Students’ conceptions analysis on several electricity concepts

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Abstract. This research is aimed to analyse students’ conceptions on several electricity concept. This is a descriptive research with the subjects of new students of Sebelas Maret University. The numbers of the subject were 279 students that consisted of several departments such as science education, physics education, chemistry education, biology education and mathematics education in the academic year of 2017/2018. The instrument used in this research was the multiple-choice test with arguments. Based on the result of the research and analysis, it can be concluded that most of the students still find misconceptions and do not understand electricity concept on sub-topics such as electric current characteristic in the series and parallel arrangement, the value of capacitor capacitance, the influence of the capacitor charge and discharge towards the loads, and the amount of capacitor series arrangement. For the future research, it is suggested to improve students’ conceptual understanding with appropriate learning method and assessment instrument because electricity is one of physics material that closely related with students’ daily life.

1. Introduction

Students’ conceptions become one of the research focuses on physics education in the last 25 years [1, 2]. The conception of learning is viewed from constructive view in which conception can build understanding than memorizing [3]. Students’ conception might be different because students have differences in processing information and the information sources are not coherent. Conception profile can be used as a reference for the educators before conducting learning process. By knowing students' conception in a learning process, it will extend the teachers' understanding of the best learning method for students [4]. The term of "conception" refers to the belief and personal meaning of students and teachers about the phenomenon of teaching and learning process in high education [5].

Conceptions have some characteristic such as dynamics, not-statics, and not permanent. Students can change their conception and approach from time to time or depends on the contexts [6]. Students’ conception can bring the personal meaning and have different characteristic based on how it is used in teaching and learning process [7]. The description of students’ conception and perception helps the teachers to determine the appropriate learning method to improve the learning result [8]. The researchers of the importance of students’ conceptions have been commonly conducted by the experts. Students’ conceptions and learning result in education are closely related [9]. The same result is also revealed by other researchers. They state that there is a relation between learning conceptions and students’ approach towards their study. Therefore, different conceptions among the students are influenced by two aspects, what to learn and how the learning [10]. Both aspects depend on the teachers’ qualifications. Therefore, it needs to conduct conception analysis to the teacher candidate included the students who continue their study in the education department.
One of the abstract concepts on physics is electricity. Electricity is invisible but it is everywhere in our daily life [11]. There are many models and analogies of electricity used, however, nothing is able to explain all the aspects [12]. The abstract characteristic of electricity causes the students and the people who have finished the physics course to have wrong ideas about it and the electricity arrangement [11]. Electricity concept is one of basic physics concepts that are important and cannot be separated at each level of education. In elementary school, students get the experience on simple electricity arrangement. On the next level, electricity is taught systematically and it belongs to the important theme [13]. Many students find conceptual difficulty continuously by analyzing simple electricity arrangement. The difficulty is that they cannot apply the formal concept related to electric current, voltage and load. As a result, students have a less conceptual model and cannot make any reasons about electricity arrangement qualitatively [14]. Students’ conception on science topic can improve students’ learning achievement and thinking skill. The focus of this research is students’ conceptions on electricity. The result of this research is expected to be used as a reference to the future researches to determine the appropriate learning method in improving students’ conception on electricity concepts as well as other science concepts.

2. Methods
This research belongs to descriptive research with the aim to describe students’ conception on electricity material. The subjects of the research were new students of mathematics and science education of Sebelas Maret University. The numbers of the subject were 279 students that consisted of several departments such as science education, physics education, chemistry education, biology education and mathematics education in the academic year of 2017/2018. Students were asked to choose the answer of the multiple-choice and wrote its reason of choosing the answer. Through the answers, it was known the students’ conceptions on electricity material. Data of the research was obtained using test instrument of multiple-choice with open-ended arguments. The instruments used consisted of 24 questions with several sub-topics as described in Table 1.

| Sub-topic                                                                 | Number of question |
|---------------------------------------------------------------------------|--------------------|
| Electric current characteristic in series and parallel arrangement         | 1, 2, 4, 6, 8      |
| Voltage characteristic in series and parallel arrangement                 | 3, 5, 7            |
| Influence of capacitor condition on closed arrangement                    | 9, 10, 11, 12      |
| Value of capacitor capacitance                                           | 13, 14, 15         |
| Influence of charge and discharge capacitor towards the loads             | 16, 17, 18         |
| Quantity in capacitor series arrangement                                  | 19, 20, 21         |
| Quantity in capacitor parallel arrangement                                | 22, 23, 24         |

3. Results and Discussion
The result of the research was obtained from students’ answers when they did the conceptual questions using the multiple-choice instrument with arguments. The instruments consisted of several sub-topics on electricity material described in table 1. Students’ conceptions on several electricity concepts showed at Table 2.

