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Learning Based on Central Idea on the Topic of Electrical Circuits to Improve Students' Concept Understanding

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Abstract: *The unstructured pieces of students' knowledge on electrical circuits cause students to have a diverse understanding of concepts, which will cause difficulties and misconceptions. Therefore, pieces of student knowledge that are still unstructured need to be directed into complete knowledge based on the knowledge possessed by experts through learning based on central ideas on electrical circuit topics. This research aims to improve the ability to understand concepts on electrical circuit topics through the application of central idea-based learning. The research design is one group pretest posttest. The research subjects were 145 junior high school students. The concept understanding test instrument uses the DIRECT test with 12 questions. The instrument used was valid and reliable (α = 0.7). Based on data analysis, it can be concluded that central idea-based learning is effective in increasing students' conceptual understanding as proven by the N-Gain value of 0.84 which is in the high category.*

Keywords: *Central idea, conceptual understanding, electrical circuit*

Pembelajaran Berbasis Ide Sentral pada Topik Rangkaian Listrik untuk Meningkatkan Pemahaman Konsep Siswa

Abstrak: Potongan-potongan pengetahuan siswa yang belum terstruktur tentang topik rangkaian listrik membuat siswa memiliki pemahaman konsep yang beragam, sehingga akan menyebabkan kesulitan dan miskonsepsi. Oleh karena itu, potongan-potongan pengetahuan siswa yang masih belum terstruktur perlu diarahkan menjadi pengetahuan yang utuh berdasarkan ilmu yang dimiliki oleh para ahli melalui pembelajaran berbasis ide sentral pada topik rangkaian listrik. Tujuan dari penelitian ini yaitu untuk meningkatkan kemampuan pemahaman konsep pada topik rangkaian listrik melalui penerapan pembelajaran berbasis ide sentral. Desain penelitian adalah *one group pretest posttest*. Subjek penelitian sebanyak 145 siswa SMP. Instrumen tes pemahaman konsep menggunakan tes DIRECT sebanyak 12 soal. Instrumen yang digunakan valid dan reliabel (α = 0,7). Berdasarkan analisis data dapat disimpulkan bahwa pembelajaran berbasis ide sentral efektif untuk meningkatkan pemahaman konsep siswa dengan dibuktikan nilai N-Gain sebesar 0,84 yang berada pada kategori tinggi.

Kata kunci: Ide sentral, pemahaman konsep, rangkaian listrik

INTRODUCTION

The topic of electrical circuits is a topic that has many applications in everyday life. This topic is taught from elementary school to university level, especially for students majoring in physics and electrical engineering. Although the topic of electrical circuits has been acquired by students since elementary school, there are still many students who fail to use and develop their understanding in analyzing electrical circuits (Bao & Fritchman, 2021; Chiu et al., 2007; Manunure et al., 2020; Moodley & Gaigher, 2019; Peşman & Eryılmaz, 2010; Prastyaninda et al., 2018; Tarmizi et al., 2017; Xu et al., 2020). Several studies have reported that students still have a lot of difficulty in solving the topic of electrical circuits (Hartanto & Nawir, 2018; Lin, 2016; Liu et al., 2022; Manunure et al., 2020; Moodley & Gaigher, 2019; Peşman & Eryılmaz, 2010). Difficulties in problem solving continue to occur from primary school to university levels (Lin, 2016; Manunure et al., 2020).

High school students understand that components that are close to the battery will get more current than components that are far from the battery (Hartanto & Nawir, 2018). Students have difficulty distinguishing between types of circuits, they assume that a series circuit has only one line, while a parallel circuit has branches in the circuit without paying more attention to the location of the branches (Lin, 2016; Liu et al., 2022; Manunure et al., 2020; Moodley & Gaigher, 2019). Students at the high school and college levels still find it difficult to convert electrical circuits in the form of symbols into real circuit images (Liu et al., 2022) and students do not understand how current can flow from the battery to the lamp in a closed circuit (Peşman & Eryılmaz, 2010).

Students' difficulties, misconceptions, and low understanding of concepts in learning electrical circuits are influenced by several factors. This misunderstanding is caused by students' initial knowledge which is still fragmented and not necessarily correct when applied to various problems (Lin, 2017). In addition, the content in the topic of electrical circuits is challenging and complex for students at all levels (Liu et al., 2022). Factors from the teacher and also the textbook also play a role in students' difficulties in understanding the concept of the topic of electrical circuits (Dwilestari & Desstya, 2022).

