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Students' Conceptual Understanding of Simple Electric Circuits and Friction Before and After Hands-on Laboratory Activities Using a Mobile Science Laboratory

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Abstract

Limited access to laboratory equipment can restrict opportunities for students in small schools to engage in practical science learning. The Mobile Science Laboratory of Surindra Rajabhat University provides a flexible outreach platform that transports laboratory equipment, learning materials, lecturers, staff, and university students to schools according to their educational needs. This study aimed to (1) implement hands-on laboratory activities on simple electric circuits and friction using the Mobile Science Laboratory and (2) compare students' conceptual understanding before and after participation. A one-group pretest–posttest design with descriptive analysis was employed. The participants were 76 Grade 9 students from a small opportunity-expansion school in Surin Province, Thailand. Two researcher-developed conceptual understanding tests, each consisting of 10 four-option multiple-choice items, were administered before and after the corresponding laboratory activities. Complete response sets were available from 76 students for simple electric circuits and 59 students for friction. Item-level percentages of correct responses were compared descriptively. The results showed higher posttest percentages for all 10 simple electric circuit items. For friction, posttest percentages were higher for nine of the 10 items, although the magnitude of change varied and some concepts remained difficult. Overall, the findings indicate positive descriptive changes in students' test performance, particularly for simple electric circuits. The Mobile Science Laboratory provides a practical approach to expanding access to hands-on science learning in small and resource-limited schools.

Keywords: Mobile Science Laboratory, conceptual understanding, simple electric circuits, friction, hands-on laboratory activities

1. Introduction

Conceptual understanding is a central goal of physics education because it enables students to explain physical phenomena, connect scientific principles with real-world situations, and apply knowledge to unfamiliar problems rather than merely memorize formulas or calculation procedures (Sarapak et. al., 2025). Nevertheless, simple electric circuits and friction remain fundamental topics that many students find difficult to understand. In electric circuits, students frequently confuse electric current, potential difference, and resistance; interpret a battery as a source of constant current; or reason locally about individual components without considering the circuit as an interconnected system (Engelhardt & Beichner, 2004). In the context of friction, students often rely primarily on everyday experiences, have difficulty distinguishing static from kinetic friction, and struggle to connect observable motion at the macroscopic level with interactions between surfaces at the microscopic level (Corpuz & Rebello, 2007). Such alternative conceptions may persist even after conventional classroom instruction and may subsequently hinder students' learning of more advanced concepts in electricity, mechanics, engineering, and other STEM-related fields.

From a scientific perspective, understanding simple electric circuits requires students to recognize the relationships among electric current, potential difference, resistance, and circuit configuration. Electric current represents the rate of charge flow through a circuit, whereas potential difference provides the energy difference that drives charge through circuit components. The current and potential difference across components depend on whether the components are connected in series or parallel and on their resistance. Students therefore need to reason about the circuit as an interconnected system rather than interpreting individual components independently (Engelhardt & Beichner, 2004; Jaakkola & Nurmi, 2008). Friction, in contrast, involves the interaction between contacting surfaces and depends on the normal force and surface characteristics. Static friction adjusts to oppose impending motion up to a maximum value, whereas kinetic friction acts when relative motion occurs between surfaces. Distinguishing these forms of friction and relating macroscopic observations to microscopic surface interactions are important for developing scientifically appropriate explanations of frictional phenomena (Besson et al., 2010; Corpuz & Rebello, 2007).

Hands-on laboratory activities have considerable potential to promote conceptual change because they allow students to manipulate equipment, make predictions, observe physical phenomena, collect and interpret data, compare experimental evidence with their prior ideas, and construct explanations based on evidence. In simple electric circuit activities, directly connecting circuit components, measuring current and voltage, observing changes in bulb brightness, and discussing circuit diagrams can help students establish meaningful relationships among circuit configuration, current, potential difference, and resistance (Jaakkola & Nurmi, 2008; Zacharia & de Jong, 2014). Conceptual change-oriented instruction further supports this process by encouraging students to articulate their initial ideas, test those ideas against experimental evidence, and revise their mental models toward scientifically accepted explanations (Taşlıdere, 2013). Similarly, laboratory activities on friction can be more educationally meaningful when students do more than follow predetermined procedures. Activities that require them to measure forces, vary surface conditions, interpret force diagrams, and explain the mechanisms underlying friction can support connections between observable evidence and scientific models of surface interactions (Corpuz & Rebello, 2007). Although virtual laboratories and simulations may produce learning outcomes comparable to those of physical laboratories in some contexts, hands-on activities continue to provide distinctive opportunities for direct interaction with equipment, measurement practice, troubleshooting, collaboration, and engagement with authentic experimental conditions (Rytting et al., 2019; Sarapak et al., 2025).

