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Determination of Middle School Students' Alternative Ideas in the "Conduction of Electricity" Unit through Score Analysis

İlyas ACET[1] Mehmet Altan KURNAZ[2]

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Abstract
This study aims to identify the alternative ideas of 6th-grade students regarding the "Conduction of Electricity" unit. Data were collected from students who had completed the electricity conduction unit. The study was conducted using a survey model with 54 6th-grade students. A test developed by Aydoğdu (2017) assessed student performance on the electricity conduction unit. The test consisted of 20 multiple-choice questions, and correct and incorrect responses were analyzed. The results showed that student responses fell into patterns such as high score-high concentration (HH), low score-low concentration (LL), medium score-medium concentration (MM), and medium score-low concentration (ML). Based on these patterns, students' alternative ideas were examined. It was found that students had misconceptions about electrical resistance and the factors that influence it. As a result, it is recommended that more efforts be made to detect and address learning deficiencies in the electricity conduction unit, that science teachers relate the topic more to everyday life during instruction, and that teachers actively work to correct students' alternative ideas.

Keywords: Electricity conduction, score analysis, alternative ideas, 6th-grade.

INTRODUCTİON

Changing societal needs influences the knowledge and skills expected from individuals. These knowledge and skills can be categorized as problem-solving, critical thinking, entrepreneurship, determination, and contributing positively to society. Educational curricula are continuously updated to nurture individuals with these qualities (Bonney et al., 2005; MEB, 2018). For the goals outlined in these curricula to be achieved, students must construct knowledge scientifically in their minds, enabling meaningful learning (Yüzbaşıoğlu & Kurnaz, 2022). Their prior knowledge and beliefs influence students' ability to construct scientific knowledge. Moreover, when students assign subjective meanings to scientific knowledge and internalize them through their experiences, it adversely affects their ability to learn accurate information (Pastırmacı, 2011). This situation creates challenges in constructing new knowledge (Hasanah, 2020). In the literature, this phenomenon is referred to as "alternative ideas," defined as mental constructs about a concept inconsistent with scientific knowledge (Salih & Polat, 2005). In other words, students interpret and understand concepts not based on scientific facts but according to their subjective perspectives (Pastırmacı, 2011). Alternative ideas represent students' explanations of concepts or topics that are not aligned with scientific knowledge (Yüzbaşıoğlu & Kurnaz, 2022). These ideas are shaped by students' naive beliefs, preconceptions, or non-scientific constructs that they generate instead of accurate scientific knowledge (Yılmaz, 2015). The presence of alternative ideas is considered one of the most significant obstacles to future learning. In recent decades, research has increasingly focused on identifying and addressing alternative ideas (Caymaz, 2020). This trend may stem from the growing recognition of the need to identify and rectify alternative ideas to enable meaningful learning. One of the areas where

[1]Corresponding Author: Dr, Ministry of National Education, Kastamonu, acet_25@hotmail.com, orcid.org/0000-0003-3324-7766
[2]Prof. Dr. Kastamonu University, Faculty of Education, Kastamonu, altan.kurnaz@gmail.com, orcid.org/0000-0003-2824-4077

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alternative ideas have been extensively studied is the topic of electricity in science education (Salih & Polat, 2005; Kapartzianis & Kriek, 2014).

Although electricity is closely related to students' daily lives, learning difficulties are encountered in understanding the associated concepts (Ayvacı, Ernas, & Dilber, 2016). Students' possession of alternative ideas contributes to these difficulties, making it harder for them to meaningfully construct new concepts in their minds (Yüzbaşıoğlu & Kurnaz, 2022). Studies have shown that students at nearly all educational levels hold alternative ideas about electricity (Çıldır & Şen, 2006; Yıldırım et al., 2008; Ecevit & Şimşek, 2017). Identifying these alternative ideas is crucial for improving electricity teaching, as they significantly influence students' comprehension of the subject (Salih & Polat, 2005). Since newly acquired knowledge is constructed by relating it to students' prior knowledge, identifying alternative ideas is critical for effectively teaching electricity.

