



Jurnal Pendidikan Fisika

<https://journal.unismuh.ac.id/index.php/jpf>

DOI: 10.26618/ewgsyz18



Using Visual Media Based on Three Levels of Representation to Address Students' Misconceptions About Parallel Resistor Circuits

Havez Rasya Lega Serano^{1)*}, Dadi Rusdiana¹⁾, Lathifa Nur Ramdhania¹⁾, Lasmita Sari¹⁾, Mohd Zaidi Bin Amiruddin²⁾

¹⁾Department of Physics, Universitas Pendidikan Indonesia, Bandung, 40154, Indonesia

²⁾Department of Science Education, Universitas Pendidikan Indonesia, Bandung, 40154, Indonesia

*Corresponding author: rsasyahvz27@upi.edu

Received: February 03, 2026; Accepted: April 14, 2026; Published: May 19, 2026

Abstract – Misconceptions about parallel resistor circuits remain a persistent problem in physics learning because students often rely on observable circuit behavior while failing to understand the invisible microscopic processes and symbolic relationships underlying current distribution. This study aimed to investigate the contribution of Conceptual Change Oriented Instruction (CCOI) supported by three-level representation-based visual media in remediating students' misconceptions about parallel resistor circuits. A pre-experimental method with a one-group pretest–posttest design was employed. The participants were forty senior high school students in West Java, Indonesia, selected through purposive sampling based on the initial identification of misconceptions. Students' conceptual states were measured using a validated Four-Tier Test consisting of conceptual questions, confidence ratings, reasoning choices, and confidence in reasoning. The remedial teaching process followed the CCOI stages and was supported by visual media representing macroscopic demonstrations, microscopic virtual simulations, and symbolic analogies. The study focused on two misconceptions: the belief that adding or removing branches affects the current in other branches, and the belief that changing the current in one branch affects the current in other branches. The results showed that 85% of students who initially held the first misconception shifted to scientific conception, while 80% of students who initially held the second misconception also shifted to scientific conception. The novelty of this study lies in integrating CCOI with a three-level, representation-based approach to visual media to explicitly remediate misconceptions in parallel resistor circuits. These findings suggest that representationally supported conceptual change instruction can help students reconstruct scientific understanding of current distribution. This study contributes to physics education by extending the application of Johnstone's three-level representation framework to the remediation of misconceptions in electricity learning.

Keywords: conceptual change; parallel circuits; physics misconception; science learning; visual media.

I. INTRODUCTION

Direct current (DC) electric circuits are a fundamental topic in senior high school physics because they introduce students to the basic principles governing electric current, voltage, resistance, and energy transformation in electrical systems. Among the essential components in DC circuits, resistors play an important role in regulating or limiting current flow, particularly because many electronic devices require controlled amounts of electric current to operate safely and effectively (Tipler & Mosca, 2008). In a resistor, part of the electrical energy carried by moving charges is converted into heat energy, which arises from the opposition encountered by free electrons as they move through a conducting material (Tipler & Mosca, 2008). From a microscopic perspective, electrical resistance arises from interactions between moving electrons and the positive ions that form the conductor lattice, leading to scattering processes that learners cannot directly observe (Halliday et al., 2014). The magnitude of resistance in metallic conductors is influenced by several physical factors, including conductor length, cross-sectional area, and material resistivity (Tehrani, 2021). Therefore, understanding resistor circuits requires students to relate observable circuit phenomena to microscopic processes and symbolic relationships.

In school physics, resistors are commonly introduced through series, parallel, and mixed circuit configurations. Series circuits are generally explained as voltage-divider circuits, whereas parallel circuits are commonly described as current-divider circuits (Halliday et al., 2014). In a series circuit, adding resistors increases the total resistance; in contrast, adding branches in a parallel circuit decreases the total resistance because more pathways become available for electric current (Halliday et al., 2014). Although this principle is conceptually central to learning about electricity, parallel resistor circuits remain difficult for many students to understand. Previous studies have shown that students frequently experience misconceptions about electric current, voltage, resistance, and current distribution in circuit branches (Achour et al., 2025; Sencar et al., 2001). Similar difficulties have also been identified among pre-service teachers, indicating that misconceptions about electric circuits may persist across educational levels (Kaulu, 2015). Recent physics education research also confirms that students' understanding of electric circuits remains characterized by misconceptions, misunderstandings, and conceptual difficulties, suggesting that learning about electricity requires more than the procedural use of formulas (Bauman et al., 2024; Özmen, 2024; Peşman et al., 2025).

The main difficulty in learning parallel resistor circuits lies in the gap between observable circuit behavior and the invisible microscopic mechanisms that explain it. Students can observe whether a bulb lights, whether the brightness changes, or whether a measuring instrument shows a different reading; however, they cannot directly observe how electrons move, how the potential

difference is maintained across each branch, or why the current in one branch is determined by that branch's resistance. As a result, students often construct explanations based mainly on visible phenomena or intuitive reasoning. For instance, they may assume that the electric current from the battery is divided into fixed portions, that adding or removing a branch changes the current in all other branches, or that changing the current in one branch automatically affects the current in the remaining branches. Although such explanations may appear reasonable from the students' perspective, they are scientifically inaccurate because each branch in a parallel circuit has its own current determined by the potential difference and resistance in that branch. Misconceptions of this kind are difficult to remediate because students often regard their prior conceptions as sufficient to explain what they observe. Conventional instruction that focuses primarily on formulas, teacher explanation, and static board diagrams may not provide enough cognitive conflict or representational support to help students reconstruct their understanding. Consequently, students' knowledge may remain fragmented, superficial, and resistant to scientific restructuring (Meijer, 2011; Treagust & Duit, 2008; Tsui & Treagust, 2006).

To address this problem, physics instruction needs to support students in connecting macroscopic observations, microscopic processes, and symbolic explanations. Misconception remediation cannot rely only on presenting correct formulas or providing verbal correction, because students may continue to apply their prior reasoning even after receiving scientific explanations. Instead, students need learning experiences that make their existing conceptions visible, confront them with contradictory evidence, and guide them toward scientifically acceptable explanations. In this context, visual media can serve as important instructional support because it can present abstract and invisible processes in more accessible forms. Visual representations can help students observe circuit phenomena at the macroscopic level, interpret invisible electron movement at the microscopic level, and relate these processes to symbolic explanations such as diagrams, analogies, and mathematical relationships. These forms of representation correspond to Johnstone's three levels of representation: macroscopic, microscopic, and symbolic (Johnstone, 2009; Nkomo & Bly, 2024). Recent evidence from STEM and physics education indicates that multiple external representations can support conceptual understanding, problem solving, and representational competence, particularly when learners are guided to connect visual, symbolic, and conceptual forms of information (Rexigel et al., 2024; Hahn & Klein, 2025; Olaogun & Hunsu, 2025).

