Students conception and perception of simple electrical circuit

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Abstract. This research aims to describe the profile of the students’ conception and perception on the simple electrical circuit. The results of this research suppose to be used as a reference by teachers to use learning models or strategies to improve understanding the physics concept. The research method used is descriptive qualitative. Research subjects are the students of physics education program, Universitas Sebelas Maret, Surakarta, Indonesia (49 students). The results showed that students have alternative conceptions. Their conceptions are (1) a high-voltage wire has an electric current and can cause electric shock, (2) the potential difference and the value of resistance used in a circuit is influenced by electric current, (3) the value of resistance of a lamp is proportional to the filament thickness, (4) the amount of electric current that coming out from the positive pole battery is the same for all type of circuit, in series or parallel (battery is constant current sources), (5) the current at any resistor in the series circuit is influenced by the resistor used, (6) the resistor consume the current through it. This incorrect conception can cause misconceptions.

Keywords: Conception, Perception, Simple Electrical Circuit

1. Introduction

Physics is believed to be hard science, so it is a difficult subject for the students [1,2]. The reasons why the concept of physics is difficult to learn are (1) an abstract concept, (2) complex systems, (3) students’ prior knowledge or experience is limited, (4) an understanding a finite symbol, (5) misconceptions that occur in students [3]. Research on the physics concept understanding is continuously conducted by researchers for a long time. The results of this research suppose to be used as a reference by teachers to use learning models or strategies to improve understanding the physics concept of the student. The research on students' understanding of the simple electrical circuit concept has been conducted by some experts [4, 5, 6, 7, 8, 9, 10, 11]. Some of the research results about electrical concept could be seen in Table 1 below.
Tabel 1. Research result related to electrical concept

| No | Year | Research Results                                                                 |
|----|------|----------------------------------------------------------------------------------|
| 1  | 2004 | The students tend to hold multiple misconceptions, even after instruction using DIRECT instrument [5]. |
| 2  | 2007 | a. Bulb give more light when the number of batteries increase (independent from the type of connection).  
b. Bulb becomes brighter when batteries are connected in parallel.  
c. Batteries are constant current sources.  
d. Current is consumed by circuit component.  
e. Bulb in series always give more brightness. [6] [7] |
| 3  | 2009 | Describe experiences of using the DIRECT to evaluate and analyze the level of conceptual knowledge [4] |
| 4  | 2012 | Students held alternative conception on the open and short circuit concept [9] |
| 5  | 2012 | Teaching with analogy has a significantly positive effect on elimination of misconception [11] |
| 6  | 2014 | Many students still had difficulties with voltage and potential. The most students were unable to link that two concepts [8] |
| 7  | 2014 | The students have some common misconceptions in electrical concept [10] |

From the result of that research, we can conclude that: (1) Students have alternative conception of electric current, potential difference, and simple circuit, (2) Students have some incorrect conception and misconception on the electrical concept. In this research, we have to know the relationship between conception and perceptions that the students have.

Electrical is an important concept in physics because it is applied our daily life. In our house, there are many electrical types of equipment that we often use, i.e. television, lamp, refrigerator, air condition, etc. Those equipment is an arrangement in complex circuit with the voltage source from the power station. The electrical circuit in our house is the more complex system, so the students need to understand the simple circuits first. Electric currents and simple circuits are fundamental concepts that have to be understood by the students in order easier to learn the electrical concept. A simple circuit is a circuit with one or more batteries, lamps, and short wires. To learn the simple circuit, the students need to understand electric current, voltage, and resistance concept. For the ohmic material, current, voltage, and resistance are described by Ohm’s law. And so the students need to understand about the open circuit. At the open circuit, the current is zero.

The students’ concept understanding is influenced by the initial concept, their perception on the concept, and the deepening of accepted concepts. Conception is the initial information that students have, before the learning activities. Perception is the basic for building knowledge. If the student's perception is incorrect, it can cause a misconception [12]. Perception occurs when students receive information, and that information will be processed in the brain based on students' knowledge [13]. The student’s perceptions are important to building knowledge. It can cause incorrect conception [14]. So we can conclude that if the concepts and perceptions that students have is incorrect, it will cause incorrect conception and even misconception. So it is necessary to choose the right learning model or strategies in deepening the concepts. By knowing the conceptions and perceptions that students have, teachers can choose the right method to improve learning outcomes [14].