The literature reveals a range of alternative conceptions that align with the framework of this study and reflect common misunderstandings about electrical phenomena. For instance, some students believe that a plastic spoon can conduct electricity due to its failure to light a bulb or that conductivity occurs through atomic vibration (Ayvacı et al., 2016). Similarly, the idea that a porcelain plate is non-conductive because it does not "attract electricity" reflects a flawed understanding of insulation (Canpolat & Ayyıldız, 2019). Others assume that water, particularly salt water, is conducive either because electricity can be generated from it or because it is turbid (Günaydın, 2019; Keser & Başak, 2013; Kömürcü, 2010). Misconceptions also extend to the belief that the compactness of particles determines conductivity (Ayvacı et al., 2016) or that pure water conducts electricity if it transmits heat and light (Keser & Başak, 2013). Students also perceive conductive materials as inherently safe to use due to their function (Ayvacı et al., 2016; Gökçe, 2018), and mistakenly believe that conductors lack resistance or that insulators possess extremely low resistance (Keser & Başak, 2013; Tiftikçi et al., 2017). Regarding electric circuits, it is erroneously believed that increasing the length of a wire or replacing conductors with more resistant materials enhances bulb brightness (Caymaz & Aydın, 2019; Saputro et al., 2018), or that bulb brightness increases with the number of bulbs used (Brna, 1988). Additional misconceptions include the belief that electricity flows faster through shorter wires (Küçüközer, 2004; Keser & Başak, 2013), that thinner wires resist electrical flow (Villarino, 2018; Keser & Başak, 2013), and that the bulbs' energy consumption influences resistance (Wainwright, 2007). Finally, some students think bulb brightness is unrelated to resistance (Hussain et al., 2013).

These misconceptions highlight the complexity of electrical concepts and the need for targeted instructional strategies to foster accurate scientific understanding. Students' prior knowledge about scientific concepts can sometimes be shaped by incomplete or inaccurate experiences, leading to persistent misconceptions. Rather than having incorrect conceptual frameworks, it may be more advantageous for learners to begin with no preconceived ideas, as misconceptions tend to obstruct the assimilation of scientifically accurate knowledge (Baki, 1999; Hırça, 2004). Because the learning process involves integrating new knowledge with existing cognitive structures, prior misunderstandings can create long-term barriers to meaningful learning (Van Riesen, Gijlers, Anjewierden & de Jong, 2018). Misconceptions formed in earlier educational stages may endure unless identified and addressed appropriately. Research shows that these misconceptions often arise from students' informal experiences or incomplete instruction and can make it difficult for them to accept or internalize scientifically accurate information later in their academic journey (Karakaya, Yılmaz, Çimen & Adıgüzel, 2020). For science learning to become genuinely meaningful, students' existing ideas must be brought to light and considered in the design of instructional interventions (Ayas, 2005).

Furthermore, understanding students' thinking, their interpretations of concepts, and how they mentally organize knowledge is essential for developing effective teaching strategies (Horton, 2007). Instruction that connects scientific content to familiar, real-world contexts helps students form more coherent and transferable understandings (Hançer, Şensoy & Yıldırım, 2003). Within science education, this contextualized approach not only enhances comprehension but also reinforces the relevance of science in everyday life (Karaaslan & Ayas, 2016). In Turkey, science education spans from early childhood to university through systematically structured curricula. However, students often carry forward beliefs formed in earlier grades—many of which may later manifest as alternative conceptions (Kızılcık, Çelikkanlı & Güneş, 2015). As stated in the examples above, it is clear that students at various levels of education have misconceptions about electricity. These findings underline the need to detect and remediate alternative conceptions early to prevent their reinforcement and ensure that scientific understanding is developed on solid foundations (Kurnaz & Ekşi, 2015). In this context, the current study aims to contribute to the identification of such alternative ideas and support the design of more effective teaching practices.

An examination of the literature reveals that various tools are used to identify and address alternative ideas about electricity. These tools include analogies (Şen & Aykutlu, 2011), drawings (Meşeci, Tekin, & Karamustafaoğlu, 2013), concept maps (Aykutlu & Şen, 2012), the learning phases method (Salih & Polat, 2005), concept tests (Demirci & Çirkinoğlu, 2004; Karakuyu & Tüysüz, 2011; Caymaz & Aydın, 2019), and open-ended questions (Küçüközer, 2003). In addition, multiple-choice academic achievement tests are frequently used to identify students' alternative ideas (Şenyiğit & Sılay, 2019). Academic achievement tests require students to choose the most accurate option from a set of responses related to a particular topic (Caleon & Subramaniam, 2010).