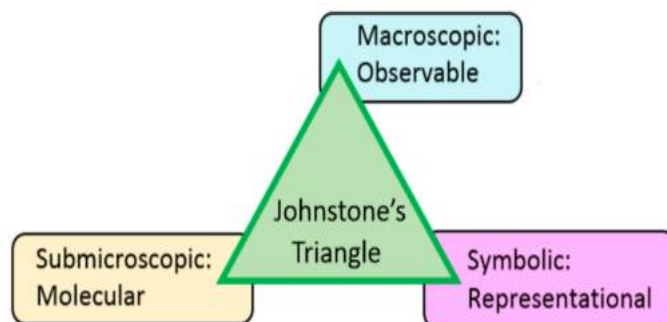


Figure 1. Johnstone's Triangle of three levels of representation

A specific solution that aligns with this representational need is the use of three-level representation-based visual media. Within Johnstone's framework, macroscopic representation refers to observable phenomena, microscopic representation to the invisible processes or mechanisms underlying them, and symbolic representation to formal or conceptual tools used to express scientific relationships. Symbolic representation is not limited to formulas or mathematical symbols; it may also include physical and non-physical analogies that help students interpret abstract concepts through familiar experiences. In electric circuit learning, for example, electric current is often analogized as fluid flow to help students understand current distribution in different branches, although such analogies need to be used carefully because they may support understanding only when their scope and limitations are made explicit (Duit et al., 2013; Bauman et al., 2024; Peşman et al., 2025). Contemporary studies continue to show that Johnstone's three-level representation framework is relevant for helping students coordinate observable phenomena, submicroscopic mechanisms, and symbolic forms when constructing scientific understanding (Nkomo & Bly, 2024; Locatelli et al., 2025). Advances in digital technology have also made it possible to present these representational forms through animations, simulations, and interactive visualizations. In physics education, such media have been reported to support conceptual understanding and conceptual change by helping students connect observable phenomena with microscopic processes and symbolic explanations (Amiruddin et al., 2025; Putri et al., 2024). Technology-based learning media, including simulations and interactive visualizations, can also increase student engagement and support the remediation of misconceptions by providing experiential access to abstract concepts that are difficult to observe directly (Achour et al., 2023; Belova & Zowada, 2020; Ramnarain & Moosa, 2017).

However, representational media alone may not be sufficient if they are not embedded within an instructional approach specifically designed to promote conceptual change. In misconception remediation, students need to experience dissatisfaction with their prior conceptions, clearly understand the new scientific conception, regard it as plausible, and

recognize its usefulness in explaining related phenomena. These conditions are consistent with the conceptual change perspective, which emphasizes the reconstruction of prior conceptions into more scientifically accepted conceptions. One instructional model designed for this purpose is Conceptual Change Oriented Instruction (CCOI), developed by [Başer and Geban \(2007\)](#). CCOI emphasizes creating cognitive conflict and supports students in reconstructing their existing conceptions through guided scientific explanations. Previous studies have examined misconceptions in electric circuits and explored the use of visual media and multiple representations in science learning ([Sianturi & Abdurrahman, 2019](#); [Bauman et al., 2024](#); [Özmen, 2024](#); [Rexigel et al., 2024](#); [Hahn & Klein, 2025](#)). Nevertheless, studies that specifically integrate CCOI with three-level, representation-based visual media to remediate misconceptions about parallel resistor circuits remain limited. Recent research in science education has largely focused on improving conceptual understanding, whereas explicit remediation of misconceptions through structured conceptual change interventions still requires further investigation ([Korur et al., 2025](#); [Suhandi et al., 2025](#)). This indicates a research gap in how conceptual change-oriented pedagogy and three-level visual representation can be systematically combined to address persistent misconceptions in parallel resistor circuits.

Therefore, this study aimed to investigate the contribution of CCOI supported by three-level representation-based visual media in remediating students' misconceptions about parallel resistor circuits. Specifically, the study focused on two misconceptions: the belief that adding or removing branches in a parallel resistor circuit affects the current flowing through other branches, and the belief that changing the current in one branch affects the current in the other branches. By integrating CCOI with macroscopic demonstrations, microscopic virtual simulations, and symbolic analogies, this study seeks to provide empirical evidence on how representationally supported conceptual change instruction can help students reconstruct their understanding of current distribution in parallel resistor circuits. This study is expected to contribute to physics education by extending the application of Johnstone's three-level representation framework to the context of misconception remediation in electricity learning and by offering an instructional approach that links conceptual change theory with visual-media-based physics instruction.

II. METHODS

This study employed a pre-experimental one-group pretest–posttest design ([Özmen, 2024](#)). This design was selected because the study aimed to investigate students' conceptual changes before and after remedial instruction using CCOI supported by three-level representation-based visual media. In this design, a pretest, a conceptual diagnostic test, was administered before the

intervention to identify students with misconceptions about parallel resistor circuits. Students who were identified as having misconceptions were then selected as research participants and received remedial instruction using the CCOI model. After the remedial teaching process was completed, a posttest with equivalent conceptual items was administered to determine students' final conceptual states. The comparison between pretest and posttest results was used to identify patterns of conceptual change related to the targeted misconceptions about parallel resistor circuits.

The participants in this study were 40 senior high school students from a single high school in West Java, Indonesia, comprising 22 females and 18 males. The participants were selected using purposive sampling because the study specifically focused on students who had demonstrated misconceptions in the initial diagnostic test. Therefore, only students identified as having misconceptions about parallel resistor circuits were included as research subjects. The remedial teaching intervention was conducted in two instructional sessions, each lasting approximately 90 minutes. The pretest was administered before the intervention, and the posttest was conducted immediately after the remedial teaching sessions. The overall research procedure consisted of four main stages: identifying students' initial conceptions, implementing remedial instruction using CCOI supported by three-level representation-based visual media, administering the posttest, and analyzing students' conceptual change patterns.

