Unveiling students’ misconceptions through computer simulation-based PDEODE learning strategy on dynamic electricity

Abstract. Several misconceptions occur in the students’ conceptions especially in the dynamic electricity concept. Misconceptions is a student’s understanding which are un-appropriate with the scientific conceptions. Furthermore, if the students’ misconceptions have not been unveiled, they could be a problem in the next learning process. As a consequence, misconceptions are important faced to be changed so that students hold true conceptual understanding. In term of unveiling students’ misconceptions, we highly need the learning process which is able to make students could understand the concept themselves. Researchers have been utilised computer simulation-based PDEODE (Predict, Discuss, Explain, Observe, Discuss and Explain) learning strategy. The purpose of the research is to unveil students’ misconceptions through computer simulation-based PDEODE learning strategy on dynamic electricity. This research has been implemented using quasi experiment with pre-test and post-test group design. The sample who are involved in this research are consisted of 27 high school’s students in the one of Bandung Barat regency and they are taken by purposive sampling technique. The research result state that the frequency of students’ misconceptions decreases 0.21 in the low category. It can be concluded that the computer simulation-based PDEODE is able to unveil students’ misconceptions on dynamic electricity.

1. Introduction
Currently researchers have already been developing a learning strategy about Computer Simulation-Based Predict, Discuss, Explain, Observe, Discuss and Explain (CS-PDEODE). A learning strategy of CS-PDEODE is more emphasis on meaningful learning of Physics to re-constructing the physics concepts, especially the concept of dynamic electricity. The concepts of dynamic electricity may include concepts: electric current, voltage, electric power, resistance, serial and parallel circuit with battery and so on. The dynamic electricity concept is guided by the concept of the electric current [1]. Case in point
when discussing about the concept of electric current (I) [1], the researchers emphasize the relationship between electric current with the resistor and electrical voltage through the equation (1):

\[ V = I \cdot R \]  \hspace{1cm} (1)

Therefore, electrical voltage, electric current and resistance are physical quantities highly associated with dynamic electricity. The concept of electric current is the basis of thinking for dynamic electrical concept. Another example, the concept of electric current takes an immense role in the concept of electric power (P). The concept of electric power is closely related to the concept of electric current and electrical voltage as seen in equation (2).

\[ P = V \cdot I \]  \hspace{1cm} (2)

Furthermore, the concept of power is closely related to the concept of energy in electricity. Once the central role of the concept of electric current makes this concept should be supported by a virtuous understanding of the concept as well. For instance, students who understand the concept of electric current well will be able to master the dynamic electrical concept well and easily. Conversely, if students experience difficulties and experience misconceptions related to electrical currents, then these students are able to experience foremost problems in learning the dynamic electrical concept.

Miscellaneous misconceptions related to the concept of electric current include: 1) students assume that an electric current passing through an electrical resistance will decrease as the current is "eaten" by the resistance; 2) students assume that the electric current in series and parallel circuits has the same amount of current; 3) the student assumes that the voltage in the series circuit is equal to the total electric voltage; and so on [2-4]. Some examples of such misconceptions clearly show that the role of electric current, electric potential in electrical circuits is very important and electrical currents become the focus of its own to be fully understood.

In order to unveil the misconceptions that occur in students related to the concept of dynamic electricity, researchers have already completed development through CS-PDEODE. The CS-PDEODE has been developed with the aim to unveil misconception that occur in students on dynamic electricity. Misconception is a students’ wrong understanding regarding to the concepts simultaneously and must also be changed using simultaneous learning strategies, one of which is CS-PDEODE. Because CS-PDEODE contains conflict cognitive strategies that can shake misconceptions from students into a belief in a true concept (scientific conception). The process of altering the conception that occurs is the process of reconstructing the conception of students experiencing misconceptions using the CS-PDEODE learning strategy (a combination of hands-on activity/doing experiment and computer simulations for abstract concepts).

The simulations used in this research are PhET simulation: 1) circuit-construction-kit-ac-virtual-lab_in and 2) PhET simulation battery-resistor-circuit_en. The simulation and animation display is in Figure 1 dan Figure 2.