However, academic achievement tests have limitations in reflecting the reasons behind students' alternative ideas. For instance, students might select the correct answer for the wrong reason or an incorrect one despite accurate reasoning. This inability to determine causality in responses is seen as a limitation of academic achievement tests (Şenyiğit & Sılay, 2019). Another limitation is that students might arrive at the correct answer not through scientific understanding but by eliminating other options or guessing. Therefore, when investigating alternative ideas using multiple-choice tests, it is essential to analyze both correct and incorrect responses (Ezberci Çevik & Kurnaz, 2019, 2021; Kurnaz, 2022; Yüzbaşıoğlu & Kurnaz, 2022).

This study focuses on identifying the alternative ideas held by 6th-grade students regarding the "Conduction of Electricity" unit. Considering the limited number of studies examining alternative ideas in this unit (Caymaz, 2020), this research is anticipated to assist teachers in designing instructional environments. Additionally, by analyzing students' incorrect responses alongside correct ones in a multiple-choice test, the study aims to contribute a new perspective to the literature examining alternative ideas. For this purpose, the research problem is formulated: "What are the alternative ideas of 6th-grade students in the 'Conduction of Electricity' unit?"

METHOD

Research Model

The study is quantitative research aimed at identifying the alternative ideas held by 6th-grade students regarding the "Conduction of Electricity" unit. The research was conducted using the survey method, one of the application-oriented approaches within the quantitative research paradigm. Survey studies are commonly employed to describe and examine existing conditions or phenomena related to a particular topic or event (Yin, 2009).

An academic achievement test was administered to 6th-grade students who had completed the "Conduction of Electricity" unit according to the current curriculum. The scores and concentration analyses were performed using the multiple-choice items in the academic achievement test. Based on these analyses, descriptive evaluations were carried out to interpret the findings.

Study Group

The present research is situated within the scope of the sixth-grade science curriculum, specifically focusing on the Conduction of Electricity unit. Accordingly, sixth-grade students constitute the study's target population. The sample was selected using a convenience sampling strategy, a method recognized for its ability to optimize time and resource management while supporting the practical continuity of the research process (Büyüköztürk et al., 2018). Depending on the nature of the research design, the unit of analysis may include a single educational institution or extend to multiple settings (Yıldırım & Şimşek, 2005).

To explore students' alternative conceptions related to the Conduction of Electricity unit, a working group comprised 54 sixth-grade students attending three public middle schools in Kastamonu during the 2021–2022 academic year. In line with methodological standards for ensuring reliability in educational research, a minimum sample size of 30 participants was maintained (Cohen et al., 2007). Consequently, the findings of this investigation may be cautiously generalized to sixth-grade student populations enrolled in public schools located within the central district of Kastamonu.

Data Collection Tools and Process

Data were collected using an academic achievement test comprising multiple-choice items developed for the "conduction of electricity" unit. The achievement test, developed by Aydoğdu (2017), consists of 20 multiple-choice items. The item discrimination index was calculated as 0.6078, and the item difficulty index was calculated as 0.6241. According to these values, the test can be classified as having medium difficulty and high discrimination for students. The Cronbach Alpha reliability coefficient of the scale was calculated as 0.87. While the test was developed before the updated 2018 curriculum, the learning outcomes for the "conduction of electricity" unit remained unchanged between the 2017 and 2018 curricula. Therefore, recalculating the item difficulty and discrimination indices was not necessary. Data were collected during the 2021-2022 academic year after completing regular teaching activities, and the achievement test was administered accordingly.

Data Analysis

The data obtained from the achievement test were analysed using the technique developed by Bao (1999). This analysis technique includes the examination of incorrect answers along with correct ones. Each item on the test was analysed individually, and the frequency and percentage values of the responses were calculated. These calculations determined the students' scores (S) and concentration factors (C). This allowed for the analysis of both correct answers and incorrect ones to explore students' alternative ideas.