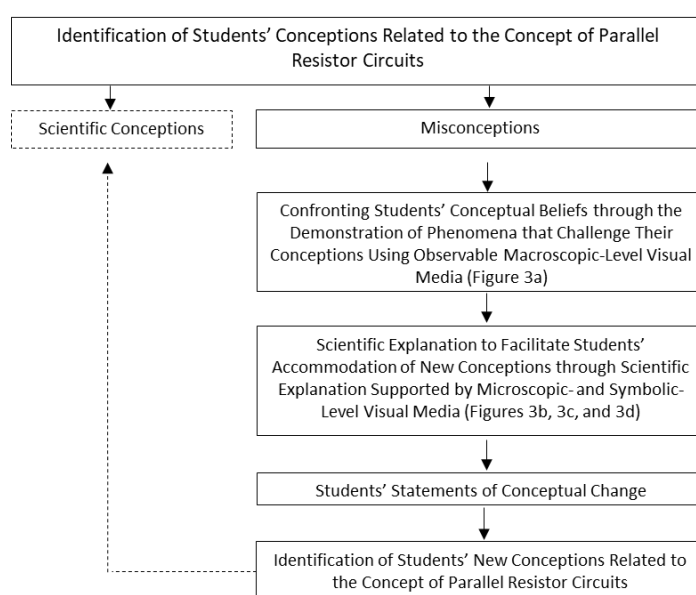


Figure 2. Stages of the remedial teaching process using CCOI

The remedial teaching process followed the stages of the CCOI model. In the first stage, students' initial conceptions of parallel resistor circuits were identified through conceptual questions and classroom discussions. This stage was intended to make students' prior conceptions

explicit and to provide a basis for identifying the misconceptions to be addressed during the remedial teaching process. In the second stage, namely belief confrontation, students were presented with macroscopic demonstrations designed to challenge their initial conceptions. Students were asked to predict the behavior of electric current in parallel branches and then compare their predictions with the observed phenomena. This comparison was intended to create cognitive conflict and encourage students to recognize inconsistencies between their prior conceptions and the actual behavior of parallel resistor circuits.

In the third stage, namely, scientific explanation for conceptual accommodation, students were guided to reconstruct their understanding through scientific explanations supported by three-level representation-based visual media. Microscopic virtual simulations were used to visualize invisible processes, such as electron movement and current distribution in parallel branches. Symbolic representations, including physical and non-physical analogies, were also used to help students connect abstract electrical concepts with familiar situations. During this stage, students discussed the scientific explanations, compared them with their previous conceptions, and gradually reconstructed their understanding based on the evidence and representations provided. In the final stage, students expressed and reflected on their revised conceptions regarding parallel resistor circuits. This stage aimed to reinforce students' scientific conceptions and evaluate the extent to which conceptual change had occurred during the remedial teaching process.

Three-level representation-based visual media previously developed by the research team were used to support the second and third stages of the CCOI process. The media consisted of macroscopic-level visual media, microscopic-level virtual-simulation media, and symbolic media in the form of physical and non-physical analogies. The macroscopic representation was used to present observable circuit phenomena, such as changes or stability in current readings when a branch was added, removed, or modified. The microscopic representation was used to show invisible processes related to electron movement and current distribution in parallel branches. The symbolic representation was used to support students' interpretation of abstract concepts through analogies and formal circuit relationships. The sequence of these representational levels was based on the view that science concepts are best taught progressively, beginning with macroscopic observation, followed by submicroscopic or microscopic interpretation, and finally symbolic representation ([Stojanovska et al., 2014](#)).

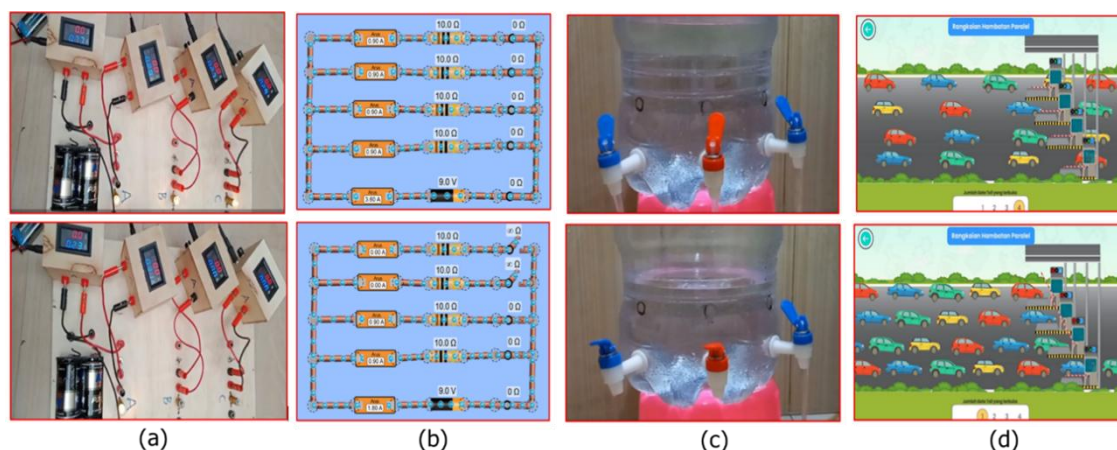


Figure 3. Three-level representation-based visual media for the concept of parallel circuits

Students' conceptual states before and after the remedial teaching intervention were assessed using a conceptual test, the Four-Tier Test (FTT), developed based on the framework of Kaltakci-Gurel et al. (2016). The FTT consisted of 10 four-tier multiple-choice items specifically designed to identify students' misconceptions about parallel resistor circuits. Each item consisted of four tiers. Tier 1 presented a conceptual question related to the target concept. Tier 2 asked students to indicate their confidence in their Tier 1 answer. Tier 3 required students to select the reason underlying their answer, while Tier 4 asked students to indicate their confidence in the reasoning selected in Tier 3. This four-tier structure allowed the researcher to distinguish between scientific conception, misconception, and no conception by considering both the correctness of students' answers and the confidence level associated with their responses.

The diagnostic results identified two major misconceptions related to parallel resistor circuits. The first misconception was the belief that adding or removing a branch in a parallel resistor circuit affects the electric current flowing through the other branches. The second misconception was the belief that changing the current in one branch of a parallel resistor circuit affects the current in the other branches. These two misconceptions became the main focus of the remedial teaching intervention. An example of the FTT item used in this study is presented in Appendix 1.