Student conceptions can be caused by factors, (1) the environment, (2) learning resources (3) experiences [15]. Conceptual knowledge is built on the experience and contextual knowledge (from the environment) in building intuition [16]. The sources of learning are the books and teachers also the learning process of deepening the concept understanding.

Electrical is an abstract concept. The students will have difficulty understanding simple electrical circuit because of their finite experience about electricity. This issue reinforces the researcher's assumption to conduct research on students' conceptions and perceptions on simple electrical circuit. The research aims to describe the profile of the students' conceptions and perceptions of simple,
electric circuit, so the teachers can choose learning strategies or models to improve concept understanding.

2. Methodology
The research method used is descriptive qualitative. Research subjects are the students of physics education program, Universitas Sebelas Maret, Surakarta, Indonesia, as many as 49 students. Data were collected using conceptual tests of simple electrical circuits accompanied by the students’ argumentation of their answer and interview.

3. Results and Discussion
Conceptual tests are given to the 2nd students of physics education program, who will take electrical magnetic (basic physics II) course. This conceptual test is done to know the students’ conception and perception of simple electrical circuit before the learning activities. However, the students have understood this concept when they were studying in high school. The conceptual test of the simple electrical circuit consists of concepts (1) the requirements of electric current, (2) current, resistance, and voltage in Ohm’s law, (3) the factors that affect the value of resistance, (4) series and parallel circuit.

The students’ conception and perception profile are described in Table 2. The percentage of students’ conceptions is presented in Table 3.

Table 2. Profile of the Students' Conception and Perception

| Correct concept                                                                 | Incorrect concept                                                                 | Students’ Perception                                                                 |
|--------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| An electrical wire have the same voltage at any point along the wire so it does not have an electric current and does not cause electric shock | 1. A high-voltage wire has an electrical current                                  | 1. A high-voltage wire has a potential difference                                   |
| 2. A high-voltage wire, can cause electric shock                               |                                                                                 | 2. Conductor who has a voltage, it also has electric current in according Ohm's law V = IR |
| 1. The potential difference in a circuit is not influenced by the electric current, but it’s influenced by the potential difference between the positive and negative poles of the voltage source. | 1. The potential difference in a circuit is influenced by electric current. If the circuit is open, there is no electric current; then there is no potential difference. | According to Ohm's law V = IR, if I = 0, then V = 0, and R = 0. An open circuit has no current, so the potential difference and the resistance in the circuit are zero |
| 2. The value of resistance of a material not influenced by electric current, but is influenced by the type of conductor (material’s resistivity), conductor length and cross-sectional area. | 2. The value of resistance used in the circuit is influenced by electric current. If the circuit is open, there is no electric current; then there is no resistance. |                                                                                     |
| The value of resistance is inversely proportional to the cross-sectional area (the thickness of the lamp filament), so the lamp with thick filament will be brighter. | The value of resistance of a lamp is proportional to the filament thickness. | The lamp with thick filament will have bigger resistance and lighter than the thin filament |
| The amount of electric current that coming out from the positive pole of a circuit is determined by the arrangement of the circuit. | The amount of electric current that coming out of the positive pole is the same for all circuit, in series or parallel circuit. | The amount of electric current coming out from the positive pole of a circuit is the same for all circuits because it has not yet entered a resistors or junction |

Table 3. Percentage of Students’ Conceptions

| Conception                                                                 | Percentage |
|--------------------------------------------------------------------------|------------|
| A high-voltage wire has an electrical current                            | 80%        |
| A high-voltage wire, can cause electric shock                            | 20%        |
| Conductor who has a voltage, it also has electric current in according Ohm's law V = IR | 40%        |
| The potential difference in a circuit is influenced by electric current. If the circuit is open, there is no electric current; then there is no potential difference. | 60%        |
| The potential difference in a circuit is not influenced by the electric current, but it’s influenced by the potential difference between the positive and negative poles of the voltage source. | 40%        |
| The value of resistance of a material not influenced by electric current, but is influenced by the type of conductor (material’s resistivity), conductor length and cross-sectional area. | 60%        |
1. At any points on the series circuit, it has a same value of the current.
2. The resistor does not consume the current in a circuit.

1. At any points on the series circuit, it has a different value of the current, and it’s influenced by the resistor used.
2. The resistor does consume the current in a circuit.

