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Correcting Students' Understanding about Simple Direct Current (DC) Circuits through Scientific Approach

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Abstract

This paper reports the effect of teaching electricity in simple DC circuits using a scientific approach on students' understanding. The study was a pre-experimental design using 12 students. They were all studying in specific first secondary schools in the sub-urban area in Kasongan City, Katingan Regency, Central Kalimantan Province. This work used the multiple-choice tests to combine reasoning and certainty of response index (CRI). This test was used as pre and post-test, respectively, to assess students' understanding of electricity in simple DC circuits. As a result, it is found that the secondary students have alternate conceptions about simple DC circuits, such as "electricity comes out of both ends of a cell" and "a circuit uses up the electric current". On the other hand, the results of this study showed that the use of a scientific approach in learning could help students achieve conceptual change about electricity in simple DC circuits. The findings from the study suggested that there was a difference in students' understanding of simple DC circuits between pre-test and post-test. The scientific approach to learning seemed to help students achieve conceptual change about electricity in simple DC circuits.

Keywords: simple DC circuits, scientific approach, students' understanding, science learning

INTRODUCTION

Research has shown that inviting students into the science learning process increases their meaningful learning experiences. Teachers who adopt student-centered will increase student engagement opportunities, which then helps them more successfully achieve the course's learning objectives. In the student-centered view, teachers are perceived as facilitators rather than a source of information to their students.

However, based on observations of science learning in several secondary schools in Palangka Raya and its surrounding areas, shows some facts that (1) learning activities are more teacher-centered, students are sitting and listening quietly, (2) science learning is still focused on "science as knowledge (product)" and (3) students' understanding of science concepts are still relatively low, especially about electricity circuits (Hartanto, Sinulingga & Suhartono 2015).

Electricity is one of the topics in first secondary school. Learning about electricity requires understanding abstract concepts, for example, the flow of electrons through a circuit that is an invisible event. Therefore, learning activities on electrical topics is always a difficult task for teachers and students. Students tend to have difficulty with electric circuits because this concept is abstract (Anita, Assagaf & Boisandi 2018). Also, students have difficulty connecting one concept to another and using mathematics to solve physics problems (Rahmawati, Nisfah & Kusairi 2019). Many studies have been implemented to describe students' ideas (primary, secondary, and university levels) about simple DC circuits (Shipstone 1984; Tsai et al. 2007; Glauert 2009; Kucukozer & Demirci 2008; Hartanto & Nawir 2017). In general, based on the results of these studies, students have unscientific explanations of simple DC circuits, such as 'the current consumed model' and 'the clashing currents model'. On the current consumed model, the students thought that current had been consumed by its closed circuits components (like a bulb, resistance, etc.). Therefore, the current diminishes when it returns to battery. While on the clashing current, the students thought that current 'flows' from both battery terminals and 'clashes' in the light bulb. Before entering formal learning, students have brought this false conception. Misconceptions that have been formed can influence science learning and are very resistant to change (Black & Lucas 2002; Kucukozer & Demirci 2008).

Recent research and innovations in science teaching and learning promoted student-centered instructional activities as an effective way for eliciting and promoting discussions of students' science conceptions. Using the student-centered activities, the students become more active, which helps them learn complex concepts (Akcay & Yager 2016; Karamustafaoglu & Mamlok-Naaman 2015; Chairam, Klahan & Coll 2015). Recent studies (Hasni & Potvin 2015; McFarlane 2013) have shown that secondary school students prefer teaching methods to play an active role in "doing" science, such as collecting scientific data through observation and experimentation. This attitude needs to change by embracing more students engaged in science learning.

The 2013 Curriculum suggests active student learning. It is written in the curriculum document that students should be active in exploring knowledge, skills, and developing attitudes. To serve experiences for the students to be active, the 2013 Curriculum suggests a scientific approach. The scientific approach is an exciting way to launch students into the process of science is to link them with practicing scientists and their work. As mentioned in the curriculum document, the approach has five activities: observing, questioning, exploring or experimenting, analyzing, and communicating (Abidin 2014).

