Worksheet analysis for revealing students’ understanding of simple DC circuits

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Abstract. Worksheets are the guideline for students to learn as they can write their own idea, notes, questions, and understandings within the worksheet. Therefore, it is easy to investigate students’ understandings about the topics. In this study, researchers aimed to elicit 70 Thai high school students’ correct understanding and misconceptions of simple DC circuits from their responses on the worksheet. The participants came from 2 schools and attended the simple DC circuits activity. Participants were asked to set up the 3 resistors series and parallel circuits then write down their response to these questions: 1) Which resistor will be burnt first? 2) Sorting amount of the current passing to each resistor and 3) Sorting amount of the potential difference across each resistor. By analysing students’ responses on the worksheet, 3 common misconceptions as 1) Clashing current misconception 2) Stored up and used up current misconception and 3) Closer circuit misconception were found.

1. Introduction
Generally, worksheets are used as the guideline for students to study in a class. Many researchers realized the important of worksheets and tried to 1) improve students’ conceptual understandings [1-5], 2) help teachers managing more interactive class [6-8], and 3) improve students’ skills [9-13] such as creative thinking process skill, science process skill, metacognition skill, and critical thinking skill. In addition, students have more freedom to respond the questions freely with their prior knowledge, own ideas, and thoughts in details because there is no scoring for students’ response to the worksheet. Thus, it would be easier for researchers to explore how students think during working on their worksheet. In this study, researchers aimed to elicit students’ correct conceptual understanding and misconceptions of simple DC circuits from their responses on the worksheet of the simple DC circuits activity.

2. Common misconceptions of simple DC circuits
From previous studies [14-19], there were many common misconceptions of simple DC circuits. Therefore, researchers classified all those previous studies into 8 categories as follows:
3. Resistor worksheet design

Resistor worksheet had been designed by the researchers for students to work along the simple DC circuits activity. There were two important parts: Prediction part and Result part. The Prediction part was planned to obtain the students’ original thoughts or prior knowledge about simple DC circuits. While, the result part was set for students to record what they observed from the demonstration.

![Series circuit diagram questions in the Prediction part of the worksheet.](image-url)
In the activity, students were asked to design two circuits, 1 series (figure 1) and 1 parallel (figure 2), that could burn at least one of the determined resistor. For series circuits, the determined resistors were 1Ω, 2Ω, and 3.9Ω. For parallel circuits, the determined resistors were 10Ω, 12Ω, and 15Ω. However, student could pick the same resistance to fill in the blanks. For instance, student can design their own series circuit as the connection of 2Ω, 2Ω, and 3.9Ω by using two 2Ω determined resistance. The values of current and potential difference of each resistor were labeled as I1, I2, I3, V1, V2, V3.

There are 3 questions for students to answer in the worksheet: 1) Which resistor will be burnt first? 2) Sorting amount of the current passing to each resistor and 3) Sorting amount of the potential difference across each resistor.

4. Methodology

4.1. Purpose of this study
This study aims to elicit students’ correct conceptual understanding and misconceptions of simple DC circuits from their responses on the worksheet. Research question is ‘What are students’ misconceptions of simple DC circuits?’.

4.2. Data collection and Data analysis
Participants of this study were 70 high school students from 2 schools in Thailand. Students were grouped into 5-6 students per group. So, there were 13 groups of students in this study. The data was collected in September 2018 and March 2019. All students attended the simple DC circuits activity that took 180 minutes to be done. There were both male and female participants. The data from all students were analyzed together without any comparison.

Resistor worksheet was a tool for collecting data. Students were asked to do the worksheet during the activity. There were several parts of the worksheet but researchers concentrated on the part of prediction which students had chance to express their own explanation with prior understanding. Students had approximately 10 to 15 minutes to conclude and write their group prediction before discussing with the class.

As students worked and discussed together, their explanations within group were similar. To analyze data, the answer of each group was checked. Also, their explanations were interpreted and categorized, by the 1st and 2nd authors, into the categories of existing common misconceptions as mentioned in the second topic and the correct understanding of simple DC circuits.
5. Results and discussion
By checking each group’s answer of 3 questions, table 1 presents the number of group of students who can answer each questions correctly. The 3 questions are: 1) Which resistor will be burnt first? 2) Sorting amount of the current passing to each resistor and 3) Sorting amount of the potential difference across each resistor.