1. The current in the series circuit is influenced by the resistor used. The difference value of the resistor affects the current used by that resistor.
2. The resistor consumes the current through it, so that the current passing through the resistor, it will be decreased.

| Table 3. Percentage of Students’ Conception |
|--------------------------------------------|
| Students’ Conception                        | Percentage |
| A high-voltage wire has the same voltage at any point along the wire |
| No conception                              | 2.04%      |
| Incorrect conception                       | 42.86%     |
| Correct conception                         | 55.1%      |
| The potential difference and the resistance in a circuit are not influenced by the electric current |
| No conception                              | 4.08%      |
| Incorrect conception                       | 93.88%     |
| Correct conception                         | 2.04%      |
| Resistance is inversely proportional to the thickness of the lamp filament (cross-sectional area) |
| No conception                              | 2.04%      |
| Incorrect conception                       | 53.06%     |
| Correct conception                         | 44.9%      |
| The amount of electric current that was coming out from the positive pole of battery in a circuit is determined by the arrangement of the resistors in circuit |
| No conception                              | 12.24%     |
| Incorrect conception                       | 73.47%     |
| Correct conception                         | 14.29%     |
| The electric current of series and parallel circuit |
| No conception                              | 4.08%      |
| Incorrect conception                       | 64.29%     |
| Correct conception                         | 31.63%     |

Based on Table 2, it can be said that the students have the incorrect conception of the simple electrical circuit. The students’ conceptions are rated by their answers and argumentations of the problems.

3.1. The requirements of electric current

The problem that was given in this case, students’ conception and perception is presented below.

Case 1:
A bird that flew suddenly hopped on a peeling wire and both of it’s legs touch that wire. What will happen to the bird?
A. Bird will be shock because the high-voltage wire
B. Bird will be shock because there is a potential difference on both of bird’s legs
C. Bird will be shock because there is a current on the wire
D. Bird will not be shock because there is no potential difference on both of bird’s legs
E. Bird will not be shock because the electric current in the circuit is small.

27 students choose the correct answer (d) and the true conception. 21 students had incorrect conceptions, one student choose answer (a), 19 students choose answer (b), 1 student choose answer (c).
One student did not choose an answer.
The perception of students that if the wire has high-voltage, then the wire has a current and can cause electric shock.

The student’ argumentation of the case 1 is presented in figure 1.

"because it’s peeling wire, so it has a potential difference at both of bird legs."

"because the peeling wire hasn’t isolator, so electric current occur and cause potential difference on bird legs."

"An electric current can cause wire has voltage, V~1, a higher current cause higher voltage. Bird alight on the peeling wire will get electric shock."

Figure 1. The students’ perception of the electric current

Based on figure 1, there is two information. First, students have the perception that the peeling wire will has a potential difference and can cause electric shock. Another perception indicates that the wire has a current that causes a potential difference. The correct concept is a wire with the high-voltage, has not currents because at any point as long as the wire has the same voltage. Electric current may occur if a circuit has the potential difference at two points. Both of bird legs in case 1 are on the same wire that has a same potential difference, so the bird does not get an electric shock. Electrical shock occurs when there is a potential difference on one part of the body with another part that causes an electric current [17].

The result of interview shows that the students can mention the condition of electric current, that is the potential difference and closed circuit. The students’ perceptions in this case are due to the experience that they have. When we were touching a high-voltage wire, we can get an electric shock. This students’ perception can cause incorrect conception. This result is consistant with the other research result which suggest that the concepts of the students and his or her cognitive processes influence what he or she sees [18].

3.2. Current, resistance, and voltage in Ohm law
The problem that was given in this case, students’ conception and perception is presented below:

Case 2:

The simple circuit on the side consists of a battery with a voltage V and a lamp with a resistance R. When the switch is open, the following correct statement based on the figure is...

i. The bulb is not light up because there is no current in the circuit

ii. The potential difference between point A and B is zero because there is no current in the circuit

iii. The potential difference between point A and B is V because the potential difference in the circuit is not influenced by the electric current.

iv. The lamp has no resistance because there is no current in the circuit.

v. The lamp has a resistance of R since the value of the resistance is not influenced by the electric current.
Only one student chose the correct answer (c) and given the correct conception. 46 students had an incorrect conception, 31 students choose answers (a), one student choose answer (b), 13 students choose answer (d), and one student choose answer (e). Two students did not choose an answer.

The perception of students about the open circuit is that there is no current, there is no resistance, and therefore there is also no voltage difference. According to Ohm's law \( V = IR \), if \( I = 0 \), then \( V = 0 \), and \( R = 0 \).

The student’s argumentation of the case 2 is presented in figure 2.