![Figure 1. Simulation view of PhET Circuit Construction kit.](image-url)
This simulation can be used as a virtual laboratory. Designing simple practical electric circuits, as well as measuring the strength of current and potential difference by using ammeter and voltmeter can be done in this simulation. Some electrical components can be used and designed by dragging the image, and can be changed the value of the amount by right click. The advantages of this simulation, among others, after the electrical circuit is completed, the circuit can be stored in the save menu. In addition to the display of lights, can be seen the brightness of the lamp by analogy the number of lines around the lamp. In this simulation there is still a weakness, namely the existence of misconception in microscopic review. Misconceptions lie in the view of electron motion flowing over the wires.

Figure 2. PhET simulation view of battery resistor circuit (1.04).

This simulation is an animation of the pumping potential. Electrons basically move from negative to positive, but in electron batteries can move from positive to negative. The ability of the battery can change the motion of electrons due to the presence of pumping potential. This simulation can illustrate the existence of pumping potential in the battery. But in its depiction there are weaknesses, pumping potential is compared with the elf in the battery that removes the electrons. While the pumping potential should be the battery is the way the battery works chemically.

In the PDEODE learning strategy, computer simulations are used in the phase II Explanation stage. The use of simulations to shape abstract concepts and reinforce students' conceptions of concepts derived from experiments. The learning of electricity necessitates adequate associate experiments to be well described. However, some experiments not being optimal, impracticable, insufficient, and students usually do not have much lack of restrictions to exercise [5]. Therefore, the researchers conducted this study with the aim to change the conception of students who experience misconception, not understand the concept, and experiencing a partial conception into the understanding of the whole concept as well as understanding according to the understanding of scientists.

2. Methods
The research method used in the study of time using quasi-experimental research with test instrument in the form of four-tier test. For analysis of data used using rubric and codification developed by Samsudin et al. [6-9] with the codification of SU, PC, NU, MC and UC stands for Sound Understanding, Partial Conceptions, Not Understanding, Misconceptions and Un-code-able. In the end of methods, we are discussing about learning activity by using CS-PDEODE. In the end of methods, we are discussing about learning activity by using CS-PDEODE.

2.1. Participant
Participants in this study were students of one of the high school boarding in West Bandung regency which amounted to 27 students. Participants are students who have not studied dynamic electrical
materials during high school and high school has a science laboratory and multimedia facilities adequate and possible to facilitate researchers in conducting research. In addition, the underlying researchers chose the participants were the licensing schools that became the location of the study. Research subjects were chosen using purposive sampling that is the technique of determining the sample with certain consideration [10].

2.2. Research Design
This research is a quantitative research using quasi method of experiment. This is done because it is not possible to control the factors that may affect the results of research. This research uses one-group pre-test-post-test design. Thompson & Panacek [10] considers that this treatment is done because the sample is not randomly chosen and the absence of a control class.

2.3. Instrument Test
Instrument is a measuring tool or facility used by researchers in collecting data to measure the variables studied instruments used in this study is Four Tier Test [11-14] to measure student misconception in the form of pre-test and post-test. The test is a test to diagnose student misconceptions, a series of multiple choice questions with semi closed answers. The test is given as an initial test before the lesson (pre-test) and at the end after the learning is completed (post-test). Example four-tier test as shown in Figure 3.

![Figure 3. An example of four-tier test instrument on battery circuit.](image)

2.4. Data Analysis
Student conception calculations are performed manually based on a combination of answers to the Four Tier Test. The analysis of the combination of answers to the Four Tier Test used in this study has been presented in Table 2.1. Combination Analysis Technique Answers on Four Tier Test. Based on the number of students experiencing misconceptions, to make the percentage used the following equation.

\[
\% = \frac{\sum SM}{\sum SS} \times 100
\]  

(3)

Notes:
\( \sum SM \) = The number of students experiencing misconceptions on each question
\( \sum SS \) = the number of students multiplied by the number of questions
3. Results and Discussion
The following are some analyses of the effect of computer simulations on concept enhancement, reduction of misconception, and decrease in the category of not understood concepts are presented in Table 1.