Students who have low concept understanding and their knowledge is still fragmented and even have a naive understanding will have difficulty when receiving problems with new contexts (Wandi et al., 2023). Students may be fluent and smooth when solving problems that are often given because it is possible that students have memorized the form of the problem and how to solve it, but this does not make students have a better understanding (Nie et al., 2019; Shen et al., 2017; Xu et al., 2020). When solving problems, students are familiar with solving problems according to the context that has been recognized (Chen et al., 2020), focus on the surface of the problem only (Xie et al., 2021), and directly list the known quantities and match with the formula that corresponds to the known quantities (Liu et al., 2022; Xu et al., 2020). Such student characters are referred to as student characters with beginner understanding (Bao & Fritchman, 2021). At the end of learning, students are expected to have the structure of understanding as owned by experts. The experts' structure of understanding is an integrated and sequentially arranged knowledge that is built based on the main idea or central idea of a science (Bao & Fritchman, 2021; Nie et al., 2019). So, experts apply knowledge concepts based on the central idea in various problem contexts. Therefore, in order for students to have a correct understanding and in accordance with the knowledge of experts, the pieces of knowledge and understanding of students that are still on the surface must be directed towards understanding the central idea. The learning that is applied to bring the pieces of students' understanding to the understanding of the central idea is central idea-based learning.

Central idea-based learning is an approach to learning that focuses on deep mastery of the main idea or central idea of a topic (Bao & Fritchman, 2021; Dai et al., 2019; Kubsch et al., 2018; Liu et al., 2022; Xie et al., 2021; Xu et al., 2020). Central ideas are ideas held by experts that are used as the main reference in reasoning, solving problems, and explaining phenomena related to the topic (Lee et al., 2011; Shen et al., 2017; Xu et al., 2020). The use of the central idea helps students to have a deep understanding like experts. The central idea acts to override the pieces of knowledge that students have in reasoning. An example of central idea-based learning in physics is when there are two interacting objects, the central idea used is Newton's law 3. The central idea that needs to be well understood is that when two objects interact, there will be an action force and a reaction force of the same magnitude and opposite direction. Central idea-based learning can also be applied to the topic of electrical circuits. An example of the use of central ideas on the topic of electrical circuits is that to analyze the circuit, the central ideas of Ohm's law and Kirchoff's law 1 are needed. When analyzing the current, voltage and resistance values in a circuit, students must use the central ideas of Ohm's law and Kirchoff's 1st law as the main idea in completing the circuit analysis assignment

In central idea-based learning, a tool for modelling students' knowledge structures called a conceptual framework is used. The conceptual framework provides guidance and structure in understanding students' knowledge structure, and how students should think like experts (Bao & Fritchman, 2021). The conceptual framework on the topic of electrical circuits for university students is shown in Figure 1. The dashed line represents the thinking of novices and the solid line represents the thinking of experts.