Scores represent the correct answers students provided for a multiple-choice question. Scores are calculated by dividing the number of correct answers by the total number of responses to that question (Bao, 1999). In addition to the correct answers, incorrect answers were analyzed using the "concentration factor." According to Bao (1999), the concentration factor takes values between 0 and 1, where 1 indicates high concentration and 0 indicates no concentration. For example, if 80 students distribute their answers evenly across all choices (e.g., 16 answers per choice), the concentration factor would be 0. If all students select the same option, the concentration factor would be 1. The formula used to calculate the concentration factor is provided below:

$$C = \frac{\sqrt{m}}{\sqrt{m}-1} \times \left(\frac{\sqrt{\sum_{i=1}^{m} n_i^2}}{N} - \frac{1}{\sqrt{m}} \right)$$

The concentration factor values obtained from this analysis were interpreted according to the coding scheme recommended by Bao (1999) (see Table 1).

Table 1. Three-Level Coding for Score and Concentration Factor

Skor (S)	Level *	Concentration Factor (C)	Level *
0~0,4	L	0~0,2	L
0,4~0,7	M	0,2~0,5	M
0,7~1,0	H	0,5~1,0	H

* L: Low, M: Medium, H: High

The concentration factor and score values were used together to interpret student performance and their alternative ideas. These patterns are explained in Table 2.

Table 2. Two-Level Coding for Student Answer Patterns (Bao, 1999)

	Pattern	Meaning
1	LL	Students show no distinct performance, and their answers appear to be random guesses.
2	LH	Students have low scores, but a majority selected the same incorrect answer.
	HH	Students demonstrate strong performance, with most answers correct.
3	LM	Students' answers are concentrated on two incorrect options.
	MH	There is a dominant trend in students' responses, though not widespread.
	MM	Students’ answers are concentrated on both a correct and incorrect option.
	ML	Students’ answers are distributed across two uncommon choices.

Based on the S and C values, patterns from Table 2 were used to analyse students' responses. Descriptive graphs were also generated to visualize the distribution of response patterns (Bao, 1999). These graphs categorize student responses into three main areas: qualified responses (HH pattern), mixed-quality responses (LM, MM), and random responses (LL).

Ethical Considerations

This study was conducted using voluntary consent forms. This study adheres to the guidelines of the "Scientific Research and Publication Ethics Directive" of the Higher Education Institutions in Turkey. No actions violating the ethics of scientific research or publication have been taken during the study.

RESULTS

The student's academic achievement test scores and concentration factor analysis results for the "conduction of electricity" unit are given in this section. The frequency and percentage values of the student's answers to the test questions were calculated. These values are shown in Table 3.

Table 3. Frequency and Percentage of Students' Responses to the Academic Achievement Test

Question *	A		B		C		D		Blank	
	f	%	f	%	f	%	f	%	f	%
1	1	1,9	49	90,7	2	3,7	2	3,7	0	0
2	17	31,5	3	5,6	30	55,6	4	7,4	0	0
3	33	61,1	11	20,4	7	13,0	2	3,7	1	1,9
4	1	1,9	34	63,0	12	22,2	6	11,1	1	1,9
5	1	1,9	2	3,7	4	7,4	47	87,0	0	0
6	38	70,4	6	11,1	8	14,8	2	3,7	0	0
7	37	68,5	2	3,7	1	1,9	14	25,9	0	0
8	8	14,8	26	48,1	10	18,5	9	16,7	1	1,9
9	2	3,7	4	7,4	2	3,7	46	85,2	0	0
10	9	16,7	36	66,7	6	11,1	3	5,6	0	0
11	8	14,8	9	16,7	15	27,8	21	38,9	1	1,9
12	1	1,9	3	5,6	46	85,2	4	7,4	0	0
13	5	9,3	3	5,6	40	74,1	6	11,1	0	0
14	5	9,3	6	11,1	40	74,1	3	5,6	0	0
15	8	14,8	10	18,5	16	29,6	19	35,2	1	1,9
16	46	85,2	6	11,1	0	0	2	3,7	0	0
17	12	22,2	3	5,6	17	31,5	22	40,7	0	0
18	7	13,0	42	77,8	2	3,7	3	5,6	0	0
19	7	13,0	22	40,7	20	37,0	5	9,3	0	0
20	26	48,1	14	25,9	4	7,4	9	16,7	1	1,9

*The option in bold font is the correct answer to that question.