Table 1. Results of student concept analysis of PDEODE learning strategy with computer simulation.

| Sub-concept | Results of Pre-test | Learning with Computer Simulation / Animation | Results of Post-test |
|-------------|---------------------|-----------------------------------------------|---------------------|
| Potential difference in open circuit | None of the students answered this question correctly, 15 people experienced misconceptions. Only one child understands the concept while the other 20 have misconception, 9 partially and 3 Un-code-able. | The biggest concept improvement lies in the concept of a potential difference in an open circuit. Students understand that in open circuits the potential difference at the ends of the battery is not zero but in accordance with the potential difference given the power source is a potential difference at the ends of electrical components equal to "zero". In learning the students are facilitated for observation by practicum and through computer simulation. | Students who initially do not understand the concept, 22% of the number of students to understand the concept. Although there are still some students who experience misconceptions, but there is evidence of an increased understanding of concepts. |
| Circuit | None of the students understood the concept, 20 people suffered misconceptions, 5 partial and 2 Un-code-able people. | An increase in other conceptual concepts on problem 3 about current and potential difference. In learning the students are facilitated for observation by practicum and through computer simulation. Here's an example of virtual simulation observations on improving the concept's understanding. | 7% of the number of students became conceptual. This results in an increased understanding of concepts and the reduction of misconceptions. |
| Current in series-parallel circuit | A total of 12 students have understood the concept, but still about 30% of students have not understood the concept and 20% chance of experiencing misconception | Improvement in understanding the concept, the reduction of other misconceptions which one of them influenced by learning by computer simulation that is at number 2 about electric current in series of lamp series. | Students who understand about 7% concept. It proves that there is a reduction of misconception and not understanding concept. |

Based on the analysis of Table 1, it was found out that the learning of PDEODE with the help of computer simulation can improve the students’ concept comprehension and the reduction of misconception, but there are still students having the chance to experience Un-code-able and partial understanding [6, 15-20]. Although in the learning has done observation phase with worksheet’s guidance, but there are still some students who do not understand when analysing the large potential difference at various points on the circuit and strong electric current flowing in the circuit. While the chance Un-code-able still arises because the student wrong answer the first level is a matter of concept, but true and sure on the third level.
The reduction of misconceptions can be analysed based on the difference in mean score of the student's pre-test and post-test scores. Table 2 shows a reduction in the number of students experiencing misconceptions related to dynamic electrical concepts.

| Misconceptions                                                                 | Pre-test | Post-test | CT | % |
|--------------------------------------------------------------------------------|----------|-----------|----|---|
| In closed circuits, the lamp will light up when there is a cable connected to both sides of the screw thread | S7, S8, S21, S22, & S24 (5) | S4 & S16 (2) | Positive (+) | 11.1 |
| In closed circuits, the light will light only and only if the positive cover of the battery is connected to the negative battery cover. | S2, S4, S6, S7, S8, S10, S11, S12, S14, S15, S19, S20, & S26 (13) | S1, S3, S6, S8, S12, S13, S16, S18, S19, S20, & S23 (11) | 40.7 | 7.3 |
| The addition of a series of batteries can increase the number of electrons in the circuit. | S2, S3, S5, S6, S8, S10, S12, S13, S15, S19, S20, S22, S23, & S24 (14) | S1, S4, S8, S11, S12, S13, S16, & S20 (8) | 29.6 | 22.2 |
| The speed of motion of electrons is very fast. | S2, S3, S4, S8, S9, S12, S13, S15, S18, S19, S20, S21, S22, & S27 (14) | S1, S4, S12, S13, S16, S20, S21, S23, & S27 (9) | 33.3 | 18.5 |
| Adding the batteries in series will make the lights brighter even in the circuit there is also the addition of lights. | S1, S8, S14, S20, S22, S23, S25, S26 ,& S27 (9) | S2, S4, S6, S16, S20, S23, & S25 (7) | 26 | 7 |
| The addition of lamps that are series or parallel series can make the smaller the current so small that the light becomes dim | S4, S7, & S12 (3) | S1, S8, & S25 (3) | 11 | 0 |
| The addition of a series or parallel series of batteries can increase the voltage and current strength so that the light becomes brighter. | S3, S4, S6, S7, S8, S13, S14, S18, S19, S20, S25, & S27 (12) | S4, S8, S9, S12, S14, S15, S16, S21, & S25 (9) | 33 | 11 |
|                                                                 | S1, S3, S4, S6, S8, S9, S10, S11, S12, S15, S16, S19, S20, & S25 (7) | S1, S4, S8, S11, S16, S19, & S25 (7) | 26 | 37 |

