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STUDENTS' MISCONCEPTIONS IN ELECTRICITY AND LEARNING STRATEGIES TO REDUCE THEM: A LITERATURE ANALYSIS

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ABSTRACT

Misconception is a conceptual misunderstanding experienced by students where the concept owned by students does not correspond to the scientific concept. Misconceptions are often found in science, especially in the topic of electricity. Electricity is one of the important topics in science that has many phenomena and connections with everyday life. In addition, electricity is assumed as an abstract concept that is difficult to understand by students. This study aims to analyse literatures that discussed about the detection of students' misconceptions in electricity concepts and the learning strategies to reduce those misconceptions. The method used in this study is a literature review with four stages: designing the review, conducting the review, analysing the literatures, structuring and writing the review findings. The research findings indicate that the most widely discussed misconception is that the lamp closest to the positive pole of the voltage source receives the largest current. In contrast, the next component receives the remaining current from the previous component. These misconceptions are still being attempted to be reduced or even eliminated. Efforts that have been applied to reduce misconceptions include implementing certain learning strategies that can build students' complete understanding of electrical concepts and combining them with simulations or virtual laboratories that can present concepts visually so that the concepts presented are no longer abstract for students. To conclude, the concept of electricity is abstract and likely to cause misconceptions in students. Therefore, the effective learning strategies have to be implemented to reduce students' misconceptions in electricity. The list of misconceptions and learning strategies that have been analysed can be used as a reference for teachers to plan appropriate learning strategies in the future to minimize misconceptions.

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Introduction

Electricity is something abstract and difficult to observe in real life. Electricity is one of the important topics in science that has many phenomena and connections with everyday life. However, there are still many misconceptions on this topic (Assem et al., 2024), and 159 misconceptions related to electricity still frequently occur (Suparno, 2013). Many of these misconceptions occur because electricity is an abstract concept that is difficult to understand (Hernandez et al., 2022). The learning that is usually done only asks students to imagine the physical phenomena of electricity. Students are not vet able to think related to abstract concepts and imagine the physical phenomena that occur in the concept of electricity (Upayogi & Juliawan, 2019).

Misconception is a conceptual misunderstanding experienced by students where the concept owned by students does not correspond to the scientific concept. Misconceptions are often found in science (Suprapto, 2020). Misconceptions can arise from various things, such as incorrect analogy, the use of everyday words that have similar meanings, or incorrect reasoning constructions (López & Marco, 2022). In addition, misconceptions can also be caused by interactions between students and their environment before they enter formal classes. Through everyday life phenomena, students build their concepts before they acquire new knowledge or concepts in the classroom (Mufit et al., 2023). When students try to build their concepts, errors may occur in constructing the correct concept and give rise to misconceptions (Mulyastuti et al., 2016).

Misconceptions held by students should not be left for too long. Teachers must immediately try to reduce misconceptions when they find out their students are experiencing misconceptions. Students who experience misconceptions must immediately receive appropriate treatment so that realize thev that thev are experiencing misconceptions (Mufit al.. et 2023). can prevent students from Misconceptions accepting new concepts by scientific concepts. Research conducted by Ramnarain & Moosa (2017) on electrical material found that some misconceptions became resistant and difficult to eliminate even though special interventions had been given to reduce students' misconceptions. It can happen because the misconceptions held by students have been held for too long, so students will find it difficult to accept new concepts (concepts that are scientific concepts) and cause their misconceptions to persist.

There have been many studies that have revealed misconceptions about electrical materials (Aligo et al., 2021; Andriani et al., 2015; Assem et al., 2024; Hidayatulloh et al., 2019; Ismail et al., 2015; Ivanjek et al., 2021; Pratama et al., 2023; Rohmah et al., 2017; Sarni et al., 2023; Trisnawati & Eso, 2020) and efforts to reduce misconceptions experienced by students (Assem et al., 2024; Frans & Wasis, 2022; Pratama et al., 2023; Ramnarain & Moosa, 2017; Ratnaningdyah & Sugiarti, 2024; Upayogi & Juliawan, 2019). The results of this literature study present a list of misconceptions about electrical materials that have been found, the discovery of the consistency of old misconceptions from year to year, and the discovery of new misconceptions that have not been widely studied before. The list of misconceptions and learning strategies that have been identified can be used as a reference for teachers to plan appropriate learning strategies in the future to minimize misconceptions. In addition, a review of misconceptions is carried out so that readers and subsequent researchers can easily identify students' misconceptions, especially for other researchers who will conduct further research on misconceptions, learning strategies to overcome misconceptions, and the creation of misconception analysis instruments on electrical materials.