Upon examining Table 3, it was observed that the question with the lowest correct response rate was Question 15, with 14.8%, and Question 20, with 16.7%. These questions involve the relationship between resistance and factors like cross-sectional area and length of the material. The highest correct response rate was for Question 1, with 90.7%, which dealt with the classifying conductive and insulating materials.

The analysis of distractor choices (incorrect answers) revealed that the most frequently selected distractor was Option A in Question 2, which 31.5% of the students chose. The least chosen distractor, at 1.9%, was Option A in Questions 1, 4, 5, and 12 and Option C in Question 7. Notably, in Question 16, none of the students chose Option C as their answer.

Table 4 shows each question's calculated score (S), concentration factor (C) values, and the resulting pattern. The S and C values for the students' responses were used to determine the patterns (e.g., HH, LL, MM, etc.). Continuing with the analysis, the S and C values for each question are provided in Table 4. These values indicate the performance and concentration levels of the student's responses to each question.

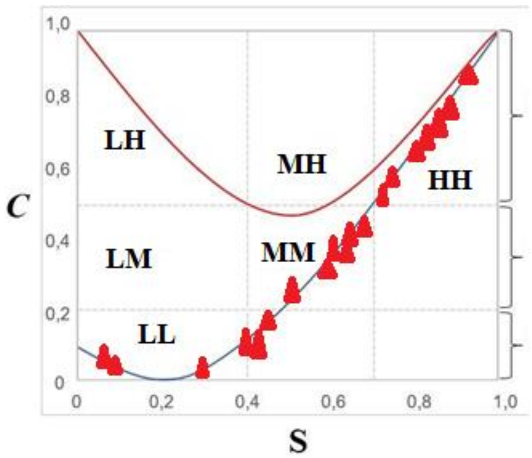
Table 4. Score (S) and Concentration Factor (C) Values for the Academic Achievement Test

Question	1	2	3	4	5	6	7	8	9	10
S	0,91	0,56	0,61	0,63	0,87	0,70	0,69	0,48	0,85	0,67
C	0,82	0,29	0,34	0,38	0,75	0,46	0,47	0,15	0,71	0,40
Pattern	HH	MM	MM	MM	HH	MM	MM	ML	HH	MM
Question	11	12	13	14	15	16	17	18	19	20
S	0,39	0,85	0,74	0,74	0,15	0,85	0,41	0,78	0,41	0,17
C	0,07	0,71	0,51	0,51	0,05	0,72	0,13	0,58	0,15	0,17
Pattern	LL	HH	HH	HH	LL	HH	ML	HH	ML	LL

S:Skor; Concentration Factor (C)

From Table 4, it can be seen that the concentration factor for students' answers was "high" in 8 questions (H level) and "medium" in 6 questions (M level). In 6 questions, the concentration factor was "low" (L level). Students' scores were high (H level) in 8 questions, low (L level) in 3 questions, and medium (M level) in 9 questions.

The graphical representation of the student's response patterns, based on their S and C values, is shown in Graph 1.



Graph 1: Patterns of Students' Responses

According to Graph 1, the students' responses were distributed across four patterns: high score-high concentration (HH), low score-low concentration (LL), medium score-medium concentration (MM), and medium score-low concentration (ML). The analysis revealed that the students demonstrated the HH pattern for eight questions, MM for six questions, OD for three questions, and LL for three. The questions that exhibited the HH pattern involved conductive and insulating materials, while the questions in the LL pattern were related to electrical resistance.

The alternative ideas identified from the students' responses to the electricity conduction unit are shown in Table 5.

Table 5: Alternative Ideas Identified in the Electricity Conduction Unit

Question	Pattern	Alternative Ideas
11 15 20	LL	Insulators have low electrical resistance. Conductors have high electrical resistance. When the cross-sectional areas of the same type of material are different, the thicker material has high electrical resistance, and the thinner material has low electrical resistance. There is a direct proportion between resistance and bulb brightness. As the length of the conductor increases, the bulb brightness increases. As the length of the conductor increases, the electrical resistance decreases.

