental-group mean increased from 23.75 to 53.47, while the control-group mean increased from 25.28 to 33.33. Descriptively, this pattern indicates a larger increase in conceptual-understanding scores in the experimental group.

The observed pattern may be associated with differences in the structure of the worksheets used within the same Learning Cycle 5E model. The developed worksheets guided students through contextual phenomena, predictions, investigations, observation tables, conceptual questions, applications, and evaluation, whereas the regular worksheets did not explicitly organize these activities according to the five phases. Such continuity may have helped students connect experimental observations with circuit conditions, current flow, component arrangements, and resistor functions rather than treat the practical activities as isolated procedures.

Before ANCOVA was conducted, the data satisfied the required assumptions. The residuals met the normality assumption, $W = .972$, $p = .181$, and the variances of the two groups were homogeneous, $F = .372$, $p = .545$. The interaction between pretest score and group was not significant, $F(1, 56) = .333$, $p = .566$, indicating that the homogeneity-of-regression-slopes assumption was met. The ANCOVA results are presented in Table 2.

Table 2. ANCOVA and Effect Size Results

Measure	Control Group	Experimental Group	Statistical Result
Adjusted posttest mean	32.64	54.17	$F(1,57)=44.324$
95% CI of adjusted mean	28.06–37.21	49.59–58.74	$p<0.001$
Adjusted mean difference		21.53	95% CI: 15.05–28.00
Partial eta squared			$\eta_p^2=0.437$
Hedges' (g)			g=1.10; 95% CI: 0.55–1.64

The ANCOVA results strengthen the descriptive pattern shown in Table 1. After initial conceptual understanding was controlled, the experimental group retained a higher adjusted posttest mean than the control group. The partial eta squared and Hedges' g values further indicate that the between-group difference was substantial in practical terms. Thus, differences in initial conceptual-understanding scores are unlikely to account fully for the observed posttest difference between the groups.

This finding is consistent with a constructivist view of learning, in which conceptual understanding develops as learners integrate prior knowledge with new information through active experience, reflection, and interaction with the learning environment (Pramana et al., 2024; Pacaci et al, 2023; Kulgemeyer, 2024). From a social constructivist perspective, cognitive development is supported through social interaction and guided assistance, allowing learners to clarify ideas and progressively develop understanding beyond what they can achieve independently (Vygotsky, 1978; Van de Pol, 2010). Within the Learning Cycle 5E, this process is supported by a coherent sequence that activates prior knowledge, provides exploratory experiences, guides explanation, extends conceptual application, and evaluates understanding (Bybee, 2015; Ruiz-Martín & Bybee, 2022).

Empirical findings from previous studies provide both supporting and contrasting evidence. Hidayati (2017) reported a conceptual-mastery gain of 0.66, categorized as moderate, following the use of inquiry-based worksheets organized around the 5E learning cycle, while Sutrisno & Nasir (2024) found that students taught through the Learning Cycle 5E achieved a higher mean posttest score than those receiving conventional instruction (82.5 vs. 70.3), with gain scores of 0.75 and 0.45, respectively. However, Ridani & Arianingrum (2024) reported that Learning Cycle 5E-based worksheets received high feasibility ratings from media experts (82.81%) and subject-matter experts (90.72%), but did not produce a statistically significant difference in chemistry literacy (Asymp. Sig. = .428 > .05).

The large between-group effect may be associated with the way the developed worksheets operationalized each Learning Cycle 5E phase. Engage was represented through contextual phenomena and prediction questions; explore was supported by investigation procedures and observation tables; and explain and elaborate included questions that required students to relate evidence to scientific concepts. Because the instructional model, content, teacher, time allocation, and assessment instrument were held constant across groups, worksheet structure represents the principal instructional difference between the two conditions. Nevertheless, the quasi-experimental design does not permit a strictly causal interpretation of this association.

The analysis was then extended to the seven indicators of conceptual understanding. The experimental group achieved higher posttest percentages than the control group on every indicator.

Table 3. Achievement of Conceptual Understanding Indicators

Indicator	Experimental posttest	Control posttest	Difference
Interpreting	80.83%	48.33%	32.50
Exemplifying	66.67%	44.44%	22.23
Classifying	51.67%	29.17%	22.50
Summarizing	20.83%	9.17%	11.66
Inferring	34.17%	21.67%	12.50
Comparing	47.78%	36.67%	11.11
Explaining	63.33%	41.11%	22.22

Table 3 shows that the experimental group achieved higher posttest percentages than the control group across all seven indicators of conceptual understanding. The largest between-group difference occurred in interpreting, whereas the smallest difference was found in comparing. Within the experimental group, interpreting showed the highest posttest achievement, while summarizing showed the lowest. This pattern suggests that students' achievement varied across the conceptual processes targeted by the worksheet activities.

The relatively high achievement in interpreting may be associated with the structure of the worksheet activities. In the engage phase, students observed and responded to contextual circuit phenomena, whereas the explore phase provided opportunities for investigation and direct observation. Observation tables and guiding questions further encouraged students to interpret circuit conditions before moving to formal conceptual explanations. Explaining also showed comparatively high achievement, which may reflect the opportunities provided during the explain phase to discuss experimental findings and relate observed evidence to scientific concepts.

By contrast, the lower achievement in summarizing and inferring indicates that students still experienced difficulty transforming observations and discussion results into concise conceptual conclusions. In the worksheets, activities targeting these indicators were concentrated mainly in the evaluate phase, where students were required to identify key information from their observations and discussions and reorganize it into conceptual statements. In Revised Bloom's Taxonomy, summarizing involves abstracting the central meaning of information, whereas inferring requires drawing logical conclusions from available evidence (Wilson, 2016). These processes require students to organize and integrate information more independently than when interpreting directly observable phenomena.

This finding is consistent with Nooritasari et al. (2019) and Burde (2020), who reported low conceptual understanding of direct-current electric circuits among junior high school students, particularly in relation to current flow and the relationship between resistance and electric current. Their findings indicate that understanding electric circuits requires students to connect observable circuit conditions with underlying conceptual relationships. In the present study, the comparatively lower achievement in summarizing and inferring further suggests that forming concise conceptual generalizations from such relationships remained challenging for some students.

The comparatively strong performance in interpreting may therefore reflect the substantial support provided through contextual phenomena, direct observation, observation tables, and guiding questions. In contrast, the lower achievement in summarizing and inferring suggests that students required greater support when transforming experimental findings and discussion results into concise conceptual generalizations. The evaluate phase could therefore be strengthened through more explicit scaffolding for identifying key findings, connecting evidence across activities, and formulating concise conclusions. Additional opportunities to apply these conclusions to varied circuit situations during the elaborate phase may also help students transfer their conceptual understanding beyond the specific investigations they conducted.

Conclusion

Under the conditions of this quasi-experimental study, the developed Learning Cycle 5E-based worksheets showed greater comparative effectiveness than regular worksheets in supporting junior high school students' conceptual understanding of current electricity when both groups were taught using the same Learning Cycle 5E model. After initial conceptual understanding was controlled, the experimental group retained a higher adjusted posttest mean, accompanied by a large between-group effect. Indicator-level analysis showed higher posttest achievement in the experimental group across all seven indicators, with the largest descriptive between-group difference occurring in interpreting. Within the experimental group, interpreting showed the highest achievement, whereas summarizing showed the lowest, suggesting that students still required stronger support in synthesizing observations and discussion results into concise conceptual conclusions. Overall, these findings suggest that explicitly structuring worksheet activities according to the 5E phases may provide additional instructional support within the same Learning Cycle 5E framework.

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