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ORIGINAL RESEARCH ARTICLE

Implementing Tinkercad in Light Vehicle Electrical Systems Learning: A Classroom Action Research Study with Grade XI Light Vehicle Automotive Engineering Students

Erwin Komara Mindarta[1*], Roice Yugo Yudhistira[1], Muhammad Farhan Naufal Yanuar Rohmat Rizqillah[1], Adelio Boby Jonathan[1], Ferdinand Sava'ul Hikmi[1], Erico Septianto[1], Muhammad Kharis 'Alaikum[1]

[1]Automotive Engineering Education Study Program, Universitas Negeri Malang, Indonesia

Correspondence: erwin.komara.mindarta.ft@um.ac.id

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ABSTRACT

Learning light vehicle electrical systems requires students to understand component functions, relationships among components, circuit workflows, and troubleshooting procedures before carrying out workshop practice. Preliminary observation in class XI TKRO 3 at SMKN 6 Malang showed that some students still had difficulty understanding wiring diagrams and that practical activities were hampered by trainers that did not always function properly. This study aimed to describe the implementation of the Tinkercad simulation medium, changes in students' comprehension test results, and students' responses over two action cycles. The study used a classroom action research design comprising planning, action, observation, and reflection. Data were obtained through pre- and post-action tests, learning observations, and a student questionnaire. In Cycle I, the mean score increased from 56.83 to 60.00. The group N-Gain recalculated from the means (maximum score 100) was 0.0734 (7.34%), in the low category. Reflection on Cycle I served as the basis for improvements in the form of more detailed explanations, more intensive guidance, and more interactive learning. In Cycle II, the mean score increased from 63.67 to 89.50. The recalculated group N-Gain was 0.7110 (71.10%), in the high category. Observations indicated that student engagement and the ability to use the simulation improved, while questionnaire responses shifted from a tendency to disagree in Cycle I to agreement in Cycle II. These findings indicate that the use of Tinkercad accompanied by guidance and action reflection was associated with improved test results in the class studied. However, differences in baseline means between cycles and incomplete reporting of several statistics limit causal interpretation and generalization. Tinkercad can be considered a supporting medium for preparing students to understand circuits before physical practice, provided that internet access, digital literacy, and the link between simulation and real automotive equipment are taken into account.

Keywords: Tinkercad; Light Vehicle Electrical Systems; Student Understanding; Circuit Simulation; Classroom Action Research.

ABSTRAK

Pembelajaran sistem elektrikal kendaraan ringan menuntut siswa memahami fungsi komponen, hubungan antarkomponen, alur kerja rangkaian, dan prosedur pemecahan masalah sebelum melakukan praktik di bengkel. Observasi awal di kelas XI TKRO 3 SMKN 6 Malang menunjukkan bahwa sebagian siswa masih kesulitan memahami diagram pengawatan dan kegiatan praktik terkendala kondisi trainer yang tidak selalu berfungsi. Penelitian ini bertujuan mendeskripsikan penerapan media simulasi Tinkercad, perubahan hasil tes pemahaman siswa, dan tanggapan siswa selama dua siklus tindakan. Penelitian menggunakan desain penelitian tindakan kelas yang meliputi perencanaan, pelaksanaan tindakan, observasi, dan refleksi. Data diperoleh melalui tes sebelum dan sesudah tindakan, observasi pembelajaran, serta kuesioner siswa. Pada siklus I, nilai rata-rata meningkat dari 56,83 menjadi 60,00. N-Gain kelompok yang dihitung ulang dari rerata (skor maksimum 100) adalah 0,0734 (7,34%), termasuk kategori rendah. Refleksi siklus I menjadi dasar perbaikan berupa penjelasan lebih terperinci, pendampingan lebih intensif, dan pelaksanaan pembelajaran yang lebih interaktif. Pada siklus II, nilai rata-rata meningkat dari 63,67 menjadi 89,50. N-Gain kelompok yang dihitung ulang dari rerata (skor maksimum 100) adalah 0,7110 (71,10%), termasuk kategori tinggi. Observasi menunjukkan keterlibatan siswa dan kemampuan menggunakan simulasi membaik, sedangkan tanggapan kuesioner bergeser dari kecenderungan tidak setuju pada siklus I menjadi setuju pada siklus II. Temuan ini menunjukkan bahwa penggunaan Tinkercad yang disertai pendampingan dan refleksi tindakan berasosiasi dengan peningkatan hasil tes dalam kelas yang diteliti. Namun, perbedaan rerata awal antarsiklus dan ketidaklengkapan pelaporan beberapa statistik membatasi interpretasi kausal dan generalisasi hasil. Tinkercad dapat dipertimbangkan sebagai media pendukung untuk mempersiapkan siswa memahami rangkaian sebelum praktik fisik, dengan tetap memperhatikan akses internet, literasi digital, dan keterkaitan simulasi dengan perangkat otomotif nyata.

