Evaluating Student’s Misconceptions and The Causes on Direct Current Concepts by Means of Four-Tier Multiple Choice Test

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Abstract. The main problem commonly faced in learning Physics is incompatibility between students’ pre knowledge in Physics concepts and the Physics concepts taught by teachers in schools. For example in Direct Current concepts, students have assumed that when there are two independent series and parallel current circuits, each composed of two identical electrical lamps as current loads, then the lamps on both circuits will light up at the same intensity. According to the Physics concept, however, the magnitude of current flows on a parallel circuit is greater than the magnitude of similar current flows on a series circuit, so that the intensity of the lamp light on the parallel circuit lights up brighter than that on the series circuit. This discrepancy may introduce a misconception to the students. This research aims to evaluate misconceptions profile of 30 numbers of 12th grade students in senior high school Ngimbang Lamongan East Java on Direct Current concepts and to identify the causes originating from themselves using four-tier multiple choice test developed by the author with ADDIE research design. The results show that all the students experienced misconceptions in throughout the sub concepts. The most frequent misconceptions was identified on the following sub concepts: Parallel Circuit, Series Circuit, Series-Parallel Circuit and Kirchoff’s 1 Law due to wrong intuition.

1. Introduction
Students’ knowledge can be achieved either from formal educational processes in school or from environment in daily life. Physics is one of the subjects taught in Science class in senior high school. In physics, concepts, theories and laws of physics relates closely to various phenomena found in our daily life. It is therefore physics learning process in a class should be delivered by relating it to phenomena in daily life so as it can be understood easily by students. In other words, learning physics means that studying phenomena along with the concepts in it [1]. But in fact, still many physics teachers found difficulties in delivering physics concepts to their students. That situation may lead misconceptions to students. For example on Direct Current concepts.

Based on the survey held earlier by the authors in Senior High School 1 Ngimbang Lamongan [2], some misconceptions on the Direct Current concepts was found. When students were given questions on series and parallel electrical circuits (see Figures 1-2), students assumed that the electric current on each resistor $R_1$ and $R_2$ in the series circuit is greater than the electric current on each resistor $R_1$ and $R_2$ in the parallel circuit. The reason is that on the series circuit there is no branch point on the circuit loop so that the current $I$ will be the same every where in the circuit ($I_1 = I_2$). On the parallel circuit in Figure 2, however, when the current $I$ flowing on the O branch point, it is divided into two, $I_1$ and $I_2$. After $I_1$...
and $I_2$ passed through the resistor $R_2$ and $I_1$ and $I_2$ decreased. These students’ assumptions are wrong. The electric current $I$ on each resistor in a series circuit is smaller than the electrical current $I$ on each resistor in a parallel circuit, because the resultant $R_{total}$ in Figure 1 is $R_1 + R_2 = 10 \, \Omega$ while the similar resultant $R_{total}$ in Figure 2 is $\frac{1}{R_1} + \frac{1}{R_2} = \frac{5}{2} \, \Omega$. This difference is termed as misconception.

![Figure 1](image1.png)  
**Figure 1.** A battery with a voltage of 1.5 volts is connected to $R_1$ and $R_2$ in a close series circuit.

![Figure 2](image2.png)  
**Figure 2.** A battery with a voltage of 1.5 volts is connected to $R_1$ and $R_2$ in a close parallel circuit.

Based on the Physics concepts, electrical current is given in Equation (1) [3],

$$I = \frac{V}{R}$$  (1)

Where, $I$ is current (Ampere); $V$ is voltage (Volt); $R$ is resistance (Ω).

Such misconceptions must be detected as soon as possible because this may interfere the student’s understanding in other concepts [4,5]. One of solutions to detect misconceptions is a four-tier multiple choice diagnostic test [6]. This kind of diagnostic test consists of four components, namely multiple choice questions (1st tier), the level of confidence in answering the question (2nd tier), the answer reason (3rd tier), and the level of confidence in choosing the reason (4th tier). Table 1 shows the combination of student’s answers (1st – 4th tiers) and the conception levels.

| Conception Level        | 1st Tier | 2nd Tier | 3rd Tier | 4th Tier |
|-------------------------|----------|----------|----------|----------|
| Understand the concept (UC) | Correct | Sure | Correct | Sure |
| Partial understanding the concept (PUC) | Correct | Sure | Incorrect | Not sure |
|                          | Correct | Sure | Incorrect | Not sure |
|                          | Correct | Not sure | Correct | Sure |
|                          | Correct | Not sure | Incorrect | Not sure |
|                          | Correct | Sure | Incorrect | Not sure |
|                          | Incorrect | Not sure | Incorrect | Not sure |
|                          | Incorrect | Sure | Correct | Not sure |
|                          | Incorrect | Not sure | Correct | Sure |
|                          | Incorrect | Not sure | Correct | Not sure |
In addition to that, the causes of misconceptions that originating from students include preconception, associative thinking, humanistic thinking, incomplete or wrong reasoning, and wrong intuition can also be detected from four tier multiple choice test. This paper is intended to evaluate misconceptions on the Direct Current concepts of 12th grade students in Science class in Senior High School 1 Ngimbang Lamongan using the developed four-tier multiple choice test and identify the causes of misconceptions originating from students themselves.