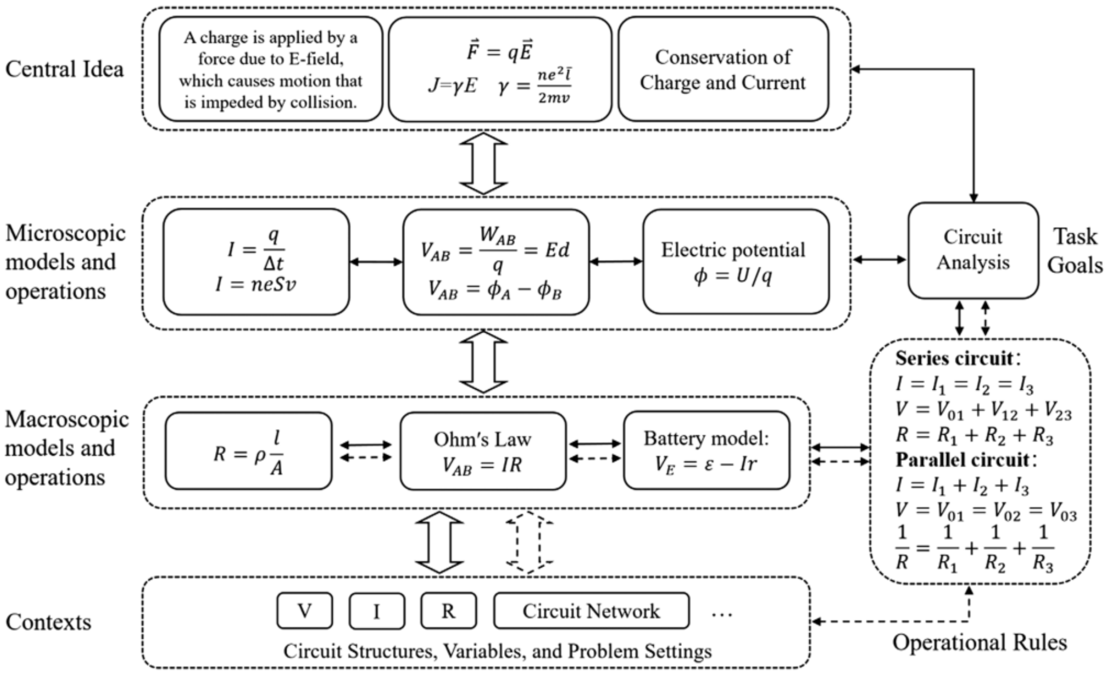


Figure 1. Conceptual Framework of the Electric Circuit Topic (Liu et al., 2022)

Research on central idea-based learning has been conducted on various physics topics such as mechanical waves (Xie et al., 2021), momentum (Xu et al., 2020), electrical circuits (Liu et al., 2022), Newton's 3rd law (Bao & Fritchman, 2021), and force and motion (Nie et al., 2019). In central idea-based research, especially on the topic of electrical circuits, there are still several things that have not been done. In previous studies, the research subjects used were still limited to the student level and high school level and the number of research subjects was still very small. Meanwhile, misconceptions on the topic of electrical circuits may also occur in junior high school students so it needs to be researched further. This is what will be done in this research.

In this study, we will implement central idea-based learning at junior high school level. Students at junior high school level are at a critical period to receive knowledge and develop that knowledge (Upayogi & Juliawan, 2019). Thus, it is expected that junior high school students will avoid misunderstandings, misconceptions, and fragmented knowledge on the topic of electrical circuits. The conceptual framework used to model the knowledge structure of junior high school students when learning the topic of electrical circuits has been designed as shown in Figure 2.

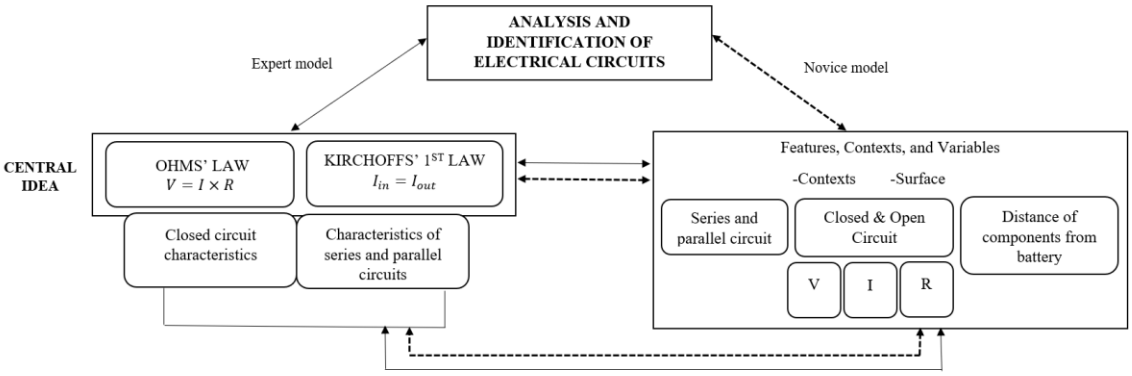


Figure 2. Conceptual Framework of Electrical Circuit Topics for Junior High School Students

The conceptual framework provides a view of how novices and experts think to solve problems on the topic of electrical circuits (Bao & Fritchman, 2021; Nie et al., 2019). The assignment given is the analysis and identification of electrical circuits. To solve the problem, experts must use the central idea to solve the problem. However, students with novice understanding are not necessarily the same as the thinking of experts. Students are still influenced by context and surface knowledge that is not necessarily correct. An example is when there is a lamp placed close to the battery and far from the battery. Students with novice understanding think that the distance of the lamp close to the battery will light up brighter because it gets the current first. This thinking is wrong, that the proximity of the components does not affect the brightness of the lamp. This should be directed to use the central idea of Ohm's law and Kirchoff's 1st law.