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Despite the educational value of laboratory experiences, access to science laboratories remains uneven across schools. Small schools, rural schools, and schools in economically disadvantaged areas may face limitations related to laboratory space, experimental equipment, maintenance budgets, safety resources, and teachers with specialized laboratory experience. University–school partnerships therefore represent a potentially effective mechanism for extending scientific equipment, expertise, and inquiry-based learning opportunities to students who might otherwise have limited access to practical science experiences. Previous studies of university-based outreach laboratories and science enrichment programs indicate that such initiatives can enable school students to participate in authentic scientific practices and interact with university lecturers, scientists, technicians, and undergraduate students (Goldschmidt & Bogner, 2016; Luehmann & Markowitz, 2007; Ronen & Tal, 2019; Tsybulsky et al., 2018). In the present study, a Mobile Science Laboratory (MSL) refers not merely to a permanently installed laboratory inside a vehicle, but to a flexible university outreach system through which selected experimental kits, instructional materials, safety equipment, university staff, and university students are transported to participating schools (Sreejivungsa et al., 2025). The laboratory activities may be selected from physics, chemistry, biology, technology, or astronomy according to the curricular level, instructional emphasis, and specific needs of each school.

Existing research has examined the effects of hands-on, virtual, and blended laboratory environments on students' conceptual understanding. Many studies have reported that practical experimentation, inquiry-oriented instruction, simulations, and multiple representations can support conceptual learning. However, findings regarding the relative effectiveness of different laboratory modalities remain inconsistent, and learning outcomes appear to depend strongly on instructional sequencing, the level of guidance provided, the quality of questioning, and the alignment between experimental tasks and the targeted scientific concepts (Sarapak, et al., 2025). Furthermore, much of the existing literature has examined electric circuits and friction separately or has focused on comparisons between physical and virtual laboratories. Comparatively limited evidence is available regarding university-operated Mobile Science Laboratories that deliver modular hands-on activities directly to schools with restricted laboratory resources. There is also a need for context-specific evidence showing how students' conceptual responses change before and after participating in MSL activities across two foundational physics topics within the same outreach implementation. The literature review supplied for this study similarly indicates that misconceptions concerning current, voltage, resistance, and friction remain common across educational levels, while many studies concentrate on immediate learning outcomes rather than the implementation of mobile laboratory services in authentic school contexts.

Accordingly, the present study aimed to (1) conduct hands-on laboratory activities on simple electric circuits and friction through a Mobile Science Laboratory and (2) compare students' conceptual understanding before and after participating in the Mobile Science Laboratory activities using pretest and posttest assessments. The study was designed to provide empirical evidence of changes in students' conceptual responses following direct engagement with physical experiments. Rather than considering only whether overall scores increased, analysis of the pretest and posttest results may also help identify concepts that showed improvement and concepts for which difficulties remained after the activities. The findings can consequently inform the revision of experimental kits, activity worksheets, guiding questions, demonstrations, and post-activity discussions so that future MSL activities respond more directly to students' alternative conceptions. In the longer term, the results may support the expansion of Mobile Science Laboratory services to additional schools and scientific topics, strengthen sustainable university–school

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collaboration, and contribute to broader efforts to reduce inequality in access to meaningful laboratory-based science learning.

2. Methodology

2.1 Research Design

This study employed a one-group pretest–posttest design with a station-rotation activity format. A total of 76 students participated in two Mobile Science Laboratory stations: Simple Electric Circuits and Friction. At each station, students completed a topic-specific pretest before participating in the hands-on laboratory activity and a topic-specific posttest after the activity and facilitated discussion. The item-level analysis included 76 valid response sets for simple electric circuits and 59 valid response sets for friction. The pretest and posttest responses for each topic were compared descriptively to examine changes in students' test performance. No comparison group or inferential statistical analysis was included.

