Students’ mental model in electric current

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Abstract. Electricity is one of essential topic in learning physics. This topic was studied in elementary until university level. Although electricity was related to our daily activities, but it doesn’t ensure that students have the correct concept. The aim of this research was to investigate and then categorized the students’ mental model. Subject consisted of 59 students of mechanical engineering that studied Physics for Engineering. This study was used a qualitative approach that used in this research is phenomenology. Data were analyzed qualitatively by using pre-test, post-test, and investigation for discovering further information. Three models were reported, showing a pattern which related to individual way of thinking about electric current. The mental model that was discovered in this research are: 1) electric current as a flow; 2) electric current as a source of energy, 3) electric current as a moving charge.

1. Introduction
One of important aspect in learning physics is that students are be able to understand the concept so that they can apply it to explain the natural phenomenon that occurs in daily life. The ability of students to understand the concept of science is demonstrated by the ability to construct and predict a theory [1]. However, students’ construction and prediction about a theory can result in a right or wrong concept. The wrong concept can be caused by mistakes in modeling a phenomenon [1]. Such errors include the inability to physically visualize phenomena and the inability to explain a phenomenon. This leads students to cause errors in concluding a phenomenon that contrary to science concept.

In recent years, researchers and educators have shown an interest in the role of model in teaching science. Model in learning has several functions. Using model can integrate learning that includes content and the process of science [2]. The process of developing and using the model play an important role to lead students to understand and solve science problems [3]. In addition, it can help students to strengthen and develop reasoning skills, analyze, and assess a phenomenon.

The topic of reasoning of a phenomenon is one of the concern topics to researchers. This is due to the emergence of the assumption that students not only understand a concept, but also must be able to reason analogically. Students must be able to explain the mechanism of phenomena causally so they can explain the facts and causes of certain situations [3]. If students have good reasoning skills, then students can think logically to draw conclusions of a phenomenon.

A model that can facilitate students’ reasoning process is mental model. Reasoning constructs are built by mental model [4]. Cognitive scientists describe the mental model as one's own conception [4,5]. Mental models are knowledge structures constructed by individuals to understand and explain experiences [6]. The mental model is a model based on cognitive theory [3]. Cognitive theory explains...
that learning is a change in mental processes and knowledge structures generated by students in interpreting a phenomenon [7].

Mental model is an internal representation. A person's mental model is built on perception, imagination, and understanding [4]. The delivery of a person's mental model uses an external representation. Representation is something that represents, describes or symbolizes objects, concepts or processes [8]. Representation as a way of communicating ideas or concepts externally (spoken language, symbols, images, and combinations) and internal (thinking) [9]. Representation in physics can be used through various ways including verbal, images, graphics and mathematics [10]. However, the external representations that students used are sometimes incompatible with the internal representations they have. Therefore, it is necessary to explore the internal representation (mental model) of the students in depth.

Electricity is one of the topics in Physics for Engineering II course. Electricity have been studied from elementary to college. In addition, the topic is closely related to everyday life. However, it does not guarantee that students have the correct concept of electricity. The topic of electricity is one of the most difficult topics for students to understand. Electric current is one of that studied in electricity. The fundamental reason for the difficulty in studying this topic is the difficulty of visualizing the concept of current, voltage, and resistance [11]. This is because of current, voltage, and resistance cannot be observed directly. In addition, a number of studies have shown that educators have difficulty determining and explaining important concepts because electricity concepts are interconnected with other concepts [12].

In the previous research [1,12,13] were used students from age 14 – 18 years. In this research was focused on the mechanical engineering students because most of them (80%) graduated from vocational school. It means that they have already more experience in practice. This research aims to explore students’ mental models of a concept. The focus of the study topic on this research is about electric current for several reasons as follows: (1) The concepts in electric current is a concept that is closely related to daily life; (2) Electric current are studied at various levels of education from primary education to college; (3) Electric current is one of the most difficult topics for students to understand.

2. Methods
This research used qualitative method. A qualitative approach that used in this research is phenomenology [14]. This study aims to explore and categorize the mental models of students on electric current phenomena. The collecting data are qualitative descriptive, actual explanation of the students’ mental model on the phenomenon of electric current.