Before being used in the study, the FTT was validated by five expert validators. The validation data were analyzed using Aiken's V coefficient (Aiken, 1985), as shown in Equation (1):

$$v = \frac{\sum s}{[n(c - 1)]} \quad (1)$$

where:

$$S = r - l_0$$

l_0 = the lowest validity assessment number

r = the number given by the validator

c = number of categories that can be selected

n = total number of validators

To interpret the obtained Aiken’s V values, particularly in relation to item validity, the criteria used in this study were presented in Table 1 (Kurniawan & Azwar, 2017).

Table 1. Interpretation of the validity coefficient

V Aiken coefficient value	Interpretation
$0.6 \leq V \leq 1.0$	Valid
$V < 0.6$	Invalid

Students’ conceptual states were determined by combining answer correctness and confidence levels across the four tiers of the FTT. The categories used in this study were Scientific Conception (SC), Misconception (MC), and No Conception (NC), following the classification framework of Amiruddin et al. (2026) and Kaltakci-Gurel et al. (2017). Students were categorized as having a Scientific Conception when they provided correct answers and correct reasoning with confidence. They were categorized as having a Misconception when they provided incorrect answers or incorrect reasoning with confidence. Meanwhile, students were categorized as having No Conception when their answers and reasoning indicated uncertainty or inconsistency, particularly when they were not confident in their responses.

Table 2. Criteria for determining students’ conceptual states

Tier 1	Tier 2	Tier 3	Tier 4	Conceptual state
Correct	Confident	Correct	Confident	Scientific conception
Correct	Confident	Incorrect	Confident	
Incorrect	Confident	Correct	Confident	Misconception
Incorrect	Confident	Incorrect	Confident	
Incorrect	Confident	Correct	Not confident	No conception
Correct	Not confident	Correct	Not confident	
Correct	Not confident	Incorrect	Not confident	
Incorrect	Not confident	Correct	Not confident	
Incorrect	Not confident	Incorrect	Not confident	No conception
Correct	Confident	Correct	Not confident	

The data were analyzed descriptively to determine the distribution of students’ conceptual states before and after the remedial teaching intervention. The number of students in each conceptual category was calculated for each targeted misconception. Conceptual change patterns

were then identified by comparing students' pretest and posttest categories. The analysis focused on identifying shifts from misconception to scientific conception, misconception to misconception, and misconception to no conception. These patterns were used to evaluate the extent to which CCOI, supported by three-level representation-based visual media, contributed to the remediation of students' misconceptions about parallel resistor circuits.

III. RESULTS

To identify students' final conceptual states after the remedial teaching intervention, a posttest was administered using items equivalent to those used in the pretest. The posttest results were analyzed based on the criteria for determining students' conceptual states, as presented in Table 2. The analysis classified students into three categories: Scientific Conception (SC), Misconception (MC), and No Conception (NC). The distribution of students' final conceptual states for the two targeted misconceptions about parallel resistor circuits is presented in Table 3.

Table 3. Results of the identification of students' final conceptual states

No	Conceptions	Number of students		
		SC	MC	NC
1	Adding or removing branches in a parallel resistor circuit affects the electric current flowing through the other branches	34	4	2
2	Changing the electric current in one branch of a parallel resistor circuit affects the current flowing through the other branches	32	4	4

Note: SC = Scientific Conception; MC = Misconception; NC = No Conception

Based on Table 3, the majority of students achieved scientific conceptions after participating in the remedial teaching process using CCOI supported by three-level representation-based visual media. For the first misconception, 34 students were categorized as having a scientific conception, while 4 students remained in the misconception category and 2 students were categorized as having no conception. For the second misconception, 32 students were categorized as having a scientific conception, whereas 4 students remained in the misconception category and 4 students were categorized as having no conception. These findings indicate that most students were able to reconstruct their conceptions after the remedial teaching intervention.

The conceptual changes experienced by students before and after the intervention were then mapped by comparing their initial and final conceptual states. The results of this mapping are presented in Figure 4 and Figure 5. Figure 4 shows the conceptual change pattern for the first misconception, namely the belief that adding or removing a branch in a parallel resistor circuit

affects the current flowing through the other branches. Figure 5 shows the conceptual change pattern for the second misconception, namely the belief that changing the current in one branch affects the current flowing through the other branches.

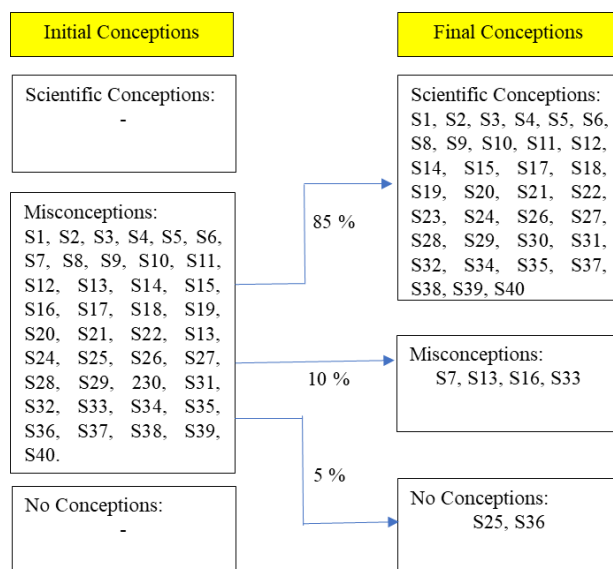


Figure 4. Map of students' conceptual change for the first misconception

The results shown in Figure 4 indicate that 85% of students who initially held the first misconception shifted to a scientific conception after the remedial teaching intervention. This result suggests that most students were able to revise their initial belief that adding or removing a branch in a parallel circuit affects the current in other branches. After the intervention, these students demonstrated a more scientifically appropriate understanding that the current in each branch of a parallel circuit is determined by the resistance in that branch and the potential difference across it, rather than by the addition or removal of other branches.