2.2 Participants

The participants were 76 Grade 9 students from a small opportunity-expansion school in Surin Province, Thailand. The school was selected purposively because it was one of the target schools served by the Mobile Science Laboratory and had limited access to science laboratory equipment. All 76 students participated in the laboratory activities. However, the numbers of valid response sets available for the item-level analysis differed between the two topics. A total of 76 valid response sets were available for simple electric circuits, whereas 59 valid response sets were available for friction. The difference in sample size resulted from incomplete or unmatched pretest–posttest responses for the Friction test. Seventeen students did not provide a complete paired response set for the Friction assessment and were therefore excluded from the item-level friction analysis. These students nevertheless participated in the laboratory activities. Before data collection, permission to conduct the activities was obtained from the school, and the students were informed about the learning and assessment procedures.

2.3 Mobile Science Laboratory Activities and Learning Materials

The Mobile Science Laboratory of Surindra Rajabhat University operates as a flexible science outreach platform that provides hands-on learning activities in physics, chemistry, biology, technology, and astronomy. The activity areas and laboratory resources delivered to each school are selected according to the school's curriculum, learning priorities, students' grade levels, and available instructional time. The university then prepares and transports the selected experiment kits, instructional materials, and activity resources to the school, where the activities are facilitated by university lecturers, staff, and students. The Mobile Science Laboratory vehicle used to transport the equipment and support the implementation of the activities is shown in Figure 1.

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Figure 1. (a) Mobile Science Laboratory vehicle of Surindra Rajabhat University used to transport selected laboratory equipment and instructional materials to participating schools. The hands-on activities: (b) Simple Electric Circuits station and (c) Friction station.

For the present study, the participating school selected physics activities focusing on simple electric circuits and friction. Accordingly, the Mobile Science Laboratory transported the relevant experimental equipment and instructional materials from the university to the school. The learning activities were organized into two stations: simple electric circuits and friction.

At the simple electric circuits station, students assembled series and parallel circuits, observed bulb operation, and practiced measuring electric current and potential difference using multimeters. At the friction station, students used wooden blocks, surfaces with different characteristics, additional masses, and spring scales to examine the force required to initiate motion and the force measured while the objects were moving. Activity sheets were used to guide the experimental procedures and allow students to record measurements, analyze the results, and summarize their observations. In this study, the activity sheets served as instructional materials and were not analyzed as a separate source of research data.

2.4 Research Instrument

Students' conceptual understanding was assessed using two researcher-developed topic-specific tests. The Simple Electric Circuits Conceptual Understanding Test consisted of 10 four-option multiple-choice items, while the Friction Conceptual Understanding Test consisted of 10 four-option multiple-choice items. Each test was administered as a pretest before the corresponding station activity and as a posttest after the activity and facilitated discussion. The two tests contained a total of 20 items. The content validity of the two researcher-developed conceptual understanding tests was evaluated by three experts using the Index of Item–Objective Congruence (IOC). The expert review focused on the alignment between each test item and the intended learning objectives and scientific concepts. Only valid response sets available for both the pretest and posttest of the corresponding topic were included in the item-level analysis.

2.5 Research Procedures

The Mobile Science Laboratory activities were implemented using a station-rotation format during a one-day visit to the participating school. Before the activities began, the research team prepared the activity areas and experimental equipment, divided the students into two groups, and explained the activity procedures and laboratory safety requirements. Two learning stations were organized: (1) Simple Electric Circuits and (2) Friction. The two student groups began at different stations and rotated after completing the full learning and assessment sequence at their first station. Each station required approximately two hours, including the topic-specific pretest, hands-on laboratory activity, discussion, and posttest. At the Simple Electric Circuits station, students first completed a 10-item pretest assessing their existing understanding of simple electric circuits. They then participated in

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hands-on activities involving the construction of series and parallel circuits, observation of bulb operation, and measurement of electrical quantities using multimeters. The instructor facilitated discussion during and after the experiments to connect students' observations with relevant concepts, including electric current, potential difference, resistance, circuit connections, and the use of electrical measuring instruments. After completing the activity and discussion, students completed a 10-item posttest on simple electric circuits. At the Friction station, students first completed a 10-item pretest assessing their existing understanding of friction. They subsequently conducted hands-on experiments using wooden blocks, spring scales, additional masses, and surfaces with different characteristics. The activities allowed students to examine the force required to initiate motion, the force measured while an object was moving, and the relationships among surface characteristics, normal force, and frictional force. Following the activity, the instructor facilitated a discussion to relate the experimental observations to the concepts of static and kinetic friction. Students then completed a 10-item posttest on friction.