Research Methods

Library research or literature study is the method used in this research. Four phases are carried out in this research literature study: designing the review, conducting the review, analyzing, structuring and writing the review (Snyder, 2019). The first stage is designing the review. The design is carried out by considering the scheme in the form of research contributions. objectives, methods, and literature search strategies. This stage is carried out by searching and selecting several literatures appropriate and relevant to the research and topics to be studied. The literature taken is from national and international journals related to the topic of electricity, and the search is carried out online and offline. The second stage is conducting the review by reading the literature to obtain and filter research data. At this stage, data on student misconceptions and their learning strategies in electricity material are obtained. The third stage is



analysis. The analysis produced is descriptive information such as author, year, topic, type of research, and impact. Then, the last stage is structuring and writing the review related to the research topic that has been written.

Results and Discussion

The discussion is conducted by describing the misconceptions found. In addition, it is also discussed regarding learning strategies and their implications for reducing misconceptions in these sub-topics.

Misconception Review

Table 1 presents an analysis of literature studies based on a combination of several scientific articles related to student misconceptions about electricity material. The topics are divided into five subtopics: electric current, electric circuits, Kirchoff's law, electrical resistance, and Ohm's law.

Table 1. Misconceptions in electricity material

Concept	Research Sources
ELECTRIC CURRENT	
The current has the same value at every point	(Turgut et al., 2011)
In a series circuit, the lamp closest to the positive pole of the voltage source receives the largest current. In contrast, the next component receives the remaining current from the previous component. The lights in the circuit can absorb current so every time it	(Andriani et al., 2015; Fajar & Supardi, 2013; Hidayatulloh et al., 2019; Sarni et al., 2023; Turgut et al., 2011) (Ivanjek et al., 2021; Sarni et al., 2023:
passes the light, the current decreases.	Siong et al., 2023; Suparno, 2013; Turgut et al., 2011)
A lamp close to the battery will shine brighter than a lamp far from the battery.	(Aligo et al., 2021; Suparno, 2013; Turgut et al., 2011)
The current will flow from the negative pole to the positive pole, so the current closer to the negative pole has a greater value than the current closer to the positive pole.	(Ismail et al., 2015; Rohmah et al., 2017; Trisnawati & Eso, 2020; Turgut et al., 2011)
Current causes a potential difference to occur.	(Fajar & Supardi, 2013; Hidayatulloh et al., 2019)
Electric current strength is the amount of electric current that flows.	(Andriani et al., 2015)
The voltage or potential difference at the battery poles causes electric current (positive charge) to flow from the positive pole to the negative pole of the battery.	(Andriani et al., 2015)
The current in a circuit is always constant.	(Siong et al., 2023)

In a parallel circuit, removing one bulb will make the other bulbs shine brighter and increase their potential difference(Hidayatulloh et al., 2019; Trisnawati & Eso, 2020)A circuit with a battery powering one light bulb will produce a greater current than a circuit using a battery to power two light bulbs.(Peşman & Eryılmaz, 2023)In a series circuit, the lights must be placed next to each other along the wire, whereas in a parallel circuit, the lights must be placed right next to each other.(Ivanjek et al., 2021)Increasing the number of lights in a circuit will cause the total resistance to become greater.(Aligo et al., 2021; Peşman & Eryılmaz, 2010; Sarni et al., 2023)Electric current will flow through the branch with more lights and the branch closest to the voltage source.(Andriani et al., 2015)If the switch is connected to two batteries connected in parallel, the brightness of the lamp and the electric current will increase.(Mandriani et al., 2015)Lights connected in parallel, the brightness of the lamp and the electric current will increase.(Monyiryivuze et al., 2011)If the switch is connected to two batteries connected in parallel, the branch and does not depend on the value of the resistor used.(Andriani et al., 2015)The amount of energy used to move the battery's charge and the charge in the circuit components.(Andriani et al., 2015)ELECTRICAL RESISTANCE Lamps are not influenced by the type of resistance because lamps only change electric current into light.(Andriani et al., 2015)The magnitude of electrical resistors is increased, it will affect the current flowing in	In a parallel circuit, removing one bulb will make the other bulbs shine brighter and increase their optential difference (Hidayatulloh et al., 2019; Trisnawati & Eso, 2020) A circuit with a battery powering one light bulb will produce a greater current than a circuit using a battery to power two light bulbs. (Peşman & Eryılmaz, 2010; Sarni et al., 2023) In a series circuit, the lights must be placed next to each other along the wire, whereas in a parallel circuit, the lights must be placed right next to each other. (Ivanjek et al., 2021) Increasing the number of lights in a circuit will cause the total the branch closest to the voltage source. (Aligo et al., 2021; Peşman & Eryılmaz, 2010; Sarni et al., 2023) Electric current will flow through the branch closest to the voltage source. (Andriani et al., 2015) If the switch is connected to two batteries connected in parallel, the brightness of the lamp and the electric current will increase. (Mbonyiryivuze et al., 2019; Turgut et al., 2010; KIRCHOFF'S LAW In a parallel circuit, the electric current entering the branched circuit has the same magnitude in each branch and does not depend on the value of the resistor used. (Andriani et al., 2015) The amount of energy used to current smoller than the resistance is on tinfluenced by the type of resistance, cross-sectional area, and length of the conducting wire. (Andriani et al., 2015) OHM'S LAW In a series circuit, if one of the resistor but will not affect the current flowing in the previous resistor. <th>Concept</th> <th>Research Sources</th>	Concept	Research Sources
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tamp on the (+) pole will remain	the same. This means that the	lamp on the (+) pole will remain	
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Concept	Research Sources
electric current at a point in a series circuit depends on its distance from the battery poles.	