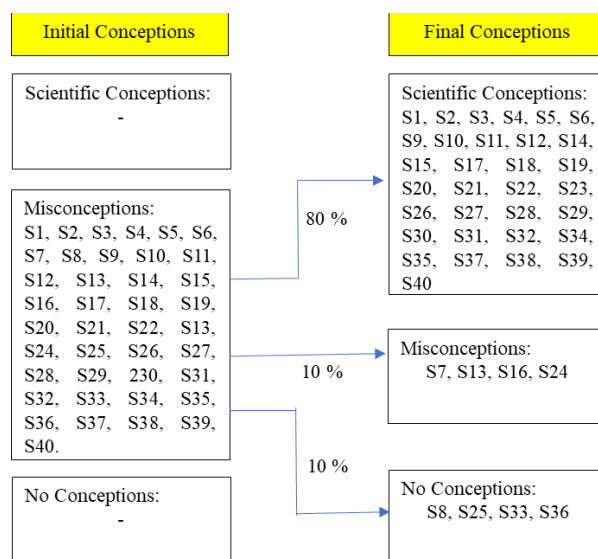


Figure 5. Map of students' conceptual change for the second misconception

The results shown in Figure 5 indicate that 80% of students who initially held the second misconception shifted to the scientific conception after the intervention. This result shows that most students were able to reconstruct their understanding of the current distribution in parallel circuits. Specifically, they no longer viewed a change in current in one branch as directly affecting the current in other branches. Instead, they recognized that each branch in a parallel circuit operates independently in terms of branch current, while the total current supplied by the battery depends on the circuit's equivalent resistance.

Although most students shifted from misconception to scientific conception, a small proportion remained in the misconception category or shifted to the no-conception category. For both targeted conceptions, 10% of students remained in the misconception category. In addition, 5% of students were categorized as having no conception for the first conception, and 10% as having no conception for the second. These results indicate that the remedial teaching process contributed positively to students' conceptual change, although it did not completely eliminate all misconceptions.

IV. DISCUSSION

The findings of this study indicate that CCOI, supported by three-level representation-based visual media, contributed positively to the remediation of students' misconceptions about parallel resistor circuits. The results showed that most students shifted from misconception to scientific conception after the remedial teaching intervention, with 85% achieving scientific conception for the first targeted misconception and 80% for the second. These findings suggest that integrating conceptual change instruction with visual media based on macroscopic, microscopic, and symbolic representations can meaningfully support students in reconstructing their understanding of current distribution in parallel circuits. This result is important because misconceptions in electric circuits have been widely reported as persistent learning difficulties among students and even pre-service teachers (Ahour et al., 2025; Kaulu, 2015; Sencar et al., 2001). Therefore, the improvement observed in this study indicates that students' misconceptions can be reduced when instruction is designed not only to present correct scientific information but also to confront prior conceptions and guide students toward conceptual reconstruction.

The positive conceptual change found in this study can be interpreted through the theoretical perspective of conceptual change. According to Posner et al. (1982), conceptual change occurs when learners experience dissatisfaction with their existing conceptions and perceive the new conception as intelligible, plausible, and fruitful. These conditions remain relevant in recent conceptual change research, which emphasizes that remediation of

misconceptions requires instructional interventions that explicitly confront students' prior conceptions and support the reconstruction of scientifically accepted explanations (Sarwar et al., 2024; Samsudin et al., 2024; Suhandi et al., 2025; Taşlıdere, 2013). In this study, the CCOI model provided instructional stages that supported these conditions. During the belief confrontation stage, students were exposed to macroscopic demonstrations that contradicted their initial beliefs about current distribution in parallel branches. This stage encouraged students to compare their predictions with observable phenomena, thereby creating cognitive conflict and dissatisfaction with their prior conceptions. The importance of cognitive conflict in misconception remediation is consistent with the conceptual change literature, which emphasizes that learners are more likely to revise their conceptions when they recognize that their existing explanations are inadequate for explaining observed phenomena (Başer & Geban, 2007; Posner et al., 1982; Treagust & Duit, 2008; Sarwar et al., 2024; Samsudin et al., 2024). Thus, the CCOI structure used in this study appears to have provided a pedagogical mechanism for making students' misconceptions explicit and open to revision.

The role of macroscopic representation was particularly important in initiating conceptual change because it allowed students to directly observe how current behaves in a parallel circuit when a branch is added, removed, or modified. Students who initially believed that changes in one branch would automatically affect the current in other branches were confronted with observable evidence showing that the current in each branch depends on that branch's resistance and the potential difference across it. This finding supports the argument that observable phenomena can serve as an entry point for conceptual restructuring when deliberately used to challenge students' prior conceptions. However, a macroscopic representation alone is insufficient, as students may observe changes in circuit behavior without understanding the underlying physical mechanisms. This limitation is consistent with the view that students' understanding often remains fragmented when instruction relies only on visible phenomena, formulas, or static representations (Meijer, 2011; Tsui & Treagust, 2006). Recent studies on multiple external representations also emphasize that meaningful conceptual understanding requires learners to connect observable phenomena to underlying mechanisms and to symbolic forms of explanation, rather than learning each representation in isolation (Rexigel et al., 2024; Hahn & Klein, 2025; Locatelli et al., 2025). Therefore, the effectiveness of the intervention in this study can be attributed not merely to demonstrations but to the systematic integration of macroscopic evidence with microscopic and symbolic explanations.

Microscopic representation also played a central role in helping students understand invisible processes underlying current distribution in parallel circuits. In conventional instruction, students often struggle to understand electric circuits because electron motion, potential

difference, and current distribution cannot be directly observed. This difficulty may lead students to construct intuitive but inaccurate explanations, such as assuming that current is divided in a fixed manner or that current shifts from one branch to another when resistance changes. Through microscopic virtual simulations, students were able to visualize electron movement and current behavior in each branch, which helped them connect observable macroscopic phenomena with the underlying mechanisms of electric current. This result is consistent with previous studies showing that multiple representations can support conceptual understanding by helping learners link observable phenomena with abstract explanatory models (Putri et al., 2024; Stojanovska et al., 2014). The use of microscopic representation in this study, therefore, contributed to the intelligibility of the scientific conception, as students could more clearly understand why current in one branch does not necessarily determine the current in other parallel branches.

Symbolic representations, in the form of physical and non-physical analogies, further supported students' conceptual reconstruction by providing bridges between abstract electrical concepts and familiar experiences. Within Johnstone's three-level representation framework, symbolic representation includes not only formulas and mathematical symbols but also conceptual tools that help learners organize and interpret scientific relationships (Johnstone, 2009; Nkomo & Bly, 2024). In the context of electric circuits, analogies such as fluid flow can help students understand current distribution by relating unfamiliar electrical processes to more familiar physical systems (Duit et al., 2013). In this study, symbolic representations helped students interpret the relationship between branch resistance, branch current, and total current in a parallel circuit. These representations supported the plausibility of the scientific conception by allowing students to relate the explanation to familiar conceptual structures. This finding aligns with previous research indicating that visual media, simulations, and interactive representations can facilitate conceptual understanding and conceptual change by making abstract scientific concepts more accessible to learners (Achour et al., 2023; Amiruddin et al., 2025; Belova & Zowada, 2020; Ramnarain & Moosa, 2017).