After completing the planned learning and assessment sequence at the first station, each group rotated to the other station and repeated the same sequence for the second topic. All 76 students participated in both learning stations and were invited to complete separate pretest and posttest assessments for simple electric circuits and friction. The item-level analysis included 76 valid response sets for simple electric circuits and 59 valid response sets for friction. The entire instructional and assessment sequence at each station was completed within approximately two hours.

2.6 Data Analysis

Students' responses were analyzed descriptively and separately for the two activity stations. Only valid response sets available for both the pretest and posttest of the corresponding topic were included in the analysis. Accordingly, students with an incomplete pretest or posttest for a given topic were excluded only from the analysis of that topic. For the Simple Electric Circuits station, the percentages of correct responses on the 10-item pretest and posttest were calculated from 76 valid response sets and compared at the item level. For the Friction station, the percentages of correct responses on the 10-item pretest and posttest were calculated from 59 valid response sets and compared using the same procedure. Because the two topic analyses were based on different numbers of valid response sets, the results were interpreted separately within each topic. No direct statistical comparison was made between the two topics. No inferential statistical tests were conducted; therefore, the findings are interpreted as descriptive differences in test performance rather than statistically significant changes.

3. Results

3.1 Implementation of the Mobile Science Laboratory Activities

The first objective of this study was to implement hands-on laboratory activities on simple electric circuits and friction using a Mobile Science Laboratory. The Mobile Science Laboratory of Surindra Rajabhat University operates as a flexible science outreach platform that provides schools with access to laboratory equipment and practical learning activities. The platform includes activity collections in several fields, such as physics, chemistry, biology, technology, and astronomy. The activities delivered to each school are selected according to the school's needs, the scientific topics to be emphasized, the students' grade levels, and the availability of appropriate laboratory resources.

For the present implementation, the participating school selected physics activities focusing on simple electric circuits and friction. The university team transported the relevant experiment kits, instructional materials, and activity sheets to the school. The

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simple electric circuit station included batteries, connecting wires, switches, light bulbs, and multimeters, while the friction station included wooden blocks, surfaces with different textures, additional masses, and spring scales. The students participated in the activities through a station-rotation format, allowing them to manipulate equipment, obtain measurements, record experimental results, and discuss their observations with the activity facilitators.

This implementation illustrates the practical role of the Mobile Science Laboratory in bringing laboratory experiences to a small school with limited access to science equipment. Instead of requiring the school to establish complete laboratories for every science discipline, the university selected and transported the required laboratory resources to the school according to its specific educational needs.

3.2 Descriptive Comparison of Pretest and Posttest Results

The second objective was to compare students' conceptual understanding before and after participation in the Mobile Science Laboratory activities, as reflected in their pretest and posttest responses. Table 1 presents the percentages of correct responses for the 10 friction items based on 59 valid response sets and the 10 simple electric circuit items based on 76 valid response sets. Because no inferential statistical analysis was conducted, the differences between the pretest and posttest results are interpreted descriptively within each topic.

The Friction Conceptual Understanding Test assessed a range of fundamental scientific concepts related to friction. Item 1 examined students' understanding of the origin of friction associated with interactions between contacting surfaces, while Item 2 assessed recognition of the SI unit of frictional force. Item 3 focused on distinguishing kinetic friction from static friction based on whether an object is moving. Items 4 and 5 assessed understanding of the coefficient of friction, including the relationship between surface characteristics, the magnitude of the coefficient of friction, and the relative ease with which an object begins to move. Item 6 examined students' understanding of the direction of frictional force relative to the direction of motion. Item 7 assessed the application of the relationship between kinetic friction, the coefficient of kinetic friction, and the normal force. Item 8 examined students' understanding of the effect of apparent contact area on friction under the simplified dry-friction model used at this instructional level. Item 9 focused on practical methods of reducing friction, particularly the use of lubricants. Finally, Item 10 assessed students' ability to calculate kinetic friction from an object's mass, gravitational acceleration, and the coefficient of kinetic friction. Collectively, these items assessed both qualitative conceptual understanding and the application of basic relationships involving frictional force and the coefficient of friction.