Kata Kunci: Tinkercad; Sistem Elektrikal Kendaraan Ringan; Pemahaman Siswa; Simulasi Rangkaian; Penelitian Tindakan Kelas.

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1. INTRODUCTION

Automotive vocational learning targets not only the mastery of declarative knowledge but also the ability to read technical information, relate working principles to components, and apply diagnostic and repair procedures. In light vehicle electrical systems, students need to understand symbols, wiring paths, component functions, and cause-and-effect relationships within a circuit. Weak understanding before practice can cause students to merely follow diagrams without grasping the technical reasons behind each connection. This condition may hinder practical work, particularly when the trainer malfunctions or when students are not yet accustomed to tracing circuit faults.

Digital technology offers an additional way to bridge abstract concepts and observable learning experiences. Simulation media allow students to try circuit arrangements, observe changes in conditions, and repeat experiments without always relying on physical equipment. In education, learning media serve as intermediaries for conveying information and can help organize learning

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experiences so that they are easier to understand (Hasan et al., 2021; Jennah, 2009). Studies on educational technology also emphasize that technology integration must be linked to objectives, governance, and learning needs rather than to device adoption alone (Akbar & Noviani, 2019; Febrianti et al., 2023; Kurniasari et al., 2023; Maritsa et al., 2021). However, the use of technology does not by itself guarantee improved learning outcomes. Its benefits depend on the alignment of the medium with learning objectives, clarity of instructions, user readiness, and the quality of teacher guidance.

Tinkercad is a web-based platform that provides electronic circuit design and simulation features. In this study, Tinkercad was used as a medium to introduce circuit design and to give students the opportunity to observe simulation results before carrying out practical work. The platform does not fully replace the experience of using components, measuring instruments, or automotive electrical trainers. Its pedagogical value lies in the opportunity for initial exploration, virtual testing of circuit relationships, and discussion of errors without the risk of damaging physical components. Its use needs to be designed so that simulation concepts remain connected to the conditions of actual vehicle electrical systems.

Previous studies have shown attention to the use of Tinkercad for learning electrical and electronic circuits. Ratnadewi et al. (2023), for example, discussed electrical circuit learning using Tinkercad Circuits among academics in Indonesia. BL et al. (2024) reported a study on Tinkercad-assisted learning in an industrial electronics subject, while Khotimah et al. (2024) examined the Tinkercad website as a learning medium and its relation to psychomotor skills. These works are relevant for positioning Tinkercad as a simulation medium, but their contexts, targets, and outcome indicators are not identical to students' understanding of light vehicle electrical systems. Digital media for vehicle electrical systems have also been developed through three-dimensional visualization based on augmented reality and instructional videos (Dharma et al., 2015; Firdaus et al., 2021), while Tinkercad-based projects have been used in learning activities and in designing simple systems (Putra & Aribowo, 2022; Putri et al., 2024).

At SMKN 6 Malang, a preliminary observation was conducted on 27 February 2025 in class XI TKRO (Light Vehicle Automotive Engineering). The problems identified included some students not understanding the material before practice, dependence on wiring diagrams, and trainer components that had broken down several times. The initial class score distribution showed that 9 students scored above 75, 7 students scored exactly 75, and 14 students scored below 75. These data indicate a need for learning that better supports conceptual understanding before students work with physical circuits.

Based on these problems, classroom action research was conducted by implementing Tinkercad and reflecting on the results of each cycle to improve the subsequent action. The study focused on three questions: how Tinkercad was implemented in light vehicle electrical systems learning; how students' comprehension test results changed across action stages; and how students responded to the use of the medium. This focus is contextual, namely to improve learning in one particular class, and not to prove that Tinkercad is always superior to all other methods or media.

The practical contribution of this study lies in documenting the process of instructional improvement from the first to the second cycle. Test results, observations, and questionnaires were

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used together to examine the changes that occurred after action and reflection. Because the study did not use a comparison group, the observed changes should be interpreted as changes during the implementation of the action in the class studied. The influence of other factors, such as differences in test materials, students' experience from the previous cycle, and increased guidance, cannot be fully separated from the use of the medium itself.

2. RESEARCH METHODS

This study employed a classroom action research (CAR) approach. The action procedure followed a cycle of planning, implementation, observation, and reflection based on the Kemmis and McTaggart model. CAR was chosen because its main purpose is to improve instructional practice in a particular class through actions that are planned, observed, and refined progressively (Ananda et al., 2015; Aqib & Maftuh, 2009; Trianto, 2011). This reflective and iterative approach is consistent with the principle of learning through action and reflection (Revans, 2011). In this study, the results of reflection on Cycle I formed the basis for adjusting instruction in Cycle II.