"since the switch is open, no current in the circuit, so there is no potential difference. The lamp resistance is not influenced by electric current."

"i. There is no current at opened circuit, so there is no potential difference, and the lamp is off (true).
ii. True, because \( V = 0 \). \( V = IR \), so \( V = 0 \), \( R = 0 \)
iii. False, because the potential difference is influenced by current \( V = IR \)
iv. True, because the resistance is influenced by current, \( R = \frac{V}{I} \), \( I = 0 \), so there is no resistance
v. False, because the resistance is influenced by current, \( R = \frac{V}{I} \)."

Figure 2. The students’ perception of the Ohm's law

Based on the student’s argumentation who have incorrect conceptions in figure 2, there are two groups of the students with different perceptions. That is, the students that assume, since the electric current is zero, the potential difference is zero, but the resistance is constant, and the other students give the argument since the electric current is zero, then the potential difference and the resistance are also zero.

There are the results of the interview with the students:

- Researcher: Explain your answer in this case!
- Student: The circuit is open, so there is no electric current in the circuit.
- Researcher: What about the potential difference and the obstacles?
- Student: By Ohm's law, if the electric current is zero, then the potential difference and the resistance is also zero.

From the student’s argumentations and interview, it is known that these incorrect perception because they assume according to Ohm's law equation, \( R = \frac{V}{I} \). In mathematic language, if one value is zero, it will result in another value is also zero. But in physics language, the current is influenced by potential difference and resistance. So if there is no current, it does not mean there is no potential difference and resistance in the circuit. The potential difference of a circuit is influenced by the potential difference between the positive and negative poles of the voltage source (batteries). The resistance of a wire is to be proportional to the length, inversely proportional to its cross-sectional area, and proportionality constant \( \rho \) is called the resistivity of the conducting material. The unit of resistivity is the Ohm-meter (\( \Omega \cdot m \)). It’s described by the equation \( R = \rho \frac{L}{A} \).

The students assume that the electric current is the main concept, which will affect to other quantities, (potential difference and resistance). This is also corresponding with the other research by [9] conducted in Malaysia, that students experience an alternative conception that when there is no current, there is no potential difference and resistance. Understanding mathematic and physics language meaning is necessary to solve this problem. Understanding of mathematic language in the
physics language needs to be emphasized to the students and the mathematical information affects student conception. Integration of the language of mathematics and physics language is necessary to reduce incorrect conception [14]. The incorrect perception of the students in interpreting the mathematical language and the physics language is causing incorrect conceptions.

3.3. Factors that influence the resistance
The problem that was given in this case, the students’ conception and perception is presented below.

Case 3:
Light bulb A and B are identical in all ways, except that bulb A’s filament is thinner than bulb B’s. They are connected to 120 V voltage source, so...

a. A will be the brighter because it has the most resistance
b. B will be the brighter because it has the most resistance
c. A will be the brighter because it has the least resistance
d. B will be the brighter because it has the least resistance
e. A and B will have same brightness

A total of 21 students have chosen the correct answer (d) and the correct conception. 27 other students have incorrect conceptions, one student chooses answer (a), five students choose answer (b), 21 students choose answer (c) One student did not choose an answer.

The perception of students, the resistance of material is proportional to the thickness of the filament. The thin filaments cause the lamp to have a small resistance, so it has more current.

The student’ argumentation of the case 3 are presented in figure 3.

"A’s filament is thinner than B’s, so A’s has the least resistance. A will be brighter."  

Figure 3. The students’ perception of the resistance

Based on the student argumentation, the students have an incorrect conception about the thickness of the filament to the resistance of material. According to the student’s perception, the resistance is proportional to the filament thickness. Conductors that have thin filaments will have the less resistance so it has most current. The true concept holds that the resistance is inversely proportional to the cross-sectional area of the conductor, in this case, it’s expressed by the thickness/thinness of the lamp filament. The results of the interviews show that students can explain the factors that influence the resistance correctly.

This students’ perception is influenced by their intuition in drawing conclusion, about the relationship of resistance and filament thickness. "More concrete conception and intuition are dominant in student's conclusion" [14].

3.4. Series and Parallel Electric Circuit
The problems that were given in this case, the students’ conceptions and perceptions are presented below.