The integration of macroscopic, microscopic, and symbolic representations in this study also strengthens the application of Johnstone's three-level representation framework in physics education. Although Johnstone's framework has been widely used in chemistry education, its application in physics misconception remediation remains relatively limited. Previous studies have emphasized the value of multiple representations in helping students construct mental models and develop deeper conceptual understanding (Murni et al., 2022; Putri et al., 2024). The present study extends this line of research by applying three-level representation-based visual media to the context of parallel resistor circuits, a topic that involves observable circuit behavior, invisible microscopic processes, and symbolic relationships. This finding is consistent with

studies suggesting that representational frameworks can support students' meaning-making by bridging observable and theoretical levels of scientific explanation (Locatelli et al., 2025; Pham & Tytler, 2022; Xu, 2022). Therefore, the contribution of this study lies not only in showing that students' misconceptions can be reduced but also in demonstrating how a representational framework originally developed in chemistry education can be adapted to support conceptual change in abstract physics topics.

The results also show that the first misconception was remediated slightly more successfully than the second misconception. The shift from misconception to scientific conception reached 85% for the belief that adding or removing branches affects the current in other branches, whereas it reached 80% for the belief that changing the current in one branch affects the current in other branches. This difference may indicate that the second misconception required a more complex conceptual reconstruction. Understanding that changing resistance in one branch affects the current in that branch and the total current supplied by the battery, but not the current in other branches, requires students to coordinate several related concepts simultaneously, including potential difference, branch resistance, equivalent resistance, and total current. This interpretation is consistent with the view that electric circuit concepts often involve interconnected macroscopic, microscopic, and symbolic relationships that are difficult for students to integrate through formula-based instruction alone (Halliday et al., 2014; Meijer, 2011; Treagust & Duit, 2008). Thus, although the intervention was effective for most students, the slightly lower percentage for the second misconception suggests that certain aspects of parallel circuit reasoning may require more extended instructional support.

The persistence of misconceptions among a small proportion of students further indicates that conceptual change is not always immediate or complete. In this study, 10% of students remained in the misconception category for both targeted conceptions, while 5% shifted to the no-conception category for the first conception and 10% for the second. This finding is consistent with the literature stating that misconceptions are often resistant to change because they are rooted in students' prior experiences, intuitive reasoning, and internally coherent knowledge structures (Addido et al., 2022; Nakiboğlu, 2026; Svoboda, 2023). Students may begin to doubt their initial conceptions after experiencing cognitive conflict, but this does not automatically mean that they fully accept and accommodate the scientific conception. Conceptual change requires learners not only to reject an inaccurate conception but also to understand, accept, and apply a more scientifically appropriate explanation. When the new conception is not yet fully intelligible or plausible to students, they may remain in a transitional state between misconception and scientific conception. This may explain why some students in this study either retained their misconceptions or shifted to no conception after the intervention.

The students who remained in the misconception category may have experienced incomplete conceptual accommodation. Although the belief confrontation stage may have created dissatisfaction with their prior conceptions, some students may not have fully understood the scientific explanation presented during the accommodation stage. This condition is consistent with studies emphasizing that conceptual change requires not only exposure to contradictory evidence but also sufficient cognitive support for learners to reorganize their conceptual structures (Sarwar et al., 2024; Samsudin et al., 2024). In this study, students who shifted to the no conception category may have recognized that their prior conceptions were no longer reliable but had not yet developed stable scientific conceptions. This indicates that no conception should necessarily be interpreted as failure, but rather as a possible transitional phase in the conceptual change process. Such a phase suggests that additional learning time, repeated representational support, and further formative feedback may be needed to help students move from uncertainty toward stable scientific understanding.

V. CONCLUSION AND SUGGESTION

This study concluded that integrating CCOI with three-level, representation-based visual media contributed positively to the remediation of students' misconceptions about parallel resistor circuits. The findings showed that 85% of students who initially held the misconception that adding or removing branches affects the current in other branches shifted to a scientific conception after the remedial teaching intervention. In addition, 80% of students who initially believed that changing the current in one branch affects the current in other branches also shifted to a scientific conception. These findings indicate that the combination of cognitive conflict, scientific explanation, and interconnected macroscopic, microscopic, and symbolic representations can support students in reconstructing their understanding of current distribution in parallel resistor circuits.

However, this study has several limitations. The research involved a relatively small number of participants from a single senior high school and employed purposive sampling, which may limit the generalizability of the findings. In addition, the study employed a one-group pretest–posttest design without a control group, so the observed conceptual changes cannot be attributed solely to the intervention with complete certainty. Future research is recommended to involve larger, more diverse samples, use experimental or quasi-experimental designs with comparison groups, and examine the long-term retention of students' scientific conceptions following instruction. Despite these limitations, this study contributes to physics education by demonstrating how CCOI can be integrated with three-level representation-based visual media to

support misconception remediation. It also extends the application of Johnstone's three-level representation framework into electricity learning, particularly in helping students connect observable circuit behavior, invisible microscopic processes, and symbolic explanations in parallel resistor circuits.