Table 2. Decreasing number of students experiencing misconceptions.
| Misconceptions                                                                 | Pre-test                  | Post-test                  | CT   | % CC |
|--------------------------------------------------------------------------------|---------------------------|----------------------------|------|------|
| Any circuit arranged by cables, lights and batteries can surely turn on the light- not necessarily lit, if the open circuit is not lit | S22, S24, S25, & S26 (17) | S4, S6, S7, S8, S12, S15, S19, S20, S25, & S26 (10) | 37   | 19   | Positive (+) | 18   |
| The potential difference between the ends of the battery in the open circuit is zero | S1, S4, S5, S6, S8, S9, S10, S13, S15, S16, S21, S23, S25 & S26 (14) | S1, S3, S4, S6, S8, S9, S11, S15, S16, S18, S23, S25, S26, & S27 (14) | 52   | 52   | Positive (+) | 52   |
| Electric current at the branching current in the mixed circuit                  | S4, S6, S7, S9, S10, S11, S12, S13, S16, S18, S20, S21, S24, S25, S26, & S27 (16) | S6, S7, S8, S10, S12, S16, S18, S19, S21, S23, S24, S25, S26, & S27 (14) | 60   | 52   | Positive (+) | 8    |
| The altered resistance in series circuit only affects the current in the component afterwards | S4, S6, S7, S11, S16, S18, S21, & S23 (8) | S1, S3, S6, S16, S21, S22, S23, & S25 (8) | 30   | 30   | No change | 0    |
| Power of electric current divided evenly on each branching current & The potential difference for each lamp is the same | S2, S3, S4, S8, S10, S15, S16, S17, S19, S20, S24, S25, & S26 (13) | S3, S6, S8, S9, S10, S11, S16, S18, & S25 (9) | 48   | 33   | Positive (+) | 12   |
|                                                                                 | S7, S11, S12, S13, S19, S20, & S25 (7) | S4, S6, S18, & S19 (4) | 26   | 15   | Positive (+) | 11   |
| % Average                                                                      | 39.8                      | 28.1                       | <M> | 0.23 |

As seen in Table 2, after applying cooperative learning PDEODE computer-assisted simulation there was a decrease in the number of students experiencing misconceptions that is with a normalized gain value of -0.23 in the low category. Yet still students who experience misconceptions even when applied apply cooperative learning PDEODE computer-aided simulations (e.g. S3, S7 and S23). It indicates that the student still holds his misconception after the intervention. As stated in the study of understanding the concept [6 - 9, 15, 21-22]. This issue is quite prevalent because the conversion of misconceptions requires a time-consuming process if it has been firmly attached to the student’s frame of thinking.
4. Conclusions
Based on the categorization of the combination of four tier test answers, we obtained profiles of student conceptions as follows. In pre-test 2.47% of students understood the concept, 39.8% of students experienced misconceptions, 27.4% of students did not understand concepts, 25% of students had a chance of misconception (partial understanding), and 4.44% of students could not be categorized (encoded). Whereas in post-test the students understood the concept increased to 10.6%, students who experienced misconception decreased to 28.1%, the students did not understand the concept dropped to 23%, students who partially understood increased to 36.8% and the last students who cannot encoded down to 1.4%.

A decrease of student misconceptions after PDEODE learning by applying computer simulation as a learning medium on dynamic electrical material, by adopting a normalized gain (n-gain) calculation is 0.23 and falls into the low category. The highest reduction of misconception is found in the concept of battery pack, a reduction of 37%.

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