Table 1 Item-Level Percentages of Correct Responses on the Pretest and Posttest for Friction and Simple Electric Circuits.

Item	Friction Pretest (%)	Friction Posttest (%)	Circuit Pretest (%)	Circuit Posttest (%)
1	0.00	3.39	35.53	88.16
2	55.93	74.58	11.84	40.79
3	45.76	38.98	26.32	68.42
4	47.46	52.54	68.42	89.47
5	22.03	35.59	69.74	97.37
6	49.15	52.54	46.05	68.42
7	42.37	44.07	35.53	57.89
8	22.03	33.90	15.79	35.53
9	32.20	42.37	67.11	71.05
10	11.86	27.12	15.79	27.63

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Note. Percentages for friction were calculated from 59 valid response sets, whereas percentages for simple electric circuits were calculated from 76 valid response sets.

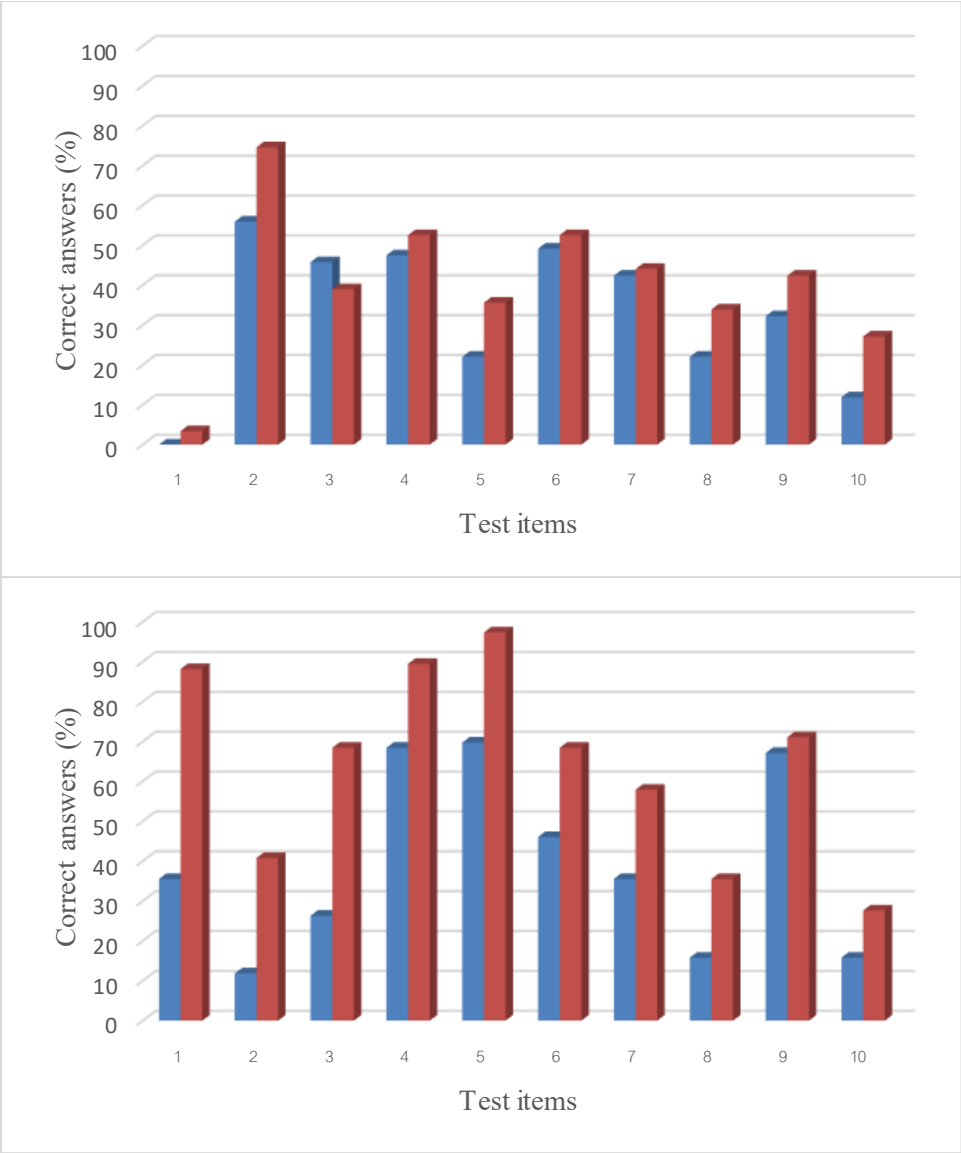


Figure 2. Item-level percentages of correct responses on the pretest (blue color) and posttest (red color) for (top) friction, based on 59 valid response sets, and (bottom) simple electric circuits, based on 76 valid response sets.

As shown in Table 1, the percentages of correct responses for all 10 simple electric circuit items were higher on the posttest than on the pretest. The largest descriptive increase was found for Item 1, for which the percentage of correct responses increased from 35.53% on the pretest to 88.16% on the posttest. Item 3 increased from 26.32% to 68.42%, while Item 5 increased from 69.74% to 97.37%. Substantial increases were also observed for Item 2, from 11.84% to 40.79%; Item 4, from 68.42% to 89.47%; Item 6, from 46.05% to 68.42%; and Item 7, from 35.53% to 57.89%. Nevertheless, the posttest percentages for some simple electric circuit items remained relatively low. Item 8 increased from 15.79% to 35.53%, and Item 10 increased from 15.79% to 27.63%. Item 9

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showed only a small descriptive change, increasing from 67.11% to 71.05%. These results suggest that although students demonstrated better posttest performance across all circuit items, some of the assessed concepts continued to present difficulties. A different pattern was observed for friction. The percentages of correct responses increased on the posttest for nine of the 10 items, but the magnitude of change varied