2. Method
2.1 Sample
Thirty numbers of 12th grade students in Science class in Senior High School 1 Ngimbang Lamongan was being the participants of this work. They have learnt the Direct Current concepts in the previous semester.

2.2 Instrument
The four-tier misconception diagnostic test was prepared step-by-step. First, potential misconceptions on the “Direct Current” concepts were identified from interview to a number of students. The results were discussed to two independent physics teachers to collect suggestions and constructed criticism. Second, ten numbers of multiple choice questions with open ended reasons was written and tested to a number of the first-year students in Physics Department, Universitas Negeri Surabaya in order to collect students’ answers on the conceptual questions. The responses were analysed. The meaningful responses and that appear frequently were chosen to write up alternative options of a multiple choice misconception diagnostic questions that were being prepared. Third, the four-tier misconception diagnostic test were obtained. The intended test instrument, the content validity and reliability of the questions was available in [2]. The developed instrument consist of Current, Resistance (RSC), Ohm’s Law, Series Circuit (SC), Parallel Circuit (PC), Series-Parallel Circuit (S-PC), Kirchoff’s 1 Law (KF’s 1 Law) sub concepts. Table 2 provides one of the intended four-tier test.

Table 2. One of the developed four-tier multiple choice test on Direct Current concepts

| Conception Level | 1st Tier | 2nd Tier | 3rd Tier | 4rd Tier |
|------------------|----------|----------|----------|----------|
| Misconception    | Incorrect| Sure     | Incorrect| Not sure |
|                   | Incorrect| Not sure | Incorrect| Sure     |
| Do not understand the concept | Incorrect| Not sure | Incorrect| Not sure |

Figure 3. Series circuit.

From the figure above, which light are the brightest?

a. L1
b. L2
c. L3
d. L1 and L3
2.3 Data Analysis

As shown in Table 1, the level of concept understanding is divided into understand the concept (UC), partial understanding the concept (PUC), misconception (MC), do not understand the concept (DUC). The student’s answers to the question in Table 2 and all other questions were analyzed using Equation (2).

\[
PA = \frac{n_x}{n_S} \times 100 \%
\]  

(2)

Where, PA is percentage of answers on each concept; \( n_x \) is the number of students that categorized as UC, PUC, MC, and DUC; and \( n_S \) is the total number of students.

Furthermore, the causes of misconceptions which include preconception (P), associative thinking (AT), humanistic thinking (HT), incomplete or wrong reasoning (R), and wrong intuition (WI) (see the answer reasons in Table 2) were calculated using Equation (3).

\[
PCM = \frac{n_x}{n_M} \times 100 \%
\]  

(3)

Where, PCM is percentage the causes of misconception; \( n_x \) is the number of students due to P, AT, HT, R or WI; and \( n_S \) is the number of students.

3. Result and Discussion

3.1 The Profile of Student’s Misconceptions in Direct Current Concepts

Figure 4 below shows the conception distribution of 30 number of students covering the sub concepts of Current, Resistance (RSC), Ohm’s Law, Series Circuit (SC), Parallel Circuit (PC), Series-Parallel Circuit (S-PC), Kirchoff’s 1 Law (KF’s 1 Law). As seen below, about 60 % of students suffered misconceptions in PC concepts, and about 30 – 40 % of students also experienced misconceptions in RSC, SC, S-PC, dan KF’s 1 Law concepts. Only less than 15 % of students interfered misconceptions in Current and Ohm’s Law concept. Furthermore, in Current concept more than 55 % of students were detected to have partial understanding the concept, and more than 15 % of other students understood...
well the concept. Meanwhile in RSC concept, about 27% of students was identified do not understand the concept, about 25% of students showed partial understanding the concept. Then in Ohm’s Law concept, the number of students who identified partial understanding and understand the concept is about 33%, about 15% of other students was detected do not understand. In SC concept, more than 25% of students showed partial understanding and do not understand the concept, about 13% of other students understood the concept. In PC concept, about 25% of students interfered do not understand the concept well and less than 10% of other students understood well the concept. Meanwhile, around 25% of students experienced partial understanding in the S-PC concept. The last, in KF’s 1 Law concept about 30% of students suffered partial understanding the concept.