Implementing central idea-based learning at the junior high school level is expected that the pieces of knowledge that students have, especially on the topic of electrical circuits, can be directed towards correct knowledge and understanding based on the central idea of the topic of electrical circuits. This will reduce difficulties, misunderstandings, and misconceptions on the topic of electrical circuits. In addition, students' understanding will improve and match the understanding of experts. The purpose of this study is to promote central idea-based learning and determine the effectiveness of central idea-based learning to improve junior high school students' concept understanding on the topic of electrical circuits.

Central idea-based research is conducted with structured steps starting with identifying the central idea. The central idea that has been determined is then formulated in the form of a sparking question that is presented at the beginning of learning. After the sparking question is posed, then the presentation of contextual problems or phenomena to students. This aims to change students' initial knowledge which is still naive. After students feel doubtful about their initial knowledge, the teacher can facilitate exploration activities together with students. This exploration activity includes investigation and experimentation activities. After the exploration activities take place, discussions are held and conceptual understanding is provided by applying the central idea in each problem that has been given at the beginning. After all activities are completed, then reflect and evaluate. This aims to see whether students' understanding has changed by referring to the correct central idea.

RESEARCH METHOD

The research design used in this study was one group pretest posttest. The research subjects used were 145 junior high school students in the 2024/2025 school year who were studying the topic of electrical circuits. The research was conducted for five meetings starting from the pretest to end at the posttest. The test instrument used to improve students' concept understanding is the Determining and Interpreting Resistive Electric Circuit Concepts Test (DIRECT) test instrument (Engelhardt & Beichner, 2004) with a total of 12 questions. The reason for using only 12 questions is because the topics in these questions are in accordance with the topics taught at the junior high school level. The description of the question numbers taken and the topics used in the questions along with their analyses are shown in Table 1.

Table 1. Description of the Question Number and Parametric Analysis (α=0,699)

No.	Problem Description	DIRECT Test Number	Correlation	Difficulty index	Discrimination index
1	Define parallel circuit	4	0,5	0,82	0,3
2	Converting real circuit pictures to symbol form circuits	13	0,6	0,81	0,38
3	Converting symbol form circuits to real circuit pictures	22	0,3	0,90	0,13
4	Comparing replacement resistance values	5	0,5	0,87	0,37
5	Calculating the value of resistance as a constant	14	0,6	0,82	0,46
6	Determine the current value at each point in the series circuit	8	0,3	0,95	0,17
7	Determine the current value at each point in the parallel circuit	17	0,4	0,89	0,23
8	Determine the voltage value at each point in a parallel circuit	15	0,5	0,86	0,32
9	Determine the voltage value at each point in the series circuit	5	0,3	0,91	0,16
10	Analyse a closed circuit	9	0,4	0,90	0,27
11	Analyse a closed circuit	18	0,4	0,90	0,29
12	Analyse a closed circuit	27	0,3	0,93	0,20
	Average		**0.4**	**0.88**	**0.27**

Based on the results of parametric analysis presented in Table 1. the validity value of the questions gets an average value of 0.4 which means that all the questions used in this study are valid. The difficulty level of the questions gets an average value of 0.88, which means that the questions are in the easy category. All questions on the test instrument are basic questions on the topic of electrical circuits, so students do not need in-depth analysis to work on questions but simply understand the central idea on the topic of electrical circuits. The value of the differential power of the questions produces varied data, with some questions showing a good ability to differentiate student understanding.

Judging from the average value of the power difference, it shows that the questions can be used to distinguish how students understand the topic of electrical circuits.

RESULTS AND DISCUSSION

The results of working on the questions were then subjected to descriptive analysis and a percentage comparison of the number of correct answers to each question during the pretest and posttest. The results of the analysis are shown in Table 2 and Table 3.