The study was conducted in the Light Vehicle Electrical Systems subject in class XI TKRO 3 at SMKN 6 Malang. Cycle I was carried out on 7 May 2025 and Cycle II on 14 May 2025. The class was selected because the preliminary observation showed that some learning outcomes had not yet reached the minimum mastery criterion (Kriteria Ketuntasan Minimal, KKM) of 75 and that there were comprehension problems before practice. The N-Gain summary table states N = 30, and the list of individual scores is likewise numbered up to the 30th student; the number of participants was therefore 30. Differences in baseline means between cycles still need to be interpreted with caution because the equivalence of the tests used was not fully documented.

Table 1. Action stages and observation focus

Stage	Reported activities	Data focus
Cycle I	Introduction to Tinkercad, simulation practice, test, observation, questionnaire	Navigation difficulties, student questions, application of concepts
Reflection	Identifying the need for more detailed explanations and guidance	Obstacles to use and understanding
Cycle II	Improved instruction; simulation with more intensive guidance	Engagement, use of the medium, test results, responses
Evaluation	Comparing summaries of tests, observations, and questionnaires	Changes during the action; not definitive causal evidence

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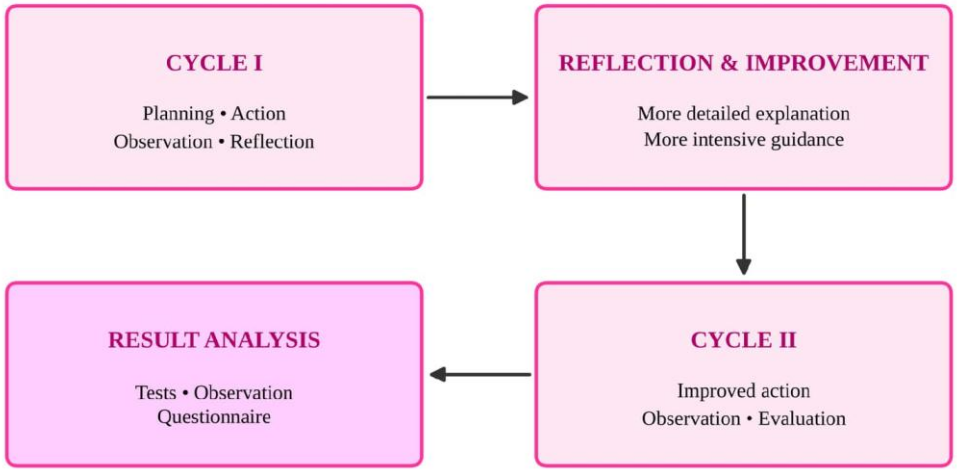


Figure 1. Flow of the two-cycle classroom action research

Data were collected through three techniques. First, pre- and post-action tests were used to measure learning outcomes as an operational indicator of students' understanding. Second, the subject teacher, acting as observer, recorded the instructor's introduction of the medium, student engagement, understanding in using the simulation, and implementation constraints. Third, a student questionnaire used a four-option scale: strongly disagree, disagree, agree, and strongly agree. The questionnaire blueprint covered ease of use, clarity of display and features, conceptual understanding, application of concepts in the simulation, understanding of component relationships, problem solving, and interest in learning.

The test material described in the blueprint related to the central lock system, including its function, components, working principle, troubleshooting, types of actuators, comparison of the central lock system with manual locks, and inspection of the central lock motor using a multimeter. The blueprint specified a multiple-choice format with cognitive levels ranging from factual knowledge to simple analysis, consistent with the use of cognitive process categories in formulating learning objectives (Wulan, 2010). The test consisted of 20 items. This article does not add information on content validity or test reliability beyond what is documented in the research records.

Table 2. Data collection and analysis matrix

Data source	Instrument/indicator	Method of analysis	Role in interpretation
Pre-test and post-test	Test scores on electrical systems/central lock material	Mean, standard deviation, recalculated group N-Gain, and exploratory paired Wilcoxon test	Indicator of test achievement
Teacher observation	Introduction of the medium, engagement, application of concepts, constraints	Thematic description based on cycle notes	Explains the implementation process
Student questionnaire	14 statements; 1–4 scale	Summary of available mean responses	Explains student perceptions

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Data source	Instrument/indicator	Method of analysis	Role in interpretation
Learning documentation	Module, test blueprint, score lists, cycle notes	Descriptive cross-checking	Context and procedural trail

Data analysis involved re-examining the list of individual scores (30 pairs in each cycle), calculating means and standard deviations, and computing the group N-Gain based on pre-test and post-test means with a maximum score of 100. The formula used was g = (mean post-test - mean pre-test)/(100 - mean pre-test). These values differ from the N-Gain figures in the original summary table; the original figures are noted for transparency but are not used as verified results. For pre-test–post-test changes, the Wilcoxon signed-rank test was computed exploratively from the available score pairs because the distribution of differences in Cycle I was not normal. Interpretation remains limited by the single-class design without a control group and by the possible influence of practice and guidance during the action.