Case 4:
Circuit A and B are consists of 2 identical lamps and a battery. The following correct statement is...

a. The current at point A (circuit A) and point A (circuit B) is the same
b. The current at point B (circuit A) and point B (circuit B) is the same
c. The current at point A (circuit A) is four than the current at point A (circuit B)
d. The current at point A (circuit A) is twice than the current at point A (circuit B)
e. The current at point A (circuit A) is a half than the current at point A (circuit B)

7 students choose the correct answer (c) and the correct conception. As many as 36 other students had incorrect conception, 22 students choose the answer (a), 4 students choose the answer (d), 10 students choose the answer (e)

6 students did not choose the answer.

The perception of students about the current that coming out from the positive pole of the same voltage source, independent from the arrangement of the resistors in the circuit.

Case 5:
A. The correct answer about electric current at the points A, B, C, D, E in the following figure is...
a. A>B>C>D>E
b. A=B>C>D=E
c. A=E>B>C>D
d. A=E>B=C=D
e. A=B=C>D=E

B. The correct answer about electric current at the points A, B, C, D, E in the following figure is...
a. A>B=C>D=E>F
b. A=B=C>D=E=F
c. A=F>B=C>D=E
D. A=F>B=E>D=F
e. A=B=C>D=E =F

For case (5.A) 19 students choose the correct answer (e) and the correct conception. As many as 28 other students had incorrect conception, 5 students choose the answer (a), 25 students choose the answer (b) 2 students did not choose the answer.

For case (5.B) 12 students choose the correct answer (c) and the correct conception. As many as 35 other students had incorrect conception, 25 students choose the answer (b), 10 students choose the answer (d) 2 students did not choose the answer.

The perception of students about the current in the series circuit is it’s influenced by the resistor used. The difference value of the resistor affects the current on that resistor. The resistor consumes the current through it, so that the current passing through the resistor, it will be decreased.

The student’ argumentation of the case 4 is presented in figure 4

"At point A, in circuit A and B, electric current not yet flow in the junction. It means electric current came from the same voltage source and no junction has the same value."

Figure 4. The students’ perception of simple circuit

Based on the student' argumentation in figure 4, the perception of the students about electric current is the current that comes out from the positive pole of the voltage source for the series, or parallel arrangement has the same value. Based on the interview, it is known that the students' perception is due to their concept understanding, the same voltage source will produce the same electric current. In the correct concept, to calculate the current that comes out from the positive pole of the battery is done by calculating the equivalent resistance first. This finding is corresponding with the other research that
the students determine an electric current independent of the circuit type. Batteries are constant current sources [6,7].

The student’ argumentation of the case 5 is presented in figure 5.

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A=B>C>D=E
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“The current at point A = the current at point B because before it passing through the resistor it was still full, after passing the resistor the current at point C decreases and after passing the resistor at point D and E it decreases too (D = E).

\[ A = B > C > D = E \]”

Figure 5. The student’ perception of electric circuit

Based on figure 5, we know that the perception of the students is the resistor consume the electric current through it, so that the current passing through the resistor, it will be decreased. From the interview, the research gets information if the students also assume that the difference value of the resistor affects the current on that resistor. The students forget that the current of the series circuit has a same value. According [6] the misconception of “consumption of the current by circuit components” is frequently encountered in the literature.

So the results showed that the students still have alternative conceptions of current, voltage, and resistance in a simple electrical circuit. Their conceptions are (1) a high-voltage wire has an electric current and can cause electric shock, (2) the potential difference and the value of resistance used in a circuit is influenced by electric current, (3) the value of resistance of a lamp is proportional to the filament thickness, (4) the amount of electric current that coming out from the positive pole battery is the same for all type of circuit, in series or parallel (battery is constant current sources), (5) the current at any resistor in the series circuit is influenced by the resistor used, (6) the resistor consume the current through it, so that the current passing through the resistor, it will be decrease. Incorrect conception is caused by students' perceptions, it’s supposed by (1) experience, (2) the understanding of mathematics language and physics language, (3) the intuition to get the conclusions, and (4) the finite concepts understanding. This incorrect conception can cause to misconceptions if the teachers did not apply appropriate learning strategies/models for the deepening of concepts. The teachers can choose a discovery learning where students do themselves directly an activity to find the concept and supported by the explanation of the teacher to provide the correct concept. Also getting students to solve conceptual problems will help students to solve more complex problems. The presentation of the concept in multirepresentation form will also support the deepening of the concept [2].