Table 2. Descriptive Analysis Results

Score	*Pretest*	*Posttest*	N-Gain
Minimum Score	0	8	0,50
Maksimum Score	8	12	1,00
Mean	3	11	0,84
Standard deviation	1,7	1,7	

In Table 2. descriptive data from student test results are presented which include the minimum score, maximum score, and average score of students during the pretest, posttest, along with the N-Gain value of students. In addition, the standard deviation value is also displayed. The minimum score of students during the pretest was 0 then in the posttest increased to 8. The maximum score of students during the pretest was 8, while during the posttest the maximum score of students increased to 12, meaning that there were students who answered all questions correctly. The average score during the pretest was 3 while during the posttest the average student score was 11. This shows an increase as evidenced by the N-Gain value of 0.84. The standard deviation value remained stable at 1.7 in both the pretest and posttest. This shows that the variation in scores between students is quite consistent.

Table 3. Percentage of Students who Got Each Problem Correct

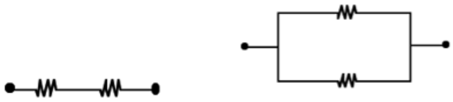
	Percentage of Students who Got Each Problem Correct											
Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Pretest	17	48	17	6,2	15	47	8,3	16	19	23	37	21
Posttest	82	80,7	89	87	82	94	89	86	91	90	89	93

In Table 3. presented the percentage of the number of correct in each question number during the pretest and posttest and very visible differences in the results of students' concept understanding on the topic of electrical circuits. The results of the correlation is $0.000<0.05$. The correlation test results mean that central idea-based learning is very influential to improve students' concept understanding on the topic of electrical circuits.

During the pretest, students who answered correctly were still relatively low, with the lowest value at number 4 which was 6.2% and the highest value at number 2 which was 48%. This shows that students' initial understanding of the topic of electrical circuits is still low. During the posttest, students' correct answers increased significantly in all questions. The highest percentage was in question number 6 (94%) and the lowest percentage was in question number 2 (80.7%).

Junior high school students experienced many mistakes during the pretest in questions number 4 and 7. Question number 4 is related to the comparison of the value of replacement resistance in series and parallel circuits. Question number 4 is shown as Figure 3.

4. Perhatikan gambar dua rangkaian di bawah ini!



Gambar 1 Gambar 2

Nilai hambatan di setiap rangkaian adalah bernilai sama. Bandingkan nilai hambatan total pada Gambar 1 dengan hambatan total pada Gambar 2. Hambatan total pada Gambar 1 nilainya ... Gambar 2.

a. empat kalinya dari
b. dua kalinya dari
c. sama dengan
d. setengah dari
e. satu per empat dari

Figure 3. Question Number 4

Students predominantly choose option c. equal to, whereas the correct answer is option a. four times of. Students think that the way to find the total resistance value is by adding up. This is true if applied to a series circuit but wrong if applied to a parallel circuit. Students' surface knowledge about calculating replacement resistance cannot be generalised to solve problems in all contexts. Therefore, students need to be directed to think and solve problems using the central idea of Ohm's law in each circuit properly.

To solve the problem in question number 4, it is necessary to remember that to find the replacement resistance / total resistance in series and parallel circuits using the formula as shown in Table 4.

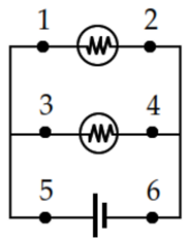
Table 4. Formula for Total Resistance of Series and Parallel Circuits

Total resistance of series circuit	Total resistance of parallel circuit
$R_{total} = R_1 + R_2 + \cdots + R_n$	$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$

By understanding the formula and how to calculate the total resistance value, students will find it easy to understand how electrical circuits work. When students are given problems with various contexts, if students already understand how the concept of current, voltage, and resistance values in each circuit, students will be able to solve the problem. This is evident from the students' posttest results presented in Table 3. Because students can already understand how to calculate the total resistance value in each circuit, the number of percentages of students who answered correctly increased to 87%. This means that there has been an increase in students' understanding in solving obstacle value problems based on the central idea of 80.8%.

Question number 7 is related to the value of current at each point in a parallel circuit. Question number 7 is displayed as in Figure 4.