Table 3. Analytical formulas relevant to the research data

Analysis	Formula	Description
Mean score	$\bar{X} = (\Sigma X_i) / N$	X_i = score of student i; N = number of students with valid data.
N-Gain	g = (S_post − S_pre) / (S_max − S_pre)	Describes improvement relative to the maximum score; values recalculated from group means are reported and distinguished from the original figures.
Percentage	$P = (f / N) \times 100\%$	f = number of students in a given category; N = number of students analyzed.
Questionnaire mean	$\bar{R} = (\Sigma R_j) / m$	R_j = summarized item score/mean; m = number of items calculated.
Wilcoxon signed-rank	W = smaller sum of signed ranks	Nonparametric test comparing two paired measurements; used exploratively because Cycle I score differences were not normal.

Note: The formulas above describe the analytical methods relevant to the type of data collected. Individual scores were not reconstructed. A paired-samples t-test was mentioned in the research report, but its full statistical output is not presented because not all details could be verified.

Operationally, Cycle I began with lesson planning and an introduction to the use of Tinkercad, followed by simulation activities, a test, observation, and a questionnaire. Reflection on Cycle I highlighted that students still asked many questions about how to use the platform, that their ability to apply concepts through simulation was inadequate, and that explanations needed to be more detailed. Cycle II was designed to address these constraints through clearer and more interactive explanations and more intensive guidance. After the Cycle II action, test, observation, and questionnaire data were reviewed again to assess changes in learning.

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3. RESULTS AND FINDINGS

Initial Conditions and Implementation of the Action

The preliminary observation showed that previous instruction relied heavily on wiring diagrams and practice using the trainer. When students did not yet understand the circuit flow, they tended to experience difficulties during practice. Damage to several trainer components also limited students' opportunities to check whether the circuits they assembled worked as intended. Tinkercad was introduced as an initial simulation tool to provide experience in designing and testing circuits in a digital environment.

In Cycle I, the action was implemented on 7 May 2025. The subject teacher served as observer, while the researcher guided the use of the medium. The observation results indicated that the instructor was fairly capable of introducing and integrating Tinkercad, but many students still asked how to use the application. Students' ability to apply electrical concepts in the simulation was judged inadequate. The reflection notes emphasized the need for more detailed explanations, guidance while students used the features, and better structuring of activities to make them more interactive.

In Cycle II, conducted on 14 May 2025, instruction was organized to address these weaknesses. Students already had accounts created in Cycle I, so learning time could be directed more toward simulation activities and subject matter. Observations in Cycle II described better student responses, increased engagement and enthusiasm, and more adequate ability to use Tinkercad. The constraints that remained mainly concerned unstable internet signals and students' questions when they encountered steps they did not yet understand.

Changes in Test Results

The list of individual scores shows that in Cycle I the mean pre-test score was 56.83 and the mean post-test score was 60.00. Four of the 30 students reached or exceeded the KKM of 75 on the post-test (13.33%). The group N-Gain recalculated from the means with a maximum score of 100 was 0.0734 (7.34%), not 0.1661 as stated in the original summary table.

In Cycle II, the individual scores yielded a mean pre-test score of 63.67 and a mean post-test score of 89.50. The recalculated group N-Gain was 0.7110 (71.10%). This change was greater than that in Cycle I. The result is consistent with the observation notes that students were more accustomed to using the platform after their experience in the first cycle and received more intensive guidance in the second cycle (Table 4 and Figure 2).

Table 4. Summary of test results and N-Gain

Cycle	N	Mean pre-test	Mean post-test	N-Gain	N-Gain category
I	30	56.83	60.00	0.0734 (7.34%)	Low
II	30	63.67	89.50	0.7110 (71.10%)	High