This research was conducted at University of Nusantara PGRI Kediri. Students who followed this research are mechanical engineering students in 2016/2017 academic year which follow the course of Physics for Engineering II especially in electricity topic. The sample consists of 59 students. The sample selection was based on heterogeneous student ability. In addition, students had experienced learning about electric current concepts at elementary, junior and senior high schools. Moreover, most of them (80%) graduated from vocational school so they have more experience in practice directly.

3. Results and Discussion
The result of constant comparative analysis to the students’ answer during pre-test and post-test is presented in Table 1. At the pre-test, there are three variations of the students’ mental model of electric current: (1) electric current as a flow; (2) electric current as a source of energy; (3) electric current as a moving charge. At post-test, there are two variations of students’ mental model: (1) electric current as a flow, (2) electric current as a moving charge.
Table 1. Students’ Mental Model in Electric Current

| Answer                                      | Pre-test | Post-test |
|---------------------------------------------|----------|-----------|
| Electric current as a flow (EF)             | 35       | 18        |
| Electric current as a moving charge (EMV)   | 8        | 41        |
| Electric current as a source of energy (ESE)| 16       | 0         |

Changing in the students’ answer from pre-test to post-test is presented with crosstabulation in Table 2. Based on Table 2, the number of students who still had electric current as a flow mental model (EF) during pre-test and post-test is about 17 students (28.8%). This indicates that students still had misconception about electric current. According to the further interview, this students revealed that they still remember “analogy of electric current as a water flow” very clearly. The proportion of students who had electric current as a moving charge mental model (EMC) at post-test increased by 41 students (69.5%) indicated that the student have experienced a correct concept change after learning.

Table 2. Cross-Tabulation of Students’ Answer in Pre-test and Post-test

| Cross-Tabulation | EF          | EMC          | Total       |
|------------------|-------------|--------------|-------------|
| Post-test        | Count       | % of Total   | Count       | % of Total   | Count       | % of Total   |
| EF               | 17          | 28.80%       | 18          | 30.50%       | 35          | 59.30%       |
| % of Total       |            |              |             |              |              |              |
| EMC              | 0           | 0.00%        | 8           | 13.60%       | 8           | 13.60%       |
| % of Total       |            |              |             |              |              |              |
| ESE              | 1           | 1.70%        | 15          | 25.40%       | 16          | 27.10%       |
| % of Total       |            |              |             |              |              |              |
| Total            | 18          | 30.50%       | 41          | 69.50%       | 59          | 100.00%      |

3.1. Electricity as a Flow
This model is categorized by lack of electric current concept. Electric current is described by “something flowing”. Students explained that it is flowing through circuit. Sometimes, they mentioned term of water pressure equals to voltage and pipe equals to resistance. The following are examples of students’ interview results.

I: "What do you think about electric current?"
S: "Electric current is something that flows. Electric current can be analogy to flowing water and the pipe equals to resistance".
I: "Is there something inside the cable so that the current can flow?"
S: "Yes, it is. On the cable there is copper."
I: "If the cable is not connected to the battery, does the electric current keep flowing?"
S: "Yes. Inside the copper there are electrons flowing so that the current can flow even though the cable is not connected to the battery."
I: "So, based on your view, what is flowing in the electric current?"
S: "I’m not sure. Maybe the electrons"

The analogy between the flow of electric current and water has been popular for more than century. That This analogy draws parallels between water pressure and voltage, flow of water and current, and constricted pipes and resistance [15]. In this model, the pump is analogous to the battery.
3.2. Electricity as a Source of Energy

This model is categorized by lack of energy concept. Electric current was described by “something” that we used in every day life. Student refers to “something” to source of energy such as battery, accu, generator, and dynamo. They was explained thay it can be used to create current, so that they can watching television, charging handphone, listening to radio, using iron. In this model, electric current is seen as energy or electricity flowing through the wires in a circuit from both terminals of the battery towards the bulb. The battery is still seen as a reservoir of electricity/energy [12].

I: "What do you think about electric current?"
S: "Electric current is something we often see in daily life. Electric current is important because it is one form of energy. Electric current is used to turn on bulb, iron, television, radio, etc."
I: "What kind of energy do you mean?"
S: "Electrical energy. If there is no electric current it does not create electrical energy."
I: "What do you think the current generated from?"
S: "It depends on the source. It can be produced from water, wind, steam, solar, nuclear.