Table 2 shows the summary of students’ conceptions on several sub-topics in electricity. Students’ conceptions are obtained through arguments or reasons on students’ answer. Misconceptions were mostly found at sub-topics 1, 4, 5 and 6. Many misconceptions need to be corrected because it will always emerge on other electricity concepts.

Sub-topic 1 contains characteristic of the electric current in series and parallel arrangement. This concept is one of the basic concepts on electricity material learned since at junior high school. Therefore, the percentage scale of misconception on sub-topic is because the students’ basic knowledge is still wrong and they only memorize and not understand the concept. The students’ difficulty in answering and parallel arrangement is also revealed by the former researchers. They state that students find
conceptual fault continuously when they analyze by using a simple arrangement such as finding difficulty in applying a concept of electrical electric current, voltage and identifying series and parallel arrangement [14]. One of the students' answers with misconceptions on sub-topic 1 shows at Figure 1.

Table 2. Students’ conception on several electricity concept

| Sub-topics | Students’ conceptions |
|------------|-----------------------|
| Electric current characteristic in series and parallel arrangement | 1. Points that are nearer with the positive pole of voltage source have higher electric current than the farther points.  
2. After passing lamp or loads, electric current is lower.  
3. In series arrangement, the low load has low electric current.  
4. In a series arrangement with identical load, it flows the equal electric current on each load.  
5. In a series arrangement with the different load, it flows the equal electric current on each load.  
6. At any node, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node.  
7. In the parallel arrangement with identical load, the electric current is divided the equal.  
8. In the parallel arrangement with identical load, if the voltage source is nearer with the load, the electric current will be higher. |
| Voltage characteristic in series and parallel arrangement | 1. In series and parallel arrangement, if the load is farther from the battery, the voltage will be lower.  
2. In series arrangement, the low loads have high voltage.  
3. In series arrangement, the low loads have low voltage.  
4. In the parallel arrangement, the high loads have low voltage.  
5. In the parallel arrangement, the high loads have high voltage.  
6. In the parallel arrangement, the voltage on each load is equal. |
| Influence of capacitor condition on the close arrangement | 1. When charging and discharging the capacitor, there is no flowing electric current.  
2. The electric current will flow after the capacitor is full.  
3. When charging and discharging the capacitor, there is flowing electric current. |
| Value of capacitor capacitance | 1. Dielectric materials cause one capacitor plate to load (negative charges).  
2. The plate that is connected to positive pole of battery contains negative charges and vice versa.  
3. The plate that is connected to negative pole of battery contains positive charges and vice versa.  
4. The addition of dielectric does not influence the value of capacitor capacitance.  
5. The voltage that is connected to capacitor and loads influences the value of capacitor capacitance. |
| Influence of capacitor charge and discharge towards the loads | 1. If the loads are nearer with the positive pole capacitor, the electric current is higher.  
2. If the loads are nearer with the battery, the electric current is higher. |
| Quantity in capacitor series arrangement | 1. If the capacitor is farther from positive pole battery, the voltage is lower.  
2. Energy saved in a capacitor is equal to the total energy.  
3. Loads on each capacitor are equal as the total loads. |
| Quantity in capacitor parallel arrangement | 1. The number of total loads is divided into each capacitor.  
2. The number of loads on each capacitor is equal to the total loads.  
3. No matter how much the value of capacitor capacitance, the capacitor voltage is equal to the total voltage. |
Based on Figure 1, students suppose that the farther the position’s lamp with energy source or battery, the value of strong electric current is also higher. Students have not been able to apply law concept 1 of Kirchhoff in that questions. Misconception in this concept is also revealed by the former researchers. They state that many students believe that the number of electric current in arrangement component depends on things that come first [15].