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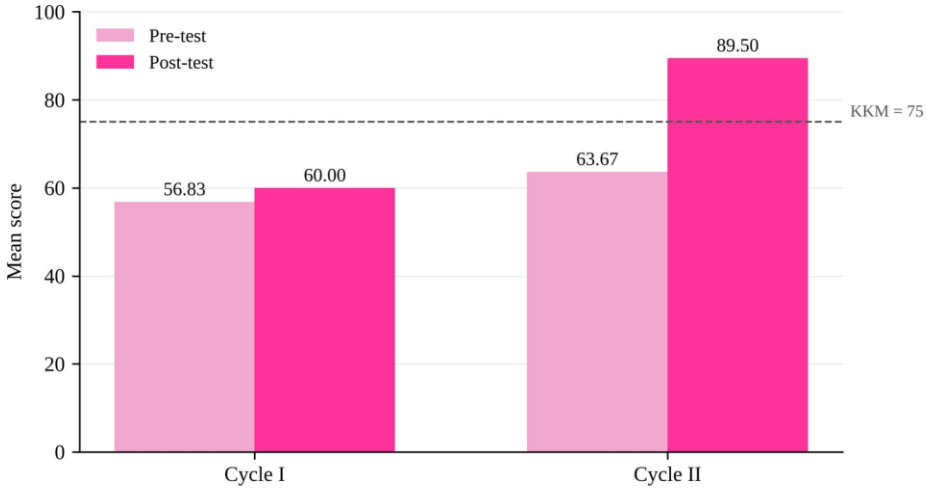


Figure 2. Comparison of mean pre-test and post-test scores

The Cycle II pre-test score (63.67 based on recalculation; 63.66 as rounded in the original table) was higher than the Cycle I post-test score (60.00). In addition, the N-Gain values in the original summary table could not be reproduced from the pre-test and post-test means using the group N-Gain formula. This article therefore presents the recalculated values of 0.0734 for Cycle I and 0.7110 for Cycle II and retains the discrepancy as a reporting note. According to the researchers' confirmation, the tests used across cycles had comparable levels of difficulty. The difference in baseline means is reported as it is and is neither removed nor obscured.

Student Responses and Process Observations

In Cycle I, the mean questionnaire response for the summarized items was 2, which on the four-option scale indicates a tendency to disagree. This response was associated with students not yet perceiving the benefits of the medium because they still had difficulty using it and did not yet understand the material sufficiently. This finding is important because it shows that acceptance of a medium is determined not only by the availability of technology but also by initial experience, clarity of instructions, and students' success in completing tasks.

In Cycle II, the questionnaire summary showed a mean response of 3, indicating a tendency to agree. Students began to feel that Tinkercad helped their understanding, in line with the reported increase in test results. This change in responses is descriptive; no specific inferential analysis was conducted to establish the significance of the change in questionnaire scores. The response scale is presented in Table 5.

Table 5. Questionnaire response scale

Score	Category	Interpretation
4	Strongly agree	Highest agreement
3	Agree	Agreement
2	Disagree	Disagreement
1	Strongly disagree	Strongest disagreement

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Observations in both cycles provide context for understanding the change in scores. In Cycle I, the main obstacles were unfamiliarity with the medium, repeated questions about features, and difficulty applying concepts in the simulation. In Cycle II, engagement was rated better, students were more active and enthusiastic, and their ability to operate the simulation improved. Nevertheless, internet access remained a supporting factor that needs attention.

4. DISCUSSION

Tinkercad as a Bridge between Concepts and Practice

The findings from Cycles I and II indicate that digital simulation can be part of the preparation for learning light vehicle electrical systems, especially when students need help understanding the relationships among parts of a circuit before physical practice. Visual and interactive media can help present representations of concepts that are difficult to observe directly. In this context, Tinkercad provides a space for students to assemble and check virtual circuits, while teachers can use the process to pose questions about component functions, current flow, and possible causes of faults.

However, the Cycle I results show that access to the application alone is not sufficient. When students do not yet understand the navigation and functions of its features, their attention may shift from electrical concepts to the technical procedures of using the software. Instructional design therefore needs to allocate time for media orientation, step-by-step demonstration, and directed practice before students are asked to complete tasks independently. This is consistent with the research reflection that called for more detailed explanations and more intensive guidance in Cycle II.

The use of simulation also needs to be accompanied by an explicit acknowledgment of the limits of digital representation. This principle is consistent with the multimedia literature, which emphasizes that visual representations should be designed to support information processing rather than merely to enhance appearance (Mayer, 2009; Arsyad, 2017; Munadi, 2013; Susilana & Riyana, 2009; Jennah, 2009). Vehicle electrical systems have component characteristics and operating conditions that are not entirely covered by general electronic circuit simulation. Simulation should therefore be positioned as a medium for building initial mental models and testing understanding, not as an absolute substitute for practice with automotive wiring diagrams, multimeters, real components, and occupational safety procedures.

Meaning of the Changes between Cycles

The mean post-test score increased from 60.00 in Cycle I to 89.50 in Cycle II. The group N-Gain recalculated from the means of each cycle was 0.0734 (7.34%) and 0.7110 (71.10%), respectively. These N-Gain values differ from those reported in the original summary table (0.1661 and 0.7073). The interpretation of change is therefore based on the verifiable means of individual scores, while the discrepancy between the original and recalculated values is recorded transparently.