4. Conclusion

Based on the results and the discussion, it can be conclude that the students conception of simple circuit is influenced by their perception and supposed by (1) their experience, (2) the understanding of mathematics language and physics language, (3) the intuition to get the conclusions, and (4) the finite concepts understanding. The incorrect concept found in this research are:

1. A high-voltage wire has a potential difference, and it can cause electric shock.
2. Conducting wire has a current that produces voltage and causes an electric shock
3. The potential difference and resistance in a circuit are influenced by electric current. If the circuit is open, there is no electric current; then there are no potential difference and resistance.
4. The thin filament causes the lamp to have less resistance, so it has more current.
5. The current that coming out from the positive pole of the voltage source is constant, independent of the type of circuit arrangement (series or parallel circuits).

6. The resistor consumes the current through it, and the current at any resistor in the series circuit is influenced by the resistor used.

This incorrect conception can lead to misconceptions, so it needs to be overcome by learning involving students to discover their concepts through scientific activities. Conceptual test and presented it in multirepresentation form can also be used to support conceptual understanding.

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References
[1] Handhika J, Cari, Suparmi, Sunarno W. (2015). External Representation to Overcome Misconception in Physics. *International Conference on Mathematics, Science, and Education* (2015) 34-37.

[2] Setyani ND, Cari, Suparmi, Handhika J. (2017) Student’s Concept Ability of Newton’s Law Based on Verbal and Visual Test. *International Journal of Science and Applied Science: Conference Series*, 1(2) p. 162-169

[3] Koba S, Mitchell TC. (2011). Hard-to-Teach Science Concepts: A Framework to Support Learners, Grades 3–5. *NSTA PRESS, 2011*, pp. 5-6

[4] O’Dwyer A. (2009). Prior Understanding of Basic Electrical Circuit Concept by First Year Engineering Students. *All-Ireland Society for Higher Education (AISHE) Conference, NUI Maynooth*.

[5] Engerhardt PV, Beichner RJ. (2004). Students’ Understanding of Direct Current Resistive Electrical Circuits. *Am. J. Phys. 72* (1) 98-115.

[6] Kocukozer H, Kocakulah S. (2008a) Secondary School Students’ Misconceptions about Simple Electric Circuits. *Journal of Turkish Science Education*. 4 (1) 101-115

[7] Kocukozer H, Kocakulah S. (2008b) Effect of simple Circuits Teaching on Conceptual Change in Grade Physics Course. *Journal of Turkish Science Education*. 5 (1) 59-74

[8] Timmermann, D and Kautz, C. (2014). Investigating Student Learning of the Voltage and Potential Concepts in Intruductory Electrical Engineering. *Frontiers in Education Conference (FIE) Proceedings, Madrid*, pp 1-4.

[9] Hussain NH, Latiff LA, Yahaya N. (2012). Alternative Conception about Open and short Circuit Concept. *Procedia – Social and Behavior Science 00 (2012 000-00000)*.

[10] Bilal E, Erol M. (2009). Investigating Students’ Conceptions of Some Electricity Concepts. *Lat. Am. J. Phys. Educ. 3* (2) 193-201.

[11] Ugur G, Dilber R, Senpolar Y, Duzgun B. (2012). The Effects Analogy on Students’ Understanding of Direct Current Circuits and Attitudes toward Physics Lessons. *European Journal of Educational Research*. 1 (2) 2011-223

[12] Goldstone, RL, Medin, LD & Schyns, PG. (1997). *Perceptual Learning: Advances in Research and Theory*. Academic Press. San Diego, California, pp. 1-14.

[13] Slavin, RE. (2006). *Educational psychology*. Pearson Education Inc, USA, pp 201-202
[14] Handhika J, Cari, Suparmi, Sunarno W. (2016). Student Conception and Perception of Newton’s Law. Proceedings of International Seminar on Mathematics, Science, and Computer Science Education. (MSCEIS 2015)

[15] Handhika J, Purwandari, Cari, Suparmi, Sunarno W. (2015). Profil Konsepsi Mahasiswa Pada Materi Kinematika. Prosiding Seminar Nasional Pendidikan Sains. 2015

[16] Lee G & Yi J. (2013). Where Cognitive Conflict arises from?: The Structure of creating cognitive conflict. International Journal of Science and Mathematics Education. 11:601Y623

[17] Thaker, MN, Phadke, BN, Patel, PD. (2013). The Effects of Electrical Hazards. International Journal of Emerging Technology and Advanced Engineering. 3(9). 569-574.

[18] Sternberg, JR and Sternberg, K. (2011). Cognitive Psychology, six edition. Cengage Learning, Canada, Wadsworth, pp. 107-108