The standard theoretical basis for this scientific approach is constructivist views of learning. Constructivist learning creates students' activity in learning the lessons (Suparno 2007). The key idea of constructivism is that knowledge cannot be transmitted directly from one teacher to another. Still, learners must actively construct their knowledge rather than receive preformed information transmitted by others (Sanjaya 2011). Under constructivism, teaching creates situations in which students can actively participate in activities that empower them to make their structures. A constructivist. perspective also has implications for education and learning in science learning activities where students construct and develop knowledge through interactions with phenomena using their initial ideas. Teaching science can stimulate students to find explanations for events and give them an insight into the nature of scientific inquiry and their finding work (Emden 2021).

A literature review strongly indicates that students commonly possess misconceptions about electricity, and these misconceptions have affected their understanding of simple DC circuits during the lessons. It is also evident from the literature that teachers can reduce these misconceptions through student-centered instructional activities. Following these reviews, this study attempted to identify students' misconceptions on simple DC circuits and employ the scientific approach to fix the misconceptions. The research aimed to investigate the first secondary students' understanding of the simple DC circuit through a scientific process.

METHODS

Research Design

In this study, one group pre-test-post-test the researcher used the pre-experimental design. The case is observed two times, before and after the treatment. Changes in the outcome of interest are presumed to result from the treatment. No control or comparison group is employed. The pre-test was disseminated before the treatment. The students in the class were exposed to the scientific approach. After the treatment, a post-test was administered to the class. The design of the study show in TABLE 1.

TABLE 1. The design of the study

Group	Pre-test	Treatment	Post-test
Experimental Group	Multiple choice test with reasoning and CRI	Scientific Approach	Multiple choice test with reasoning and CRI

Treatment

As mentioned in the curriculum document, the approach has five activities: observing, questioning, exploring or experimenting, analyzing, and communicating (Abidin 2014). In general, applying those five activities of the scientific approach for science lessons is as follows.

TABLE 2. Scientific approach for science learning activities

Scientific Approach	Application in Teaching Science
Observing	Students see, observe, read, and listen to teacher's explanation or demonstration about electricity.
Questioning	Students deliver some question related to the observation and define some questions, prediction.
Exploring	Students collect data through simple experiment about simple DC circuits.
Analyzing/Associating	Students analyze the data. Students draw conclusions from the result of data analysis.
Communicating	Students present their conceptual understanding according to the conclusion they have made in form written text or oral.

Participants

Twelve participants in this study comprise ninth-grade students (age range 13-14 years) at a first secondary school in sub-urban area in Kasongan City, Katingan Regency, Central Kalimantan, Indonesia. Most students at this school were from a lower-middle-class socio-economic level.

Instruments

The measuring tools consisted of the understanding tests (pre-test and post-test) used to evaluate the students' understanding in the simple DC circuit. The test combines multiple-choice with reasoning and Certainty of Response Index (CRI) techniques (Hakim et al. 2012). CRI is the level of confidence of the students in answering each question. This confidence level used a scale from 0 to 5. Students are asked to choose the available alternative options and write down the reasons related to the answer desired. Then, students provide a level of confidence in the answer. The test was validated by a panel consisting of two science teachers and one physics lecturer. The test is shown in FIGURE 1. It is assumed that the duration between application of the same test as pre-test and post-test is sufficient for students to forget the items.