REFERENCES

- Achour, M., Khouna, J., & Tahiri, A. (2023). The use of serious games in physics: A review of selected empirical studies from 2012 to 2021. *International Journal of Information and Education Technology*, 13(12), 1998–2003. <https://doi.org/10.18178/ijiet.2023.13.12.2014>
- Achour, M., Khouna, J., & Tahiri, A. (2025). Can serious games reduce electric current misconceptions among 10th grade Moroccan science pupils. *International Journal of Information and Education Technology*, 15(4), 795–802. <https://doi.org/10.18178/ijiet.2025.15.4.2285>
- Addido, J., Burrows, A., & Slater, T. (2022). The effect of the conceptual change model on conceptual understanding of electrostatics. *Education Sciences*, 12(10), 1-16. <https://doi.org/10.3390/educsci12100696>
- Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement*, 45(1), 131–142. <https://doi.org/10.1177/0013164485451012>
- Amiruddin, M. Z. B, Suhandi, A., Samsudin, A., Coştu, B., & Kaniawati, I. (2025). Perspectives on future research in conceptual change for science education: Systematic literature review. *Africa Education Review*, 21(2), 1–41. <https://doi.org/10.1080/18146627.2025.2503146>
- Amiruddin, M. Z., Suhandi, A., Fratiwi, N. J., Nurdini, N., Samsudin, A., & Coştu, B. (2026). Unveiling students' conceptions of hydrostatic pressure: A cross-sectional analysis. *Journal of Education and Learning (EduLearn)*, 20(2), 1120–1129. <https://doi.org/10.11591/edulearn.v20i2.23710>
- Başer, M., & Geban, Ö. (2007). Effect of instruction based on conceptual change activities on students' understanding of static electricity concepts. *Research in Science & Technological Education*, 25(2), 243–267. <https://doi.org/10.1080/02635140701250857>
- Bauman, L. C., Hansen, B., Goodhew, L. M., & Robertson, A. D. (2024). Student conceptual resources for understanding electric circuits. *Physical Review Physics Education Research*, 20(2), 1-21. <https://doi.org/10.1103/PhysRevPhysEducRes.20.020128>
- Belova, N., & Zowada, C. (2020). Innovating higher education via game-based learning on misconceptions. *Education Sciences*, 10(9), 1-10. <https://doi.org/10.3390/educsci10090221>
- Duit, R., Treagust, D. F., & Widodo, A. (2013). Teaching science for conceptual change: Theory and practice. *International handbook of research on conceptual change*, 487–503. Routledge. <https://doi.org/10.4324/9780203154472.ch25>

- Hahn, L., & Klein, P. (2025). The impact of multiple representations on students' understanding of vector field concepts: Implementation of simulations and sketching activities into lecture-based recitations in undergraduate physics. *Frontiers in Psychology, 16*, 1-13. <https://doi.org/10.3389/fpsyg.2025.1544764>
- Halliday, D., Resnick, R., & Walker, J. (2014). *Fundamentals of physics*. John Wiley & Sons.
- Johnstone, A. H. (2009). *Multiple representations in chemical education, 31*(16), 2271-2273. <https://doi.org/10.1080/09500690903211393>
- Kaltakci-Gurel, D., Eryilmaz, A., & McDermott, L. C. (2016). Identifying pre-service physics teachers' misconceptions and conceptual difficulties about geometrical optics. *European Journal of Physics, 37*(4), 1-30. <https://doi.org/10.1088/0143-0807/37/4/045705>
- Kaltakci-Gurel, D., Eryilmaz, A., & McDermott, L. C. (2017). Development and application of a four-tier test to assess pre-service physics teachers' misconceptions about geometrical optics. *Research in Science and Technological Education, 35*(2), 238-260. <https://doi.org/10.1080/02635143.2017.1310094>
- Kaulu, G. (2015). Physics student teachers' misconceptions about basic electronics: A case of BSc. Ed and BEDMAS students at UNZA. *International Journal of Multidisciplinary Research and Development, 2*(9), 155-160. <https://www.allsubjectjournal.com/assets/archives/2015/vol2issue9/2-8-109.pdf>
- Korur, F., Korumaz, K., & Erduran Avci, D. (2025). Enhancing students' conceptual understanding: An interventional study on the knowledge revision components framework using online materials. *SAGE Open, 15*(3). <https://doi.org/10.1177/21582440251372501>
- Kurniawan, R., & Azwar, S. (2017). Konstruksi skala kepedulian terhadap penggunaan energi. *Jurnal Ilmu Perilaku, 1*(1), 22-32. <https://doi.org/10.25077/jip.1.1.22-32.2017>
- Locatelli, S. W., Yeung, A., Mocerino, M., & Treagust, D. F. (2025). Student-generated diagrams showing salt dissolution: Patterns of levels of representation and an assessment rubric. *International Journal of Science Education, 1*-24. <https://doi.org/10.1080/09500693.2025.2542988>
- Meijer, M. R. (2011). *Macro-meso-micro thinking with structure-property relations for chemistry education: An explorative design based study*. Utrecht University. <https://research-portal.uu.nl/en/publications/macro-meso-micro-thinking-with-structure-property-relations-for-c/>
- Murni, H. P., Azhar, M., Ellizar, E., Nizar, U. K., & Guspatni, G. (2022). Three levels of chemical representation-integrated and structured inquiry-based reaction rate module: Its effect on students' mental models. *Journal of Turkish Science Education, 19*(3), 758-772. <https://doi.org/10.36681/tused.2022.148>
- Nakiboğlu, C. (2026). Senior pre-service chemistry teachers' perceptions, alternative conceptions and knowledge structure regarding radiation and radioactivity. *Chemistry Education Research and Practice, 27*(2), 793-827. <https://doi.org/10.1039/D5RP00347D>
- Nkomo, S., & Bly, A. (2024). Developing a threshold concept assessment rubric: Using the Johnstone's triangle framework for understanding intermolecular forces. *Journal of Chemical Education, 101*(11), 4694-4703. <https://doi.org/10.1021/acs.jchemed.4c00236>