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The difference in baseline scores between cycles needs to be considered when assessing the magnitude of change. The Cycle II pre-test was reported as 63.66 (63.67 based on recalculation), higher than the Cycle I post-test of 60.00. According to the researchers' confirmation, the tests used across cycles had comparable levels of difficulty; the difference in baseline means is therefore not explained as a consequence of differing test difficulty. The difference may still reflect learning that had already taken place, differences in conditions at the time of measurement, or variation in student scores. Because the study did not use a comparison group, these findings indicate changes in outcomes during the action, not definitive evidence of cause and effect.

Re-examination of the 30 pairs of individual scores produced an exploratory Wilcoxon signed-rank test: Cycle I, $W = 0$, $p < .001$ (exact/software-approximated $p = .000174$), and Cycle II, $W = 0$, $p < .001$ ($p = .00000345$) (Table 6). The p values are written as $p < .001$ to avoid excessive precision. These results indicate changes in paired scores within the available data but do not prove that Tinkercad alone caused the change. Questions about test equivalence and the absence of a comparison group continue to limit inference.

Table 6. Re-examination of paired score changes

Cycle	n pairs	Pre-test (M ± SD)	Post-test (M ± SD)	Wilcoxon W	p
I	30	56.83 ± 14.17	60.00 ± 12.39	0	< .001
II	30	63.67 ± 16.55	89.50 ± 7.11	0	< .001

Note: The Wilcoxon test was recalculated from 30 score pairs per cycle. The results are exploratory and must be interpreted within the limits of a single-group classroom action research design without a comparison group. The equivalence of test difficulty across cycles was confirmed by the researchers.

Student Responses and Sustainability of Implementation

The change in mean questionnaire responses from 2 to 3 indicates a shift from a tendency to disagree to agreement. This change is reasonable when viewed together with the observation notes: after becoming familiar with the platform in Cycle I, students were better prepared to participate in the activities in Cycle II. Acceptance of the medium should therefore be understood as a process that can develop as students' competence in using it and their success in completing tasks increase.

Although positive responses are important information for improving instruction, perception questionnaires are not identical to measures of understanding. Assessment of learning outcomes needs to be based on clear indicators and measurement procedures (Sudjana, 2010; Slavin, 1994; Uno, 2011). Students' perceptions may be influenced by the ease of the application, classroom atmosphere, teacher support, or the novelty of the medium. Conclusions about understanding should therefore rest primarily on test results, while questionnaires and observations serve as supporting data to explain the learning experience.

The finding regarding signal disruptions shows that online simulation requires infrastructure support. Teachers need to prepare alternatives in case the internet connection fails, such as structured demonstrations, offline worksheets, or shared devices used in pairs. Account and device readiness should also be checked before the lesson so that face-to-face time is not spent resolving

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access problems. These strategies are practical implications of the constraints recorded in this study, not results of separate tests.

Implications for Vocational Learning

In practical terms, the implementation of Tinkercad can be arranged into a sequence of activities, taking into account the choice of active learning models and planned media support (Hasan et al., 2021; Khotimah et al., 2024): (1) relating the material to the vehicle electrical system; (2) explaining the symbols and functions of components; (3) demonstrating the simulation interface; (4) assigning circuit tasks with gradually increasing difficulty; (5) asking students to predict results before running the simulation; (6) comparing predictions with results; and (7) connecting simulation findings with wiring diagrams and measurements on physical equipment. This sequence translates the action experience into an instructional design that can be tested further.

Teachers also need to design questions that encourage reasoning rather than merely assessing whether a circuit can run. Learning needs to link simulation results with explicit learning objectives and strategies (Susilana & Riyana, 2009; Akbar & Noviani, 2019). For example, students can be asked to explain the function of a component, predict the effect of a broken path, compare two configurations, or compose diagnostic steps. Such activities help keep the medium focused on conceptual understanding. Nevertheless, this study did not measure each of these abilities separately, so their effectiveness needs to be evaluated in further studies.

To strengthen the evidence, future studies can document the blueprint, validity, and reliability of the test instruments used, report anonymized individual data with a consistent number of participants, and combine test scores with practical performance rubrics. If the aim is to estimate the specific effect of Tinkercad, a design with a comparison group or more controlled repeated measurements may be considered. Cross-class and cross-school studies are also needed before the results are generalized.

Principles for Designing Simulation Activities

The results of the action show the importance of arranging simulation activities in stages. At the initial stage, the teacher can introduce the learning objectives and the problem context, for example, the symptom of a central lock that does not respond to commands. Students then identify the components and describe the workflow before assembling the circuit on the platform. This sequence prevents simulation activities from turning into trial-and-error activities oriented solely toward technical success. Within the framework of learning media, visual representations are more beneficial when linked to verbal explanations, guiding questions, and tasks that require students to explain the reasons for their technical decisions (Hasan et al., 2021; Susilana & Riyana, 2009).