7. Rangkaian di bawah ini memiliki nilai hambatan yang identik. Urutkan nilai arus pada titik 1,2,3,4,5, dan 6 dari yang tertinggi hingga yang terendah.



a. 5,3,1,2,4,6
b. 5,3,1,4,2,6
c. 5=6, 3=4, 1=2
d. 5=6, 1=2=3=4
e. 1=2=3=4=5=6

Figure 4. Question Number 7

The dominant answer of students in question number 7 during the pretest was c. 5=6, 3=4, 1=2, even though the correct answer is option d. 5=6, 1=2=3=4. Students assume that the largest current value is at a location / point close to the energy source / battery. The closer the component is to the energy source, the greater the current value and the farther the component is from the energy source, the smaller the current. This is in line with research from Lin (2016) and Manunure (2020) which states that students strongly believe that the distance or proximity of the component to the location of the energy source will affect the current and voltage values. (Lin, 2016; Manunure et al., 2020). Students know that the value of the resistance attached to the circuit has the same value, but students still cannot use Kirchoff's law 1 in parallel circuits.

The researcher used the central idea of Kirchoff's law 1 to overcome students' misunderstandings in problem number 7. The researcher focused the discussion on the conservation of electric current through Kirchoff's law 1 which states that: "the total current in a parallel circuit is divided proportionally to the resistance on each branch, while the current at certain points depends on the branching rule". In simple terms, Kirchoff's law 1 explains that the value of the current entering the branching is equal to the value leaving the branching.

The researcher asked students in groups to visualize the branching of the current using a simple tool, a plastic straw through which water passes. The plastic straw acts as a circuit line and the water are the flow of electric current. The researcher and students made the shape of the straw into the main straw which was connected to a branched straw and then flowed with water. From this media, students are asked to observe how the amount of water enters the main straw and the branch straw. After students understand the analogy of the incoming and outgoing currents through the straw and water media. But students still have difficulty with the resistance in the circuit at points 1,2,3, and 4. To understand these problems, the researcher invites students to prove it again through the PhET virtual laboratory application.

Through the PhET virtual laboratory, students are asked to create a circuit that is exactly the same as the picture in question number 7. Then students make the circuit into a closed circuit so that they can see how the current flows and passes through each branching in the circuit. The researcher asked students to make variations in the value of the installed resistance. After the students observe how the current flows, then the researcher asks a question: why do points 5 and 6 have the same current value? Is the current at points 3 and 4 greater than the current at points 1 and 2? Prove it! Through simple lab work, observations, and questions based on scientific argumentation, students can be guided in their understanding of electric current using the central idea of Kirchoff's 1st law. This method is simple, easy to understand, and effective for explaining abstract concepts in a concrete way.

Central idea-based learning applied to electric current problems such as problem number 7 has a positive impact on students' concept understanding. At the time of the pretest students who answered correctly only 8.3%, after the application of central idea-based learning the number of percentages of students who answered correctly increased to 89%. This means an increase of 80.7%. Central idea-based learning is proven effective to improve students' concept understanding on the topic of electrical circuits.

CONCLUSSIONS AND RECOMENDATIONS

Central idea-based learning on the topic of electrical circuits has been shown to be effective in improving junior high school students' concept understanding. Through this approach, students are able to understand complex concepts. These concepts include such as the difference between series and parallel circuits, current value, voltage value, resistance value, and converting real circuit images to circuit symbol images and vice versa in more depth.

The results showed a significant increase in posttest scores compared to pretest scores. This increase is shown by the increase in the average score, standard deviation value, and the increase in the number of percent of correct answers of students in each question number. Data analysis also showed that students experienced improved understanding of concepts with varying levels of difficulty of the questions.

Central idea-based learning helps overcome students' naive thinking and fragmented knowledge in three ways. These are presenting concepts in a structured and connected manner, linking the material to everyday life so that it is easier to understand, and emphasizing conceptual understanding through visualization, experimentation and interactive discussion. Thus, central idea-based learning is not only effective in improving students' concept understanding, but also helps students build sustainable and integrated knowledge. This strategy can be a solution in physics learning to overcome students' difficulties in understanding the topic of electrical circuits.

Recommendations that can be conveyed by researchers for further research are, to understand the difficulties and misconceptions of students on the topic of electrical circuits in depth. Students' initial knowledge and students' fragmented knowledge are not necessarily all wrong and not necessarily all right, so the teacher as a facilitator must be able to bring students' fragmented knowledge into intact knowledge based on the correct central idea. By using the correct central idea, students will not misunderstand when solving problems with any context. In addition, this central idea-based learning is expected to be carried out in learning with a short time, so that teachers fully understand what students' learning difficulties are and the right way to bring students to think using the right central idea.

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