- Olaogun, O., & Hunsu, N. J. (2025). A systematic review of factors that predict and mediate conceptual change. *European Journal of Psychology of Education*, 40(58). <https://doi.org/10.1007/s10212-025-00959-1>
- Özmen, K. (2024). Health science students' conceptual understanding of electricity: Misconception or lack of knowledge? *Research in Science Education*, 54(2), 225–243. <https://doi.org/10.1007/s11165-023-10136-3>
- Peşman, H., Arı, Ü., Karakaya Cirit, D., & Ayazgök, B. (2025). Effect of amount of guidance in inquiry-based physics laboratory on conceptual understanding and metacognitive awareness. *Science & Education*, 34, 3667–3687. <https://doi.org/10.1007/s11191-024-00595-z>
- Pham, L., & Tytler, R. (2022). The semiotic function of a bridging representation to support students' meaning-making in solution chemistry. *Research in Science Education*, 52(3), 853–869. <https://doi.org/10.1007/s11165-021-10022-w>
- Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, 66(2), 211–227. <https://doi.org/10.1002/sc.3730660207>
- Putri, A. H., Suhandi, A., & Samsudin, A. (2024). Investigating the impact of three levels of representation-based visual media on students' mental models. *Physics Education*, 59(6). <https://doi.org/10.1088/1361-6552/ad82cc>
- Ramnarain, U., & Moosa, S. (2017). The use of simulations in correcting electricity misconceptions of grade 10 South African physical sciences learners. *International Journal of Innovation in Science and Mathematics Education*, 25(5), 1-20. <https://pure.uj.ac.za/en/publications/the-use-of-simulations-in-correcting-electricity-misconceptions-o/>
- Rexigel, E., Kuhn, J., Becker, S., & Malone, S. (2024). The more the better? A systematic review and meta-analysis of the benefits of more than two external representations in STEM education. *Educational Psychology Review*, 36(124), 1-59. <https://doi.org/10.1007/s10648-024-09958-y>
- Samsudin, A., Zulfikar, A., Saepuzaman, D., Suhandi, A., Aminudin, A. H., Supriyadi, S., & Coştu, B. (2024). Correcting grade 11 students' misconceptions of the concept of force through the conceptual change model (CCM) with PDEODE* E tasks. *Journal of Turkish Science Education*, 21(2), 212–231. <https://doi.org/10.36681/tused.2024.012>
- Sarwar, M. N., Shahzad, A., Ullah, Z., Raza, S., Wasti, S. H., Shrahili, M., Elbatal, I., Kulsoom, S., Qaisar, S., & Nazar, M. F. (2024). Concept mapping and conceptual change texts: A constructivist approach to address the misconceptions in nanoscale science and technology. *Frontiers in Education*, 9, 1-14. <https://doi.org/10.3389/educ.2024.1339957>
- Sencar, S., Yılmaz, E. E., & Eryılmaz, A. (2001). Lise öğrencilerinin basit elektrik devreleri ile ilgili kavram yanlışları. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 21, 113–120. http://www.efdergi.hacettepe.edu.tr/shw_artcl-1041.html
- Sianturi, I. N., & Abdurrahman. (2019). Exploring multiple representation preference to develop students misconception inventory in measuring of students science conception awareness.

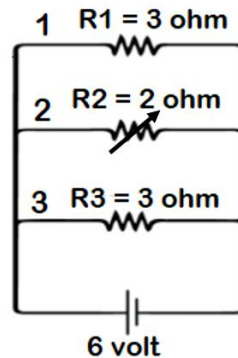
Journal of Physics: Conference Series, 1233(1), 1-7. <https://doi.org/10.1088/1742-6596/1233/1/012039>

- Stojanovska, M., Petruševski, V. M., & Šoptrajanov, B. (2014). Study of the use of the three levels of thinking and representation. *Contributions, Section of Natural, Mathematical and Biotechnical Sciences*, 35(1), 37-46. https://www.researchgate.net/publication/318964698_STUDY_OF_THE_USE_OF_THE_THREE_LEVELS_OF_THINKING_AND_REPRESENTATION
- Suhandi, A., Samsudin, A., Fratiwi, N. J., Nurdini, N., Feranie, S., Purwanto, M. G., Linuwih, S., & Coştu, B. (2025). Altering misconceptions: How e-rebuttal texts on Newton's laws reconstructs students' mental models. *Frontiers in Education*, 10, 1-15. <https://doi.org/10.3389/educ.2025.1472385>
- Svoboda, J. (2023). Processing misconceptions: Dynamic systems perspectives on thinking and learning. *Frontiers in Education*, 8, 1-12. <https://doi.org/10.3389/educ.2023.1215361>
- Taşlıdere, E. (2013). Effect of conceptual change oriented instruction on students' conceptual understanding and decreasing their misconceptions in DC electric circuits. *Creative Education*, 4(4), 273–282. <https://doi.org/10.4236/ce.2013.44041>
- Tehrani, M. (2021). Advanced electrical conductors: An overview and prospects of metal nanocomposite and nanocarbon based conductors. *Physica Status Solidi (A)*, 218(8), 1-17. <https://doi.org/10.1002/pssa.202000704>
- Tipler, P. A., & Mosca, G. (2008). *Physics for scientists and engineers* (6th ed.). W. H. Freeman and Company.
- Treagust, D. F., & Duit, R. (2008). Conceptual change: A discussion of theoretical, methodological and practical challenges for science education. *Cultural Studies of Science Education*, 3, 297–328. <https://doi.org/10.1007/s11422-008-9090-4>
- Tsui, C. Y., & Treagust, D. F. (2006). Understanding genetics: Analysis of secondary students' conceptual status. *Journal of Research in Science Teaching*, 44(2), 205–235. <https://doi.org/10.1002/tea.20116>
- Xu, L. (2022). Towards a social semiotic interpretation of the chemistry triangle: Student exploration of changes of state in an Australian secondary science classroom. *International Journal of Science and Mathematics Education*, 20(4), 705–726. <https://doi.org/10.1007/s10763-021-10190-1>

Appendix (Bahasa to English)

Sample Four-Tier Test (FTT) Related to the Concept of Parallel Resistor Circuits

Three resistors are connected in parallel to a constant 6-volt voltage source, as shown in the figure below. The resistance value of the resistor in branch 2 can be varied. In each branch, an electric current flows whose magnitude depends on the resistance value in that branch.



Tier-1

In your opinion, if the value of R2 is changed from 2 ohms to 1 ohm, the electric current whose magnitude will change is

- The electric current in all branches, including the current flowing through the battery
- The electric current in branch 1, branch 3, and the current flowing through the battery
- The electric current in branch 2 and the current flowing through the battery
- Only the electric current flowing through the battery

Tier-2

Are you confident with the answer you provided in Tier-1?

- Confident
- Not Confident

Tier-3

The reason you used when answering the question in Tier-1 is

- The total electric current flowing in a parallel circuit must remain constant, so a change in the magnitude of current in one branch will affect the magnitude of current in all branches.
- A parallel circuit is a current-divider circuit, so when there is a change in the current magnitude in one branch, for example branch 2 where the current increases, then the electric current in branches 1 and 3 will decrease because the current shifts to branch 2.

- c. Each branch in a parallel circuit has its own characteristics and is independent of the other branches, so when there is a change in the electric current magnitude in one branch, it will not affect the electric current in the other branches, except for the total current flowing through the battery.
- d. The electric current coming from the battery has a certain fixed value and is then distributed to each parallel branch, so if there is a change in the current in one branch, the other branches will automatically change as well, except for the current flowing through the battery.
- e.

Tier-4

Are you confident with the answer you provided in Tier-3?

- a. Confident
- b. Not Confident