Connecting Digital Representations with Real Objects

An important principle in vocational learning is maintaining continuity between conceptual models and the work environment. Circuit simulation provides an opportunity to observe relationships among components under relatively controlled conditions, but workshop skills also include selecting measuring instruments, interpreting measurement results, identifying component conditions, working accurately, and safety. Teachers can therefore use simulation results as material for discussion before students work on real circuits. After the simulation, students should

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be asked to compare the schematic with the vehicle wiring diagram, check measurement points, and explain differences between virtual results and practical findings. This study did not separately measure the transfer of skills to real equipment; this recommendation is an instructional implication that needs to be tested in further research.

The Role of Reflection in Classroom Action Research

The change from Cycle I to Cycle II was not merely a change of medium but also a change in the quality of implementation based on reflection. In the first cycle, students still devoted their attention to learning the interface and asked for help when running the simulation. Reflection directed improvements toward more detailed explanations, better interaction, and more intensive guidance. In the second cycle, the observation notes described better responses and engagement. This pattern is consistent with the logic of classroom action research: the initial action is used to identify actual obstacles, and this information then becomes the basis for adjusting the next action (Ananda et al., 2015; Trianto, 2011).

Assessing Understanding and Interpreting N-Gain

N-Gain is used as a summary of score change relative to the maximum possible improvement. Based on group means and a maximum score of 100, the recalculated N-Gain was 0.0734 in Cycle I and 0.7110 in Cycle II. These values differ from the N-Gain listed in the original summary table. This difference should not be ignored; the article reports the recalculated figures as reproducible results and explains the original figures as a calculation discrepancy. Interpretation across cycles remains limited by the classroom action research design without a comparison group and by the limited reporting of instrument validity and reliability.

Implications for Instrument Development

The test blueprint covers the function of the central lock, identification of components, working principle, troubleshooting, types of actuators, comparison of central lock and manual lock systems, and inspection of the motor using a multimeter. This coverage addresses several levels of ability, from recognizing factual information to applying and analyzing. Future instrument development should ensure that each indicator is represented proportionally and that test items have appropriate levels of difficulty. Documenting the validity and reliability of the instrument will strengthen the traceability of measurement quality, while performance rubrics can complement cognitive scores with evidence of practical ability. This article does not claim to have carried out a new validation of the instrument.

Implementation Conditions and Equitable Access

Web-based simulation offers flexibility because students can repeat exercises, but it also creates dependence on devices and networks. The Cycle II notes on unstable signals show that digital instructional design needs to consider access explicitly. Teachers can prepare alternative scenarios, download supporting materials that can be accessed offline, or arrange pair work when the number of devices is limited. These steps are not intended to replace the use of the platform but to ensure that technical disruptions do not eliminate learning opportunities. The use of technology should be judged by its contribution to learning objectives rather than by the novelty of the devices used (Arsyad, 2017; Munadi, 2013).

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Feedback Principles during Simulation

Feedback given while students work on the simulation needs to be specific and oriented toward thinking processes. When a circuit does not work, the teacher should not immediately show the final answer but should invite students to trace the source of the problem through a logical sequence of checks. Students can be asked to state the symptoms, estimate which components may be faulty, check circuit connections, and then explain the reasons for choosing the next step. This approach helps turn errors into sources of information for learning. In this study, the Cycle I observation showed that students still asked many questions and were not yet fluent in applying concepts in the simulation; providing examples, guiding questions, and staged feedback is therefore a relevant response to the constraints identified.

Managing Student Activities and Learning Time

Simulation-assisted learning needs to allocate time in a balanced manner among explanation, demonstration, practice, and reflection. If the introduction to the application is too brief, students who are not yet familiar with it will have difficulty following the core tasks. Conversely, if device orientation is too long, the time available to discuss electrical concepts becomes limited. Teachers can use a short task at the beginning of the lesson to check account readiness and navigation, then move on to more challenging activities. Worksheets should include objectives, an initial schematic, students' predictions, testing steps, observed results, and reflection questions. Such a design also makes it easier for teachers to identify whether errors arise from conceptual misunderstanding or from difficulty operating the medium.

Distinguishing Learning Outcomes from Engagement

Observation notes on students' enthusiasm and activity provide information about the process but cannot be used as a substitute for comprehension scores. Students may appear active because they are interested in the technology without fully understanding circuit principles. Conversely, quieter students may still be able to answer the questions correctly. Future studies therefore need to operationalize engagement indicators clearly, such as participation in discussions, task completion, quality of explanations, and the ability to collaborate. These indicators can be combined with concept tests and practical assessments so that success is not determined solely by perceptions or visible activity.