DISCUSSION

This study analyzed a multiple-choice test related to the "Conduction of Electricity" unit by including correct and incorrect student responses. This analysis was conducted by examining students' scores and concentration factors. Based on this analysis, efforts were made to identify students' alternative ideas regarding the unit. In studies such as this one, a distribution of student responses clustering in the upper-right corner of the graph (Figure 1) for each question indicates and is expected to reflect quality learning (Ezberci Çevik & Kurnaz, 2019, 2021; Kurnaz, 2022; Yüzbaşıoğlu & Kurnaz, 2022). According to the distribution shown in Figure 1, it can be concluded that participants did not exhibit consistent quality learning about the topic. At the same time, some subtopics were adequately learned, others were insufficiently understood.

An analysis of the academic achievement test responses revealed that Questions 15 and 20 had the lowest correct response rates. These questions related to electrical resistance, with Question 15 measuring the relationship between cross-sectional area, length, and resistance and Question 20 assessing the relationship between conductor length, resistance, and bulb brightness. Thus, electrical resistance poses significant learning difficulties for students. The low correct response rates for these questions are seen in the studies of Acet & Akyüz, (2020). Therefore, it can be stated that it is consistent with the findings in the literature.

In addition to these questions, Questions 8, 11, 17, and 19 also had scores below 50%. These questions, which focus on electrical resistance, featured distractors related to factors such as the unit of resistance, its measurement, and variables affecting resistance. Electrical resistance is recognized as a challenging concept to learn (Gaigher & Kriek, 2007; Viard & Khantine-Langlois, 2001). Studies on electrical resistance indicate that learning deficiencies related to this concept exist across nearly all educational levels (Apaydın et al., 2019). Unaddressed learning deficiencies in earlier grades can hinder future learning. For instance, a study by Apaydın et al. (2019) involving pre-service teachers found that their prior knowledge about electrical resistance was significantly flawed. Pre-service teachers described electrical resistance using terms such as "reaction," "something that opposes current," "barrier," "reverse force," "reaction," "impediment," "force," "energy," and "resistance." Considering that the teaching of electrical resistance begins in the 6th grade, it is plausible that the learning deficiencies identified here persist into later years. Based on these findings, it can be concluded that there are deficiencies in teaching electrical resistance effectively.

The literature suggests that challenging topics, when supported by contextual approaches, lead to more meaningful and lasting learning (Karslı Baydere & Aydın, 2019; Yüzbaşıoğlu, 2022). Therefore, insufficient use of contextual teaching approaches in the instruction of electrical resistance may contribute to these deficiencies. Ayvacı et al. (2016) found that using context-based materials significantly improved students' conceptual understanding of conductive and insulating materials. From this perspective, future studies should explore the role of contextual approaches in teaching electrical resistance.

The question with the highest correct response rate in the academic achievement test was Question 1, at 90.7%. This knowledge-based question focused on materials' electrical conductivity and insulation properties. It can be inferred that students do not face significant difficulties in learning to classify conductive and insulating materials or understanding their properties.

Using the analytical framework Bao (1999) proposed, students' S and C values can be used to identify learning deficiencies and design effective instructional strategies (Kurnaz et al., 2018). The results of the study revealed that Questions 11, 15, and 20 were categorized under the LL pattern, which could indicate that students have deficiencies in learning related to these questions. This may also reflect a lack of scientific understanding of the topic (Yüzbaşıoğlu & Kurnaz, 2022). The medium difficulty level of the test items supports the prediction that students may have provided random responses due to a lack of scientific knowledge. Based on this analysis, it can be stated that students hold alternative ideas related to electrical resistance. As shown in Table 2, the LL pattern indicates that students exhibit low performance and provide responses that appear to result from random guesses. The literature supports the presence of alternative ideas about resistance at all levels of education (Küçüközer, 2003; Tiftikçi et al., 2017; Canpolat & Ayyıldız, 2019). This finding aligns with the results of the current study. The relationship between resistance and factors such as conductor type, length, and cross-sectional area may be too abstract for 6th-grade students, contributing to learning deficiencies. These deficiencies could create obstacles for subsequent learning.

For Question 11, 27.8% of the students selected distractor "C." The statement in Option II, "The resistance of conductors is low, and the resistance of insulators is high," was marked incorrect according to the students' responses. This suggests that students have alternative ideas about the resistance of conductive and insulating materials. Specifically, students believe that "insulating materials have low resistance, while conductive materials have high resistance."