**Figure 4.** The conceptions distribution of students in Direct Current sub concepts. UC = understand the concept, PUC = partial understanding the concept, MC = misconception, DUC = do not understand the concept.

Students who suffered misconceptions mostly due to memorizing the formula without understand the concept. For example, in PC concepts (Question No. 9): “In Figure 5, a battery is connected to a lamp A. What happens to the lamp A when switch S is positioned ON?”

**Figure 5.** Parallel circuit [3].

Most students choosed the wrong answer, however they were sure with their reasons. According to some students, when the S switch is positioned ON, the total resistance in the circuit is smaller than when the switch is positioned OFF because the circuit turns into a parallel circuit. This leads the total current in the circuit to becomes greater than the total current when the switch is OFF. The student’s answer is clearly different from the Physics concept, saying that after the S switch is positioned ON, the lamp A was not turn on because it is short circuit [8].
Second, in KF’s 1 Law concepts (Question No. 10): “Look at the following figure! If two resistors $R_1$ and $R_2$ ($R_2 = 2R_1$) are arranged in parallel circuit as in Figure 6, how is the current $I_1, I_2, I_3,$ and $I_4$ in the circuit below?”

![Figure 6. Parallel circuit][3]

Student understand that the current $I_3$ entering through at the branch point $a$ will be handled by the two resistors $R_1$ and $R_2$, so that the current $I_4$ coming out of the branch point $b$ becomes smaller than $I_3$. Whereas according to the Physics concept, the current $I_3$ that enters through the branch point $a$ is equals to the current $I_4$ coming out of the branch point $b$ [3]. Thus, it appears that students interfered misconception. This misconception occurs because the question requires conceptual understanding, not just based on the formula.

Third, in S-PC concepts (Question No. 6): “Look at the following pictures (Figure 7 and 8)! The two electrical circuits consisting of two identical lights $L_1$ and $L_2$ and the voltage source also equal. Compare the brightness of $L_1$ and $L_2$ in Figure 7 and 8”.

![Figure 7. Series circuit.][4] ![Figure 8. Parallel circuit.][5]

The student’s answered that the lights $L_1$ and $L_2$ in Figure 7 are brighter than the lights in Figure 8. They reasoned that the current in Figure 7 is not divided, while that in Figure 8 the current is divided into branch point. According to the Physics concept, the lights that are arranged in parallel is brighter than the lights in the series circuit, because the total current in the parallel circuit is greater than the total current in the series circuit.

As see in Figure 4, the partial understanding concept dominates Current concepts. For example, Question No. 1: “Look at the following picture in Figure 9! Figure 9 shows a battery connected to a lamp via a cable. In what circuit will the light turn on?”

![Figure 9. Illustration for Question Number 1][8]

In this question, about 55% of students answered the question well. But they didn't know what the reason is. Student’s assumed that the switch must be added to the circuit so the lights can turn on. On
the other hand, the physics concept explains that the closed circuit is the positive pole and negative pole and must be connected to the lamp.

3.2 The Profile of Student’s Misconceptions in Direct Current Concepts Based on The Causes

Figure 10 shows the distribution of students misconceptions in some Direct Current sub concepts based on the causes which include preconception (P), associative thinking (AT), humanistic thinking (HT), incomplete or wrong reasoning (R), and wrong intuition (WI).

As shown, more than 50% of students suffered misconceptions caused by WI in KF’s 1 Law concept. The WI’s also become the dominant cause for the sub concepts of SC, PC, and S-PC. Misconception occurs in question numbers 6, 9, 10 mainly caused by WI. The cause of P contributes 3 – 20%, the cause of AT contributes 3 – 24%, the cause of HT contributes 20 – 25%, the cause of R contributes 3 – 50%. In the RSC concept, AT is the most dominant cause of misconception, which is more than 20%. Meanwhile in the Current, RSC, Ohm’s Law, PC, S-PC concepts, the cause of HT is 0%. In Ohm’s Law and PC concepts, the cause of AT is 0%, and the last in SP concept, the P causes is 0%. The causes of WI can be overcome by giving events that can be felt directly by students. For example, the physics teacher can invite students to conduct experiments in the laboratory. This is very important for teachers, because if students is only given theoretical knowledge without being followed by empirical experiences such as laboratorium work and activities in the field that can make them feel directly, it will not be easy for the teacher to explain that the knowledge possessed by students it is wrong. Precisely the misconceptions that students have will continue to be embedded in the minds of students (resistant) and difficult to repaired. This method can also be applied to overcome other causes of misconceptions such as P, AT, HT and R.
4. Conclusion
This work reveals that misconceptions indeed occur in Direct Current concepts and the dominant cause is wrong intuition. Having this result, it is recommended for Physics teacher in secondary high school to take a concrete action by involving the students to empirical learning experience.

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