Alignment of the Medium with Automotive Competencies

The selection of Tinkercad needs to consider the competencies to be achieved. For introducing circuit concepts, component relationships, and predicting the behavior of simple circuits, simulation can provide a practice environment that is relatively easy to repeat. However, for diagnostic competencies in specific vehicle systems, teachers need to ensure that the simulation configuration corresponds to the electrical principles being taught. Not all characteristics of vehicle circuits, load conditions, connection faults, and automotive component behavior can be represented directly on a general-purpose platform. Mapping learning objectives against the capabilities of the platform is therefore an important step before preparing worksheets.

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Recommendations for Staged Implementation

Implementation can begin with a joint demonstration showing how to build a simple circuit and read its results. The next stage is guided practice with structured instructions, followed by pair practice to solve circuit problems. Once students are sufficiently familiar, the teacher can assign individual tasks that require students to make predictions, run the simulation, and explain the results. At the end of the activity, students compare their findings with wiring diagrams and real components. This sequence is a pedagogical recommendation derived from the obstacles and improvements reported, not a sequence that has been experimentally compared in this study.

Research Limitations and Future Agenda

The study was conducted in a single class over two cycles within a relatively short period. Its results cannot be generalized directly to other classes or schools. The absence of a comparison group means that the specific influence of Tinkercad cannot be separated from the effects of practice, guidance, and prior learning experience. According to the researchers' confirmation, the pre-tests and post-tests across cycles had comparable levels of difficulty; however, details of instrument validity and reliability still need to be reported more completely. The mismatch between the original N-Gain and the values recalculated from the means is also a reporting limitation explained in this article. The available results do not yet provide all the psychometric and statistical details required for independent evaluation, so the findings should be understood as evidence of instructional improvement in a local context rather than definitive evidence of the universal superiority of one medium.

Future studies can strengthen the design through several steps. First, documenting the blueprint, validity, and reliability of the tests used, and transparently reporting the basis for constructing tests across cycles that were confirmed to have comparable difficulty. Second, reporting analytical procedures and summary data completely, including means, standard deviations, test statistics, p values, and appropriate effect sizes. Third, adding practical assessments to examine whether understanding gained through simulation carries over to skills in using measuring instruments and checking physical circuits. Fourth, repeating the implementation in other classes or schools so that conditions that support and hinder the use of the medium can be compared.

Synthesis of Findings

Overall, the test data show an increase in scores in Cycle II, while observations and questionnaires provide context on changes in students' experiences. These three data sources complement each other but do not serve the same function: tests describe achievement on the instrument used, observations explain visible learning behavior, and questionnaires capture students' perceptions. When the results of all three move in the same direction, the interpretation of instructional improvement becomes more plausible, but this does not remove the limitations of the design. Such descriptive triangulation strengthens understanding of classroom processes; it does not replace the need for consistent data and a stronger design to estimate the specific effect of the medium.

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5. CONCLUSION AND SUGGESTIONS

Classroom action research in class XI TKRO 3 at SMKN 6 Malang showed that the implementation of Tinkercad, accompanied by improvements in action between cycles, coincided with improved comprehension test results in light vehicle electrical systems. In Cycle I, the mean score changed from 56.83 to 60.00; the recalculated group N-Gain was 0.0734 (7.34%). After instruction was improved through more detailed explanations, more interactive activities, and more intensive guidance, Cycle II recorded a mean pre-test score of 63.67 and a mean post-test score of 89.50; the recalculated group N-Gain was 0.7110 (71.10%). These N-Gain values were calculated from group means and differ from the N-Gain figures in the original summary table.

Observations and questionnaires also indicated improvements in the learning experience: students were more active and enthusiastic in Cycle II, and the summary of responses shifted from a mean of 2 in Cycle I to 3 in Cycle II. Tinkercad has the potential to support initial understanding before physical practice, but the effectiveness of its implementation depends on orientation to its use, guidance, internet access, and integration with real automotive practice. Because the study was conducted in a single class without a comparison group and the N-Gain values in the original summary table could not be reproduced from the reported means, these results should be interpreted contextually and should not be used to claim a definite causal relationship.

Teachers are advised to provide gradual orientation to the use of Tinkercad, prepare worksheets that link simulation with automotive wiring diagrams, and ensure that every activity requires students to explain the technical reasons behind the circuit arrangement. Schools need to support devices and internet connectivity and provide learning alternatives when online access is disrupted. Future research should clarify the number of participants, standardize or explain differences in instruments across cycles, report statistical test results completely, and assess practical skills on physical equipment.

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