Table 1. The number of group who can answer each questions correctly.

| Question                  | Number of group who give the correct answer in series circuit | Number of group who give the correct answer in parallel circuit |
|---------------------------|--------------------------------------------------------------|---------------------------------------------------------------|
| Question 1                | 2                                                             | 8                                                             |
| Question 2                | 5                                                             | 2                                                             |
| Question 3                | 3                                                             | 3                                                             |
| Question 1 and Question 2 | 1                                                             | 0                                                             |
| Question 1 and Question 3 | 1                                                             | 0                                                             |
| Question 2 and Question 3 | 3                                                             | 2                                                             |
| Question 1, Question 2 and Question 3 | 1 | 0 |

The trend of answering the correct answer from table 1 shows that most groups cannot correctly answer question 1 concurrently with question 2 and/or question 3. Only one group that can answer all 3 question correctly in series circuit. The interesting point is ‘Why can some group of students give the correct answer for both second and third questions but NOT the first question?’.

Unfortunately, from students’ responses, none of students explain the reasons for question 2 and question 3. In addition, there are many groups of students that can answer question 2 and/or question 3 correctly but not the first question. This result revealed that students might remember contents from a previous class, but they could not apply or did not realize what they learn to solve the real or different situation. Moreover, even though students could answer the first question correctly, their explanations were not corresponded with the answer of question 2 and/or question 3. The example response of the group of students who could correctly answer all questions is shown in table 2.

Table 2. The example response from a group that gave the correct answer to all questions.

| Series circuit design           | First question responses                                                                 | Second question responses | Third question responses |
|--------------------------------|----------------------------------------------------------------------------------------|----------------------------|--------------------------|
| 2Ω - 1Ω - 3.9Ω                | The 3.9Ω resistor will be burned first because it has the highest potential different so the current cannot flow any further. | $I_1 = I_2 = I_3$         | $V_3 > V_1 > V_2$       |

The explanation of this group was described that ‘Current cannot flow any further.’. Actually, their answer for question 2 should be ‘$I_1 = I_2 > I_3$’ to relate with their reason. But, their answer was that ‘Current are all equal for all resistors.’. Thus, they might remember the properties of series circuits from what they had study in a class before.
Table 3. The examples of students’ explanations to the first question.

| Group | Students’ explanations to the first question | Common misconceptions |
|-------|---------------------------------------------|-----------------------|
| A     | The middle resistor will be burned first because its position is in the middle and current came from both terminal of battery. | Clashing current |
| B     | The first resistor will be burned first because the highest current flow through it. | Stored up current or Used up current |
| C     | The closet resistor will be burned first because the current separated to it first and it is the closet resistor. | Closer circuit misconception |
| D     | The closet resistor will be burned first because it is the highest amount of resistance so the amount of current is the least. (their design had 15Ω resistor as the closet one.) But, as this resistor is the closet one, the current will be stored the most there. | Closer circuit misconception |

Nevertheless, from the result of all explanations, there were no group of students who could give the correct reason to any questions. According to the first question ‘Which resistor will be burnt first?’, students’ explanations revealed that they had the common misconceptions related to the series circuits as 1) Clashing current misconception and 2) Stored up or used up current misconception (Students did not explain clear enough to classify the answers were Stored up current or Used up current.). There was a few different point between these two misconceptions. For Stored up current, when the current enters the first load, that load will store all of the current and use it as an energy. No more flow after the first load. In contrast, the Used up current allows the current flow to the next load but decreasing its amount.

In parallel circuits, Closer circuit misconception is the only common misconception that was found. The examples of students’ explanation to the first question are shown in table 3. Also, the number of group of students who have these misconceptions are presented in table 4.

Table 4. The number of group which have the existing common misconceptions.

| Type of circuit | Misconceptions found                          | Number of group |
|-----------------|----------------------------------------------|-----------------|
| Series circuits | Clashing current                             | 1               |
|                 | Stored up current or Used up current          | 1               |
| Parallel circuits | Closer circuit misconception               | 2               |

6. Conclusion and implementation
From the result of this study, three existing common misconceptions of simple DC circuits were found from students’ explanations in their worksheet including Clashing current misconception [15-16], Stored up or Used up current misconception [14-16, 18], and Closer circuit misconception [14-17]. This results could be implied that even students remember the basic properties of series and parallel circuits, such as the property of current, but they could not link those properties to be the reason of a resistors’ burning. For the further study, researchers plan to improve the activity and worksheet to be more intense and suitable for improving students’ understanding of simple DC circuits. Conceptual test might be used to cooperate with the worksheet for analyzing students’ correct conceptual understanding and misconceptions before and after the activity for more reliable results.

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