considerably. Item 2 showed the largest increase, from 55.93% on the pretest to 74.58% on the posttest. Item 10 increased from 11.86% to 27.12%, Item 5 increased from 22.03% to 35.59%, Item 8 increased from 22.03% to 33.90%, and Item 9 increased from 32.20% to 42.37%. However, several friction items continued to have relatively low percentages of correct responses after the activities. In particular, Item 1 increased only from 0.00% to 3.39%. Moreover, Item 3 was the only item for which the percentage of correct responses decreased, from 45.76% on the pretest to 38.98% on the posttest. Items 6 and 7 also showed only small changes, increasing from 49.15% to 52.54% and from 42.37% to 44.07%, respectively. The friction results therefore indicate positive descriptive changes for several items but also show that some concepts remained difficult for the participating students. Figure 2 provides a visual comparison of the pretest and posttest percentages for the two topics. The upper graph presents the item-level results for friction, whereas the lower graph presents the results for simple electric circuits.

As illustrated in Figure 2, the posttest bars for simple electric circuits were consistently higher than the corresponding pretest bars across all 10 items. In contrast, the differences between the pretest and posttest bars for friction were less consistent. Although most friction items showed higher posttest percentages, several changes were small, Item 1 remained particularly low, and Item 3 showed a lower percentage on the posttest.

3.3 Discussion of the Simple Electric Circuits Results

Based on the 76 valid response sets, the consistently higher posttest percentages for the simple electric circuit items suggest that the students demonstrated better performance after participating in the circuit activities. One possible explanation is that the activity allowed students to construct actual circuits, observe whether the light bulbs operated, compare circuit arrangements, and use multimeters to obtain direct measurements. These observable outcomes may have helped students connect circuit diagrams and abstract electrical quantities with the behavior of actual electrical components.