For Question 15, the most frequently chosen options were "C" (29.6%) and "D" (35.2%), which surpassed the correct response, "A" (14.6%). Higher concentration indicates more prominent alternative ideas. In Option C, students compared the resistance of two materials based on their thickness. According to student responses, "For materials of the same type, thicker pieces have lower resistance, while thinner pieces have higher resistance" was marked incorrect. Thus, students appear to hold the alternative idea that "for materials of the same type with different cross-sectional areas, thicker materials have higher resistance, while thinner materials have lower resistance."

In Option D of Question 15, the statement "The bulb in a circuit with material one will shine brighter" was presented. According to the question, Material 1 had the lowest measured resistance among the options. Although Option D should have been correct, many students marked it as incorrect. This suggests that students hold the alternative idea that "resistance and bulb brightness are directly proportional."

For Question 20, the most frequently chosen options were "A" (48.1%) and "B" (25.9%). This question described a scenario where a 20 cm copper wire in an electric circuit was replaced with a 40 cm copper wire, and the effects on bulb brightness and resistance were examined. In Option A, the statement "The brightness of the bulb increases" was considered correct based on the students' responses. This indicates that students hold the alternative idea that "as the length of the conductor increases, the bulb brightness also increases." Another frequently chosen distractor, Option B, included the statement "The circuit resistance decreases," which students also marked as correct. This implies that students believe "as the length of the conductor increases, the electrical resistance decreases."

Questions exhibiting the HH pattern (1, 5, 9, 12, 13, 18) were related to conductive and insulating materials and, in some cases, bulb brightness (14, 16). A notable observation is that most of the questions categorized under the HH pattern (75%) pertained to electrical conductivity and insulation. Research on 6th-grade students' understanding of electricity suggests that one of the topics with the most identified learning deficiencies and alternative ideas is electrical conductivity and insulation (Ayvacı, Ernas, & Dilber, 2016; Günaydın, 2019; Günel, Atila, & Büyükkasap, 2009; Keser & Başak, 2013). This highlights the potential contributions of studies to identify and address learning deficiencies and alternative ideas related to this topic.

In questions related to electrical resistance (e.g., length-cross-sectional area-material type), students' responses concentrated on two incorrect options, representing the ML pattern (100%). The lack of studies addressing learning deficiencies and alternative ideas about electrical resistance in the literature may contribute to this issue. Studies on electrical resistance tend to focus on higher education levels (Caymaz, 2020). These studies primarily examine the relationships between resistance and current, resistance and potential difference, and the conceptual representation of resistance. The current study, however, emphasizes the factors influencing resistance, highlighting its significance.

CONCLUSION and RECOMMENDATIONS

This study investigated sixth-grade students' alternative conceptions regarding the Conduction of Electricity unit, with a particular focus on their understanding of electrical resistance. The findings revealed that while students exhibited relatively accurate knowledge concerning the classification of materials as conductors or insulators, they held several misconceptions related to the concept of resistance. These alternative ideas encompassed the factors that influence electrical resistance—such as the type, length, and thickness of the conductor—as well as misunderstandings about the relationship between resistance and bulb brightness.

The analysis of student responses highlighted a number of recurring misconceptions, including the belief that conductive materials possess high resistance while insulating materials exhibit low resistance; that thicker wires have greater resistance than thinner ones of the same material; and that an increase in the length of a conductor leads to both greater brightness in bulbs and a decrease in electrical resistance. These findings suggest a fundamental misunderstanding of the principles underlying resistance and its observable effects in simple electric circuits.

In light of these outcomes, it is evident that students struggle to construct scientifically accurate mental models of electrical resistance, despite showing competence in identifying conductive and insulating materials. Therefore, targeted instructional interventions are necessary to correct these misconceptions and support conceptual change. It is recommended that future research further examine the root causes of these misunderstandings and develop instructional materials that effectively link the abstract concept of resistance to real-world phenomena. Moreover, science educators should integrate context-based learning strategies that explicitly connect resistance to everyday experiences, thereby enhancing students' conceptual understanding and minimizing persistent misconceptions.

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