The misconceptions identified above can be used as a reference for teachers to plan future learning strategies to minimize conceptual misunderstandings so as not to hinder students from receiving new knowledge in the learning process that students will receive. Teachers can also create question instruments concerning the table above to conduct misconception analysis on their students.

Learning Strategies and Their Implications for Reducing Misconceptions of Electrical Material

Research related to reduction of misconceptions is still being intensively carried out overcome learning difficulties to and misconceptions experienced by students. In order to reduce misconceptions through learning, teachers must have information related to students' initial knowledge and in which parts students experience misconceptions so that teachers can direct appropriate learning to build correct concepts (Turgut et al., 2011). Teachers must identify students' prior knowledge before introducing concepts to learning (Mbonyiryivuze et al., 2019). Based on this, it is important to conduct a pretest before learning to determine students' initial knowledge and identify misconceptions they experience.

Handling misconceptions is ideally done by providing scientific facts and confronting wrong concepts with correct concepts based on direct experience (Mufit et al., 2023). Here are some learning strategies that have been carried out and the results of their reduction in electrical material. **Table 2.** Summary of research on learning strategies to reduce misconceptions about electricity material

Article Research Summary

Information	·	
(Assem et al.,	Research Purpose:	
2024)	To identify misconceptions and	
Title:	eliminate student misconceptions by	
Identifying and	using inquiry-based learning.	
Dispelling	References/Supporting Statements:	
Students'	Determining appropriate and effective	
Misconceptions	learning strategies in dealing with	
about Electricity	misconceptions can be done if teachers	
and Magnetism	understand the potential for	
Using Inquiry-	misconceptions and students' prior	
Based Learning	knowledge (Turgut et al., 2011).	
in Selected	Identification of prior knowledge can be	
Junior High	used to guide students' conceptual	
Schools	development and change. Students must	
Journal:	be aware of the presence of	
	misconceptions and make decisions	

Articlo	Docoarch Summary
Information	Kesear ch Summary
	1 4 1 4 4 4 4 4 4
ASEAN Journal	about whether or not to reconstruct the
for Science	concept (Cakir, 2008). To improve
Education	conceptual understanding of electricity
	and magnetism material, constructive
	IDL) (IDL)
	(IBL) are suggested (Afra et al., 2009).
	inquiry-based learning is designed using
	live teaching stages: exploring,
	explaining, exploring, elaborating, and
	evaluating (Assem et al., 2024). This
	activity will help students to reconstruct
	concepts and nandle their
	Degeorgh Degultar
	The use of inquiry learning models is
	The use of inquiry learning models is
	missensentions. Inquiry makes students
	learn through conceptual investigation of
	that students are shrifted the sense that
	that students can clarify the concepts
	they have and realize the existence of
	misconceptions. This awareness can
	make students willing to replace their
	misconceptions with scientific concepts.
(Ratnaningdyah	Research Purpose:
& Sugiarti,	This study aims to determine the effect
2024) Title	of the inquiry learning model on
Thue:	reducing student misconceptions.
Jumlah	Inquiry learning will prepare students for
Juillian Mahaaiawa yana	independent experimental situations and
Manaalami	approximation and account with another so
Miskonsensi	that later students can build their
Fisika pada	understanding of concepts to form
Matori Listrik	scientific conceptions and reduce the
Dengen Model	level of misconceptions (Patnaningdyah
Dengan Mouer Pembelajaran	& Sugjerti 2024)
Inkuiri	Research Results
Incurnel	The inquiry learning model based on the
Jurnal Inovasi	stages of investigation can facilitate
dan	students' management of cognitive
Pembelajaran	conflicts and building correct scientific
Fisika (IIPF)	conceptions. It can reduce student
1 ISIKa (311 I)	misconceptions and improve them into
	appropriate scientific conceptions. The
	use of the inquiry learning model
	resulted in a 20% reduction in
	misconceptions.
(Pratama et al.,	Research Purnose:
2023)	This study aims to reduce students'
Title:	misconceptions about the concept of
Reduksi	capacitors.
Miskonsepsi	References/Supporting Statements:
Mahasiswa pada	Students involved in visual experiments
Prinsip Keria	can gain a correct scientific conceptual
Kapasitor	understanding related to capacitors'
melalui	working principles, observe voltage and
Penerapan	current changes, and manipulate possible
Simulasi PhET	variables (El-Tawargy & Elshabaan,
Journal:	2023). This visual experiment was used
Inovasi	with the help of PhET. PhET simulations
Pendidikan	can be used to explore information
Fisika	related to student misconceptions about
	electricity (Eveline & Permatasari, 2022)
	and are effective in reducing student