The findings are consistent with Jaakkola and Nurmi (2008), who reported that learning environments combining practical laboratory activities with appropriate representations can support students' understanding of simple electricity. Similarly, Taşlıdere (2013) suggested that instructional activities designed to confront learners' existing conceptions can contribute to the restructuring of misconceptions in direct-current electric circuits. Zacharia and de Jong (2014) also emphasized that physical and virtual manipulatives can help learners relate scientific representations to observable electrical phenomena. The relatively large descriptive changes for several circuit items may therefore be associated with the immediate and visible nature of the experimental outcomes. Students could observe changes in bulb brightness, examine the consequences of different circuit arrangements, and use measuring instruments to relate current and potential difference to the operation of a circuit. Such activities may make the relationships among circuit components more accessible than instruction based only on verbal explanations or circuit diagrams. However, the relatively low posttest percentages for Items 8 and 10 suggest that some aspects of circuit learning remained challenging. These items may have involved concepts requiring more complex interpretation or quantitative reasoning. Hands-on experience alone may not automatically produce a complete understanding of mathematical relationships in electric circuits. Additional guided calculations, visual representations, repeated measurements, and explicit discussion of the

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relationships among current, potential difference, and resistance may therefore be required.

3.4 Discussion of the Friction Results

Based on the 59 valid response sets, the friction results were less consistent than the simple electric circuit results. Although nine items showed higher percentages of correct responses on the posttest, several increases were small, and some concepts appeared to remain difficult. The very low posttest result for Item 1 suggests that the concept assessed by this item was not adequately clarified through the activity as implemented. Similarly, the decrease observed for Item 3 suggests that participation in the activity did not necessarily resolve the students' understanding of the concept assessed by that item. These findings are consistent with previous research indicating that misconceptions about friction can be persistent. Corpuz and Rebello (2007) found that learners may retain misunderstandings about frictional force even after receiving formal physics instruction. They argued that understanding friction requires learners to connect observable motion with interactions occurring at the contact surfaces. These interactions cannot always be understood through direct observation alone. The friction activity in the present study required students to use a spring scale to compare the force needed to initiate motion with the force measured while an object was moving. Although the procedure provided a direct measurement experience, the difference between maximum static friction and kinetic friction may not have been sufficiently visible when students relied only on the movement of the spring-scale pointer. Besson et al. (2010) indicated that carefully designed friction activities combining observations, experiments, theoretical discussion, and structural models can help students develop richer reasoning and overcome difficulties in understanding friction. The findings suggest that the friction activity should be refined to make the relevant force changes more observable. For example, the activity could incorporate a digital force sensor, a force–time graph, slow-motion video, or a guided worksheet that explicitly asks students to identify the maximum force immediately before motion and compare it with the force during motion. The activity should also include questions designed to challenge common beliefs, such as the assumption that a larger apparent contact area always produces greater friction.

3.5 Educational Implications of the Mobile Science Laboratory

Beyond the item-level pretest and posttest results, the implementation demonstrates how a university-based Mobile Science Laboratory can support science learning in small or resource-limited schools. Surindra Rajabhat University's Mobile Science Laboratory is not restricted to one subject or one fixed set of equipment. It can provide activities in physics, chemistry, biology, technology, and astronomy, depending on the learning priorities identified by each school.

This flexible service model allows a school to request activities that are relevant to its curriculum and students. The university can then prepare the selected laboratory equipment, activity sheets, instructional materials, and facilitation team and transport these resources directly to the school. In this way, students in schools without complete laboratory facilities can still gain opportunities to conduct experiments and use scientific instruments.

The Mobile Science Laboratory also provides a potential learning environment for university students who participate as activity facilitators. By assisting with equipment preparation, explaining experimental procedures, supervising school students, asking guiding questions, and supporting group discussions, university students can practice science communication, classroom management, and the facilitation of hands-on learning. For students preparing to become teachers, participation in Mobile Science Laboratory

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outreach may provide authentic experience in adapting scientific explanations to school students and conducting activities outside a conventional university laboratory.

However, the development of university students' teaching competencies was not directly measured in the present study. Therefore, this benefit should be interpreted as an educational opportunity associated with the outreach model rather than as a measured research finding. Future studies could investigate how participation in Mobile Science Laboratory activities influences pre-service teachers' teaching confidence, laboratory facilitation skills, science communication, and ability to manage activity-based learning.