Misconception in another sub-topic is at sub-topic 4. It is about the value of capacitor capacitance. Capacitance is a new term for students and becomes one of the new sub-topics in senior high school. Example of question and answer with misconceptions showed at Figure 2.

![Figure 1](image1.png)

**Figure 1.** Example of a question and students’ answer with conceptions at sub-topic 1.

Based on Figure 2, students still find difficult to determine the influence of capacitance and loads on plate capacitor when the electric switch is turned on. Students suppose that if the electric switch is on, it will cause the electric current flows from positive to negative pole battery. Therefore, the electron is left on plate A, while plate B becomes positive plate. Students’ misconception in this topic is caused by students who think that capacitor plate is functioned to save loads, not energy. Misconception in this topic is same as the result of the former researchers. The students suppose that capacitor (battery and capacitor) is filled with the load that flows through one part arrangement [16].

![Figure 2](image2.png)

**Figure 2.** Example of question and answer with misconceptions is at sub-topic 4.
At sub-topic 5, students also have the misconception. This sub-topic contains the influence of capacitor charge and discharges towards the loads. In this topic, students are asked to determine the condition of light when the capacitor is being charged and discharged. The term of charge and discharge becomes the new term for students who find misconception in this concept. Many students do not understand the condition when the capacitor is filled and many experiments are conducted to observe the lamp during charging and discharging the capacitor [15]. Example of students’ question and answer with misconceptions in this sub-topic showed at figure 3.

Figure 3 is an example of students’ question and answer concerning the influence of charge and discharge towards the loads with misconceptions. In this question, students consider that the further of the positive pole battery will make the lamp to be brighter because there is no load and students ignore the characteristic of an arrangement. Moreover, students consider that the electric current is used to fill the capacitor until full before it is used to turn on the lamp. It is same as the former research that students think that the plates connected to another positive terminal must be filled because the electric current is firstly filled. Besides that, students also consider that the lamp before capacitor has higher electric current so that the light is brighter than the lamp after capacitor [17].

Another sub-topic with misconception is at sub-topic 6 that discusses the quantity of capacitor series arrangement. In this sub-topic, students are asked to determine the charges, energy, and a voltage on each capacitor on a series arrangement. Students have not understood the characteristic of series and parallel arrangement of a capacitor. They have not been able to differentiate the characteristic of an arrangement on resistor and capacitor. Example of students’ questions and answers at this sub-topic showed at Figure 4.
Pay attention to the electrical arrangement below!

C₁ = C₂ = C₃ = C

How is the voltage on each capacitor?
A. V₁ = V₂ = V₃ = V
B. V₁ = V₂ = V₃ = 3V
C. V₁ = V₂ = V₃ = \frac{1}{\sqrt{3}} V
D. V₁ < V₂ < V₃
E. V₁ > V₂ > V₃

Example of students’ answer

A B C D (E)

Alasan:

Perbanding terbakal dari C, tegangan terbesar pada kapasitor terdekat.

“It is contrary with C, the highest voltage is the nearest capacitor”

Figure 4. Example of students’ questions and answers with misconception at sub-topic 6.

Figure 4 shows the example of students’ questions and answers at sub-topic 6. The question asks about the capacitor series arrangement with an equal capacitance value of each capacitor. Students are asked to determine the voltage on each capacitor. Students still find difficult to differentiate the characteristic of electric current and voltage on resistor and capacitor arrangement. At the example of students’ answer, students consider that the voltage is contrary with the capacitor. The voltage depends on the distance and the capacitor position. Therefore, if the capacitor is nearer (short distance), the voltage is also higher.

Electricity is one of the materials in physics that closely related to daily life. However, the conceptual understanding about electricity still becomes the challenge to the students in various level of school. Some researches over the world show that students still find difficulty and misunderstanding after systematical teaching [14, 18, 19, 20]. The common difficulty is about the disability to connect theoretical electricity model to the real arrangement, the incomplete understanding of a basic electrical concept, and the disability to understand the characteristic of electrical arrangement [14, 20, 21]. The difficulty and misunderstanding are still resistant towards the change [19]. The other results of the research also found that in the world, it is often to find students who can remember the adequate knowledge about electricity in senior high school [22].