Based on the result of the interview, student view electric current concept as a kind of energy. They refer this energy to electrical energy. Sometimes, they mentioned kind of source energy such as dynamo, battery, accumulator, and generator. Terms like “energy” and “electricity” were used to designate the material substance flowing in a circuit. The battery was imagined as a passive container that only stores electricity and wears out as its content is used up in the circuit elements [12]. Current travels quickly around the circuit and is used up in the bulb. Subjects holding this model did not describe a circuits’ behavior in terms of internal mechanism and processes.

3.3. Electricity as a Moving Charge

In this model, students held the view that electric current is consists of electric charges in motion. This charges move along the conductor. They also explained that current can move only in a closed circuit. Battery is used to maintain the potential difference.

I: "What do you think about electric current?"
S: "Electric current is something that flows."
I: "What do you mean by something?"
S: "Electric charge. The charge moves along through the wire. In addition, the electric current can be measured with an amperemeter."
I: "How the current keep flowing?"
S: "It is because of the battery. The battery maintain the potential difference between both terminal."

Electric current is the electrical charge that flows in a material due to potential differences [16]. The amount of electric current flowing depends on the amount of charge and the difference in electrical potential. The concept of electric current can be illustrated as in Figure 1.

Figure 1. Electrical charges flow through material surface (Source: Serway & Jewett, 2010)
Figure 1 illustrates the electrical charge across a surface. The direction of the electric charge is perpendicular to the surface area. The moving electric charge can be positive and negative. An electric current is defined as the rate of electrical charge passing through the surface area. Mathematically, an electric current is defined as

\[ I = \frac{\Delta Q}{\Delta t} \]  

Where \( I \) is the electric current, \( Q \) is the electrical charge, and \( t \) is the time. The unit of electric current is C/s or better known as ampere. Determination of electric current direction based on direction of positive charge. The direction of the electric current is opposite to the direction of the electron. This is because the electrons are negatively charged. The phrase "flow of electric current" is an expression that is not right [16].

Electric current is a flow of electric charge, so it is necessary to suppress the capture during the lecture to avoid misconception. If the ends of the conductor wire are connected to form a circuit, then all points in the circuit are at the same electrical voltage. Therefore, the electric field in the circuit becomes zero. This causes the absence of electric charge displacement so that there is no electric current. In the phenomenon of the ends of the wire the conductor is connected to a battery, all points in the circuit are not equal, causing a voltage difference. The battery causes a potential difference between the ends of the circuit and generates an electric field in the wire. The electric field causes the electrons to move to produce an electric current. If a battery is used to generate an electric current on a conductor, then there is a continuous change of chemical energy in the battery that is the energy of motion of electrons into energy in the conductor. This causes the temperature in the conductor to increase. In a simple electrical circuit, energy is transferred from a source such as a battery to a device (lamp, resistor).

This study revealed that there are three students’ mental model in electricity that is: 1) electric current as a flow; 2) electric current as a source of energy; 3) electric current as a moving charge. At post-test, most of students (69.5%) have a correct conception about electric current. However, there are 18 students (30.5%) still have the wrong conception. Based on the analysis of students’ answers during pre-test, interview, and post-test, 18 students still have thought that the electric current is something that flow. This indicates that the student has not gained a learning experience that is capable of changing the correct concept about electric current. Based on the results of interviews, students with misconceptions reveal that the electric current is like "water flow", so the students generalize the concept of electric current as "flow of electricity". Seven of the eighteen students also revealed that their experience when they were in high school showed that teachers were used analogy the concept of electric current such as water flow. Based on observations during lectures, lecturer have not provided confirmation of the flow context of electric current. Therefore, it is important for educators to pay attention to the use of language while teaching. This is in accordance with the results of research which states that one of the difficulties students understand a concept because of the use of ambiguous language [17-21].

4. Conclusion
This aim of the research was to expore students’ mental model in electric current. This study revealed that there are three variations of students’ mental model in electric current that is electric current as a flow, electric current as a source of energy, and electric current as a moving charge. The study revealed misconceptions by students about electric current. Based on their explanations, these misconceptions were “electric current as a flow” and “electric current as a source of energy”. It was clear from the literature that electric current was a difficult concept to understand and it was proved in this study. This suggested teachers and other education practitioners required opportunities to develop their content-specific pedagogical knowledge so it can helps them teach certain concepts appropriately and overcome the issues related to misconceptions.

5. References
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