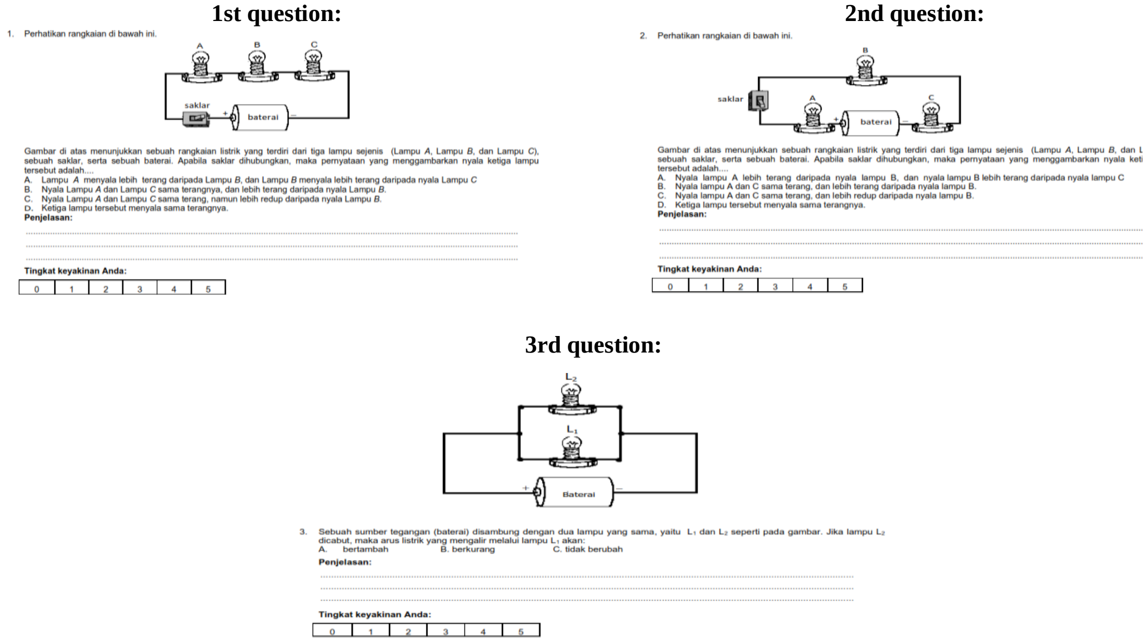


FIGURE 1. Test questions used in this study

This study was conducted for three weeks period. Each week, science classes for two meetings. Each group took a pretest in the first meeting, which lasted 40 minutes. The first until third weeks, the class participated in the learning activities using the scientific approach with five stages: observing, questioning, experimenting, associating, and communicating on topic simple DC circuits (consists of current, ohm's law, series, and parallel circuits, and power). In the last meeting, the class took a posttest, which lasted 40 minutes.

Data Analysis

Pre-test and post-test for the process domain of science teaching were administered to students in science class. The researchers analyzed the test items under the following categories (TABLE 3) suggested by Hakim et al. (2012). A panel of three lecturers decided the students' into TABLE 3 from the Physics Education Program, University of Palangka Raya, who are experienced in science and science education.

TABLE 3. The criteria for CRI modified

ANSWERS	REASONS	CRI VALUE	DESCRIPTION
True	True	> 2.5	Understand the concept (Good understanding)
True	True	< 2.5	Understand the concept but are not confident with the answers given (Good understanding)
True	False	> 2.5	Misconception
True	False	< 2.5	Do not know the concept (no understanding)
False	True	> 2.5	Misconception
False	True	< 2.5	Do not know the concept (no understanding)
False	False	> 2.5	Misconception
False	False	< 2.5	Do not know the concept (no understanding)

RESULTS AND DISCUSSION

Results

The results from the test item in pre-test and post-test are shown in TABLE 4. It can be seen that students' responses were classification in the term, (1) no understanding, (2) good understanding, and (3) misconceptions. The result in TABLE 4 confirmed an improvement between pre-test and post-test.

No students could provide the correct answer ("good understanding") in the pre-test. However, in the post-test after the scientific approach, many students could give the correct answer. The percentage of students' responses classified as "good understanding" increased from the pre-test to the post-test. The percentage change in student responses on the first question from 0% to 100%. On the second question from 0% to 92%. And on the third question from 0% to 83%.