Article Information	Research Summary	Article Information	Research Summary
(Frans & Wasis, 2022) Title: Penerapan LKS Berbasis PhET untuk Mereduksi Miskonsepsi Siswa pada Materi Arus Listrik Bolak Balik Journal: Jurnal Penelitian Pembelajaran Fisika	misconceptions (Hikmawati et al., 2023). Research Results: The percentage of misconception reduction obtained was 34.3%. This presentation was obtained by reducing misconceptions during the pretest by 41.3% and the posttest by 6.9%. The results of this study can be used as a reference that virtual simulations can be used in learning complex physics materials. Research Purpose: Reduce students' misconceptions about alternating current electricity material by implementing LKS assisted by PhET virtual laboratory simulations. References/Supporting Statements: Students need scientific investigations through experiments and remember every step of the activities carried out by students so that students can continue to develop their scientific investigation and concept discovery skills independently by using virtual laboratories such as PhET. This PhET simulation media can help teachers understand concepts to students and effectively improve conceptual (Masita et al., 2020). Research Results: This study obtained the results of an increase in conceptual understanding in 3 classes of respondents as indicated by an increase in the average score (N-gain) of 0.7944, 0.6819, and 0.8421, with a category that tends to be high. This increase in conceptual understanding is in line with a decrease in misconceptions	(Hidayatulloh et al., 2019) Title: Reduksi Miskonsepsi Siswa Pada Materi Listrik Dinamis Menggunakan Ebook Interaktif Jurnal Pendidikan Fisika dan Teknologi	stages of PhET operational simulation. The advantage of PhET, which can present a visualization of electrical phenomena, allows students to see in detail abstract events that are not visible so that they can build concepts correctly and have an impact on reducing student misconceptions (Upayogi & Juliawan, 2019). Research Results: There was a 50% decrease in misconceptions about static electricity phenomena, a 41% decrease in misconceptions about physical quantities in electrical circuits, and a 41% decrease in misconceptions about energy and electrical power. Research Purpose: Develop an interactive ebook to reduce misconceptions about dynamic electricity material. This study describes the validity of the ebook, the effectiveness of the ebook to reduce misconceptions, and the practicality of the ebook. References/Supporting Statements: Using simulation software is important to foster interest in learning, visualize knowledge, and minimize learning difficulties (Fiscarelli et al., 2013). The minimal learning difficulties are expected to improve students' conceptual understanding and reduce their misconception levels. Research Results: The results showed that interactive ebooks were very effective in reducing students' misconceptions about dynamic electricity material to the point that
(Upayogi & Juliawan, 2019) Title: Reduksi	Research Purpose: Reduce misconceptions by building conceptual knowledge and building students' procedural knowledge through		misconceptions could decrease by 52%, and it can be concluded that the ebook is suitable for use in physics learning in dynamic electricity material.
Miskonsepsi Melalui Pembelajaran Berbasis Virtual Lab Journal: Journal of Teaching and Learning Physics	virtual laboratory-based learning, namely using PhET. References/Supporting Statements: The learning process by instilling procedural knowledge is very important to develop in physics learning. This procedural knowledge is mostly developed through laboratory practicums, causing conceptual knowledge to develop in every learning process (Yusrizal et al., 2017). However, the limited equipment in the laboratory means that students cannot visualize the electrical concepts they have obtained. (Upayogi & Juliawan, 2019). Virtual laboratories are one solution to the limited equipment in the learning environment. Learning is carried out using the help of virtual laboratories such as PhET and Student Worksheets which contain detailed and clear steps and	(Ramnarain & Moosa, 2017) Title: The Use of Simulation in Correcting Electricity Misconceptions of Grade 10 South African Physical Science Learners Journal: International Journal of Innovation in Science and Mathematics Education	Research Purpose: The use of interactive computer simulation to overcome misconceptions about the concept of electrical circuits. Misconceptions were detected using a three-tier diagnostic test on 130 student samples. References/Supporting Statements: Computer simulations offer an ideal and dynamic representation of concepts compared to direct experiments conducted in laboratories, which tend to be expensive and dangerous in electrical concepts (Obsborne & Hennessy, 2003). The simulation was conducted using Physics Education Technology (PhET) developed by the University of Colorado. Some of the advantages offered by PhET on electrical materials are: (1) teachers do not need to spend many teaching costs to buy circuit