3.6 Interpretation of the Findings

Overall, the findings provide encouraging descriptive evidence of students' learning following participation in the Mobile Science Laboratory activities. For simple electric circuits, the percentages of correct responses increased across all 10 items, indicating a consistently positive pattern in students' posttest performance. For friction, higher posttest percentages were observed for nine of the 10 items, although the magnitude of change varied across the assessed concepts. These findings indicate a more consistently positive descriptive pattern following the hands-on activities in simple electric circuits, while positive changes were also observed for most friction items. The different patterns observed between the two topics may be associated with the nature of the scientific concepts and the ways in which the experimental outcomes could be observed. In the simple electric circuit activities, students could directly construct circuits, observe bulb operation, compare series and parallel arrangements, and measure electric current and potential difference. These immediate and visible outcomes may have helped students connect abstract concepts with actual circuit behavior. In contrast, some aspects of friction, particularly the transition from static to kinetic friction and the interactions between contacting surfaces, are less directly observable and may require additional representations and guided interpretation. The item-level analyses were conducted using the complete response sets available for each topic: 76 sets for simple electric circuits and 59 sets for friction. Analyzing the two topics separately allowed the study to retain the available complete data and provide a clear description of students' response patterns within each learning activity. This topic-specific approach was appropriate for identifying concepts that showed positive changes and concepts that may benefit from further instructional support. Within the scope of the one-group pretest–posttest design, the findings provide useful evidence of positive learning trends following the Mobile Science Laboratory activities. Although the study focused on descriptive item-level comparisons, the results offer practical information for improving experimental equipment, activity sheets, guiding questions, and post-activity discussions. They also support the potential of the Mobile Science Laboratory as a flexible outreach model for providing meaningful hands-on science experiences to students in schools with limited laboratory resources.

4. Conclusion

This study implemented hands-on laboratory activities on simple electric circuits and friction using the Mobile Science Laboratory of Surindra Rajabhat University and descriptively compared students' pretest and posttest responses. A total of 76 Grade 9 students from a small opportunity-expansion school participated in the station-based activities. The item-level analysis included 76 valid response sets for simple electric circuits and 59 valid response sets for friction. The university transported the selected experiment kits, instructional materials, lecturers, staff, and university students directly to the school, allowing students to engage in circuit construction, electrical measurement, and investigations of static and kinetic friction within their school environment. Based on the 76 valid response sets for simple electric circuits, the posttest percentages were higher than the pretest percentages for all 10 items. However, some items continued to have

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relatively low percentages of correct responses after the activities. Based on the 59 valid response sets for friction, the posttest percentages were higher for nine of the 10 items, but the pattern of change was less consistent. Item 1 remained particularly low, and Item 3 showed a lower percentage of correct responses on the posttest. These findings indicate more consistent positive descriptive changes in test performance for simple electric circuits than for friction. The findings should be interpreted cautiously because the study employed a one-group pretest–posttest design without a comparison group, the numbers of valid response sets differed between the two topics, and no inferential statistical tests were conducted. Therefore, the results represent descriptive differences in students' test performance and should not be interpreted as statistically significant effects caused exclusively by the Mobile Science Laboratory activities. In addition, the evaluation of the researcher-developed tests focused on content validity; additional psychometric evidence, including item difficulty, discrimination indices, and reliability coefficients, was not available for the present study. Future studies should include these psychometric analyses to provide more comprehensive evidence regarding the quality of the assessment instruments. Overall, the Mobile Science Laboratory provides a practical approach to expanding access to hands-on science learning in small and resource-limited schools. Future friction activities should incorporate clearer visual representations, guided conceptual questions, repeated measurements, and tools that make changes in frictional force easier to observe. Although the outreach model may also provide valuable facilitation experience for university students, this outcome was not directly measured in the present study.

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Declaration

The authors declare that Generative AI (ChatGPT/Gemini) was only used to help improve the English language and for minor translation tasks. The AI was not used to create any scientific content, conduct data analysis, or interpret results. All ideas, experimental design, data collection, analysis, and conclusions were solely carried out by the authors. Following ethical research standards and academic integrity policies, the authors confirm that AI tools were used openly, ethically, and under the full supervision of the authors to ensure the manuscript's accuracy and appropriateness.

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