TABLE 4. Students' Pre-Test and Post-Test Result about simple DC circuits

Category	1st question				2nd question				3rd question			
	Pre-test		Post-test		Pre-test		Post-test		Pre-test		Post-test	
	n	%	n	%	n	%	n	%	n	%	n	%
Good understanding	0	0	12	100	0	0	11	92	0	0	10	83
No understanding	5	42	0	0	4	33	0	0	8	67	1	8
Misconception	7	58	0	0	8	67	1	8	4	33	1	8

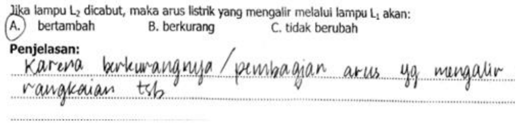
In the test, we wanted to find out students' understanding of simple DC circuits and investigate their misconceptions. As shown in TABLE 5, based on pre-test and post-test results, the students had two misconceptions in common. The first was "the current consumed model," and the second was "the clashing currents model". Both misconceptions were popular in the literature (Shipstone 1984; Tsai et al. 2007; Kucukozer & Demirci 2008; Hartanto & Nawir 2017).

TABLE 5. Common students misconceptions about simple DC circuits with this study

Student Misconceptions	1st question		2nd question		3rd question	
	Pre-test	Post test	Pre-test	Post test	Pre-test	Post Test
	n	n	n	n	n	n
The current consumed model	5	0	4	1	4	1
The clashing currents model	2	0	4	0	0	0

According to TABLE 5, in the pre-test, many students possessed misconceptions as they thought that the bulb nearer to the battery would be brighter because most of the current passed through this bulb. They believe that bulbs use up current, so its value decreases during the circuit. The current is more significant in "Bulb A" because it is closer to the battery. Also, because there is less current available, "Bulb C" is the dimmer of three bulbs. Students' responses that current flows in one direction around the circuit and its used up so that less is available to other bulbs. This misconception is named "the current consumed model". In addition to the consumption model, students understand that current flows from battery terminals and clashes in the light bulb. The current is more significant in "Bulb A" and "Bulb B" because it is closer to the battery, "Bulb C" is the dimmer of three bulbs. Students' responses that depict current coming from the positive and negative battery should be consumed by the bulbs in the circuit. This misconception is named "the clashing currents model" in prior studies. According to the related literature, these two misconceptions were the most common and resistant misconceptions among students. This misconception is also found in studies implemented with students in different nations and age groups. Student responses are analyzed to identify their understandings and misconceptions. Then, the results of this analysis were used to determine the triumph of the scientific approach implementation.

pre test answer


Jika lampu L_2 dicabut, maka arus listrik yang mengalir melalui lampu L_1 akan:
A. bertambah B. berkurang C. tidak berubah
Penjelasan:
Karena berkurangnya / pembagian arus yg mengalir rangkaian tsb

post-test answer

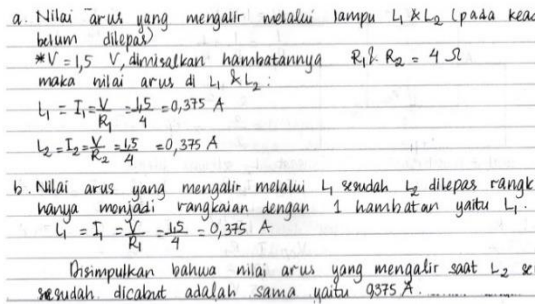

a. Nilai arus yang mengalir melalui lampu L_1 & L_2 (pada keadaan belum dilepas)
*V = 1,5 V, dimisalkan hambatannya R_1 & R_2 = 4 Ω
maka nilai arus di L_1 & L_2:
$L_1 = I_1 = \frac{V}{R_1} = \frac{1,5}{4} = 0,375$ A
$L_2 = I_2 = \frac{V}{R_2} = \frac{1,5}{4} = 0,375$ A
b. Nilai arus yang mengalir melalui L_1 sesudah L_2 dilepas rangk... hanya menjadi rangkaian dengan 1 hambatan yaitu L_1.
$L_1 = I_1 = \frac{V}{R_1} = \frac{1,5}{4} = 0,375$ A
Disimpulkan bahwa nilai arus yang mengalir saat L_2 se... sesudah dicabut adalah sama yaitu 0,375 A.