	2019)
	Research Results.
	There was a 50% decrease in
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	electricity material. This study describes
	the validity of the ebook, the
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k	misconceptions, and the practicality of
	the ebook.
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	to foster interest in learning, visualize
	knowledge, and minimize learning
	difficulties (Fiscarelli et al., 2013). The
	minimal learning difficulties are
n	understanding and reduce their
	misconception levels
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Article Information	Research Summary
Information	boards, and students can get fast and quality conceptual feedback through PhET (Finkelstein et al., 2005) and avoid the possibility of failed experiments due to equipment damage, (2) PhET simulations enable students to be more active in learning, and students can construct their knowledge independently to produce conceptual changes and eliminate misconceptions (Jaakkola et al., 2011), (3) can create more visualizations of the circuits at one time which allows students to compare the circuits to build a concept, (4) allows students to reflect on the concept, modify the concept with direct feedback (Zacharia & Olympiou, 2011), (5) encourage students to interact with their peers to share experiences and discuss problems they encounter (Upayogi & Juliawan, 2019). Research Results: The use of simulation can be used as a learning medium to develop cognitive understanding and can facilitate students' investigations into their preconceptions. The decrease in misconceptions occurred in 6 discussions of concepts out of 11 concepts given. Some misconceptions still exist and are difficult to eliminate because some misconceptions are resistant, even though there are interventions that have been specifically
(Fajar & Supardi, 2013) Title: Pengaruh Penggunaan Model Pembelajaran	misconceptions. Research Purpose: Find out the profile of misconceptions in dynamic electricity material and to test the effect of using the inquiry learning model to reduce students' misconceptions in Dynamic Electricity material
Inkuiri (Inquiry Learning) Terhadap Penurunan Miskonsepsi Pada Materi Listrik Dinamis Kelas X SMA 2 Jombang Journal: Jurnal Inovasi Pendidikan Fisika	References/Supporting Statements: This inquiry learning through personal discovery is inseparable from cognitive conflict-based learning. Cognitive conflict arises due to conflict in the minds of students because of observing a phenomenon that is "anomalous". In order to reduce misconceptions and change preconceptions held by students, students must be actively involved in managing cognitive conflicts to find solutions (Suparno, 2013). Research Results: This study obtained the results of reducing misconceptions on questions about current consumption models, namely 37.5% and 43.8%. Electrical

The majority of studies in Table 2 use inquiry learning models and scientific approaches.

They are combined with multimedia assistance to teach electrical concepts. In physics learning, the use of inquiry learning models, problem-based learning and scaffolding learning becomes more effective when combined with virtual laboratory media such as PhET (Banda & Nzabahimana, 2021). Learning involving media or multi-learning models can help students understand concepts as a whole so that it can improve conceptual understanding and reduce misconceptions (Ulfah et al., 2021). Learning using inquiry learning can also be very effective if proper learning guidance is carried out (Siantuba et al., 2023). Building conceptual understanding is a very important element in reducing the level of misconceptions. Reducing misconceptions in students can be done by strengthening their conceptual and procedural knowledge. The use of additional media, such as virtual laboratories, can present visualizations of abstract concepts in electrical concepts so that students understand more about the concepts they are studying. It makes simulations and virtual laboratories widely used in learning to reduce misconceptions about electrical material.

Conclusion

The concept of electricity is abstract and likely to cause misconceptions in students. Some sub-concepts often detected as misconceptions are in the sub-concept of electric currrent. Many studies that use multimedia assistance in learning are solutions to build conceptual understanding and reduce student misconceptions. The multimedia that is widely used is a virtual laboratory in the form of PhET, which is considered to be able to visualize abstract electrical concepts so that students can construct knowledge correctly. Choosing the right simulation and learning strategy is crucial to reduce student misconceptions, especially in abstract concepts such as electricity.

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