4. Conclusion

Based on the result of the research and analysis, it can be concluded that most of the students still find misconceptions and do not understand electricity concept on sub-topics such as electric current characteristic in the series and parallel arrangement, the value of capacitor capacitance, the influence of the capacitor charge and discharge towards the loads, and the amount of capacitor series arrangement. For the future research, it is suggested to improve students’ conceptual understanding with appropriate learning method and assessment instrument because electricity is one of physics material that closely related with students’ daily life.

5. References

[1] Pfundt H and Duit R 1988 Bibliography. Students' alternative frameworks and science education (West Germany : Kiel Univ)
[2] Pardhan H and Bano Y 2001 Science teachers' alternate conceptions about direct-currents Int. J. Sci. Educ. 23 301-318
[3] Abdullah S and Abbas M 2006 The effects of inquiry-based computer simulation with cooperative
learning on scientific thinking and conceptual understanding *Malaysian online journal of Instructional Technology* **3** 2 1-16

[4] Kennedy C 2010 *IJAS* **3** 111-122

[5] Devlin M 2006 *Challenging accepted wisdom about conceptions of teaching in academic development* *IJTLHE* **18** 112-119

[6] Kember D and Kwan K P 2000 2002 Lecturers’ approaches to teaching and their relationship to conceptions of good teaching *Instr. Sci.* **28** 469-490

[7] Entwistle N J and Walker P 2002 Strategic alertness and expanded awareness within sophisticated conceptions of teaching (Dordrecht : Springer)

[8] Handhika J, Cari, Suparmi, Sunarno W 2016 Student conception and perception of Newton’s law *AIP Conference Proceedings* **1708** 070005

[9] E. J Van Rossum and Simone M Schenk 1984 The relationship between learning conception, study strategy and learning outcome *Educ. Psychol.* **54** 73–83

[10] Marton F, Dall’Alba, G and Beaty E 1993 Conceptions of learning *Int. J. Educ. Res.* **13** 277-300

[11] Kollöffel B and de Jong T 2013 Conceptual understanding of electrical circuits in secondary vocational engineering education: Combining traditional instruction with inquiry learning in a virtual lab *Journal of engineering education* **102** 375–393

[12] Frederiksen J R, White B Y, and Gutwill, J 1999 Dynamic mental models in learning science: The importance of constructing derivational linkages among models *Journal of research in science teaching* **36** 7 806-836

[13] Toulia E H, Talbia M and Radida M 2015 *Procedia Soc. Behav. Sci.* **197** 278 – 280

[14] McDermott L C and Shaffer P S 1992 Research as a guide for curriculum development: An example from introductory electricity. Part II: Design of instructional strategies *Am. J. Phys.* **60** 994-1003

[15] Wainwright C L 2007 *Toward Learning and understanding electricity: Challenging persistent misconceptions* (Science Education: Pacific University)

[16] Thacker B A, Daniel U and Boys D 1999 Macroscopic phenomena and microscopic processes: Student understanding of transients in direct current electric circuits *Phys. Educ. Res.* **67** 25-31

[17] Bilal E and Erol M 2009 Investigating students' conceptions of some electricity concepts *Lat. Am. J. Phys. Educ.* **3** 193-201

[18] Fredette N and Lockhead J 1980 Student Conceptions of Simple Circuits *Phys. Teach.* **18** 3 194-198

[19] Shipstone D M 1984 A study of children's understanding of electricity in simple DC circuits *Eur. J. Sci. Educ.* **6** 185-198

[20] Duit R and von Rhoneck C 1998 Learning and understanding key concepts of electricity *Connecting research in physics education with teacher education*. International commission on physics education 1-6

[21] Ronen M and Eliahu M 2000 Simulation-A bridge between theory and reality: The case of electric circuits *J. Comput. Assist. Lear.* **16** 14-26

[22] Psillos D 1998 Teaching introductory electricity *International commission on physics education*

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