FIGURE 2. An example of student's answers before and after implementation of scientific approach in third question

In FIGURE 2, there is an analysis of students' answers which shows an increasing understanding of simple DC circuits. These results indicate that their misunderstanding of simple DC circuits has been reduced. For example, in the third question that tests students' understanding of parallel circuits (Figure 2), written answers indicate that students do not know the correct answer to the concept of parallel circuits in the pre-test. After the treatment, there was an increase in understanding of the concepts in the students' answers, indicating that their understanding of concepts increased and misconceptions decreased or even disappeared.

Discussion

The findings of this study indicate that before the treatment, students already had misconceptions about simple DC circuits. Both misconceptions, the current consumed model and the clashing currents model, were widespread misconceptions in the literature (Shipstone 1984; Tsai et al. 2007; Kucukozer & Demirci 2008; Hartanto 2015) that also found in this study. One important note from this study is that important for teachers to find out students' conceptions about the nature of science to develop lessons and activities that challenge concepts of science's nature (Hammerich 2002). Students bring some misconceptions based on their interactions with their environments to science classes (Posner et al. 1982).

Other findings from this study indicate that learning through a scientific approach influence positively students' (Handayani 2021) misconceptions about simple DC circuits. The researcher implemented this research to find students' misconceptions about simple DC circuits and the impact of the scientific approach to reduce these misconceptions. This study shows that the application of the scientific method positively impacts students' understanding of simple electric circuits.

The teacher can change students' misconceptions to scientific conceptions through the scientific approach. Students construct their knowledge through a process in which they work with simple experiments to make observations as a scientist. The teacher can explain the reason for these changes with the scientific approach. This possibly occurred because students who attended the learning with a scientific method had the opportunity to be actively involved in education. Especially at the exploring stage, students are collaboratively involved in experimental activities and build their understanding of the science events they learned. At the step of associating and communicating, students analyze and convey whether the knowledge they have acquired follows scientific concepts. During this stage, if their understanding is wrong, students are allowed to improve their knowledge with the teacher's help. Then, they were asked to apply this knowledge in different situations. With various activities, for example, experiments, discussions, presentations, or reading, most of the time in class is used by students to build their knowledge. Indeed, in these various activities, the teacher is still involved in the mentoring process, but the guidance comes from questions or needs of students. The literature claims that using the scientific approach developed for teaching and learning concepts affects students' success (Prabowo 2015; Triyuni 2016).

The results of this study also show that even though most students have a good understanding of simple DC circuits, some students still have misconceptions. According to data, after applying learning with the scientific approach, many students still had misconceptions, particularly on second and third questions. As noted in previous studies, this study underlined that the misconceptions are challenging to change. These findings are similar to prior studies ((Black and Lucas 2002; Kucukozer and Demirci 2008). In another study using samples aged 8-11 years old, to increase conceptual understanding of electrical circuits, variations of teaching materials such as using diagrams can be used (Preston 2019).

CONCLUSION

This study wanted to move secondary students from teacher-centered to more student-centered using the scientific approach. The participants involved in this study consisted of secondary students studying science lessons. Students overcame their initial misconceptions gathered from pre-test results and improved their understanding of electricity in a simple DC circuit. Accordingly, we concluded that the scientific approach implemented in the science class enhanced the students' understanding of electricity in simple DC circuits.

As a result of this study, learners misunderstand how nature works. To overcome misconceptions, learners need to construct new understandings actively. Thus, teachers face the critical challenge of identifying misunderstandings and giving students opportunities to learn the facts for themselves. According to this study, applying scientific learning can change the habits of teachers in dominating the learning class. Using a scientific approach, the students become more active, which helps students learn difficult simple DC circuit concepts. In this case, the simple DC circuits learning is oriented to facilitate students' scientific process as scientists discover scientific products. Science is a body of knowledge and a way of knowing. One important underpinning for learning science through a scientific approach is students' understanding of the nature and structure of scientific knowledge and the processes by which it is developed

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