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Abstract

The study aimed at identifying grade 12 student misconceptions about the electrical potential of spherical conductors in public high schools in Al Ain, United Arab Emirates. The study employed a quantitative research method and an exploratory survey design. A TTMC test was given to the students as a post-test following the completion of a unit of study. The study sampled 200 participants selected randomly from five boys' schools and five girls' schools. The results of the study revealed that the students had correct responses for only two question items (1 & 6) in tier one. Moreover, students had correct responses in only one question item (4) in tier two. Overall, many students displayed multiple misconceptions concerning most of the test items in both tier one (scientific content) and tier two (scientific reasoning). The results showed many misconceptions and misunderstandings of various concepts in the high school physics curriculum.

Keywords: Misconceptions; TTMC; two-tier; grade12.

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تقييم المفاهيم الخاطئة للجهد الكهربائي لموصل كروي مشحون لدى الطلاب

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مستخلص البحث :

تهدف الدراسة إلى تحديد المفاهيم الخاطئة لدى طلاب الصف الثاني عشر حول المفاهيم الخاطئة للجهد الكهربائي للموصلات الكروية المشحونة في المدارس الثانوية العامة في العين ، الإمارات العربية المتحدة. استخدمت الدراسة طريقة البحث الكمي وتصميم المسح الاستكشافي. تم إعطاء اختبار TTMC للطلاب كاختبار ما بعد الانتهاء من وحدة الدراسة. وأخذت الدراسة عينة من 200 مشارك تم اختيارهم عشوائيا من خمس مدارس للبنين وخمس مدارس للبنات. كشفت نتائج الدراسة أن الطلاب لديهم إجابات صحيحة عن عنصرين من الأسئلة فقط (1 و 6) في المستوى الأول. علاوة على ذلك ، كان لدى الطلاب إجابات صحيحة في بند سؤال واحد فقط (4) في المستوى الثاني. بشكل عام ، عرض العديد من الطلاب مفاهيم خاطئة متعددة تتعلق بمعظم عناصر الاختبار في كل من المستوى الأول (المحتوى العلمي) والمستوى الثاني (التفكير العلمي). أظهرت النتائج العديد من المفاهيم الخاطئة وسوء الفهم لمختلف المفاهيم في منهج الفيزياء في المدرسة الثانوية.

الكلمات المفتاحية: المفاهيم الخاطئة ; إختبار (إختيار متعدد من طبقتين) ; الصف الثاني عشر.

Introduction

The understanding of scientific concepts and phenomena is a key component of any science curriculum. Previous investigations of student understanding of physics concepts have shown that students possess misconceptions about physics concepts. Science educators and researchers agree that the prevalence of misconceptions among students not only presents serious obstacles to learning in physics, but also interferes with further learning (Caleon & Subramaniam, 2010). Thus, to promote effective learning, there is a need to identify the causes of these misconceptions and find ways to fix them and prevent them from occurring (Caleon & Subramaniam, 2010).

There are various assessment methods to identify student misconceptions in physics education, such as observation, interviews, multiple-choice tests (one-tier, two-tier, and three-tier tests), surveys, oral or written open-ended questions, and concept maps (Arslan, Cigdemoglu, & Moseley, 2012). To ensure the effectiveness of learning, a diagnostic formative assessment approach is required to develop clinical judgment about student understanding of significant scientific ideas and processes (Adodo & Gbore, 2012).

Two-tier multiple-choice tests were used in this study to identify student misconceptions. A two-tier test is a two-level multiple-choice test that diagnoses students’ alternative conceptions (Tsai & Chou, 2002). Two-tier multiple-choice (TTMC) testing was used by Chiu, Chiu, and Ho (2002) on electrical circuits and states of matter, respectively – and has been shown to be very successful in educational settings (Williams, 2006). Thus, using TTMC testing is appropriate for identifying student misconceptions; moreover, it helps not only to test student understanding but also to assess higher levels of cognitive thinking (Treagust, 2006).

In TTMC testing, conceptual questions are asked in multiple-choice format in the first tier of the questions. Then, the possible explanations for the answers in the first tier are asked (in multiple-choice format) in the second tier of the questions. In three-tier testing, a third stage asks about whether they are sure about their responses given in the first and second tiers (Kizilcik, Çelikkanli, & Gunes, 2015).

Purpose of the Present Study

The purpose of the present study is to identify student misconceptions about the electrical potential of spherical conductors among grade 12 students attending public high schools in Al Ain, United Arab Emirates (UAE), and to examine the nature of these misconceptions and whether misconceptions differ according to gender.

Research Questions

To investigate the above-mentioned purposes, the following research questions were formulated:

RQ1: How do grade 12 students understand the concept of the electrical potential of spherical conductors?

RQ2: What is the nature of the identified misconceptions of the grade 12 students?

RQ3: Is there any significant difference between male and female grade 12 students in terms of misconceptions in physics?

The Research Context

The new educational philosophy of the United Arab Emirates (UAE) focuses on the practical application of scientific concepts to prepare students to become innovative citizens of a post-petroleum world and new century (National Innovation Strategy, 2015). The UAE aims for science, technology, and innovation to become the drivers of sustainable socio-economic development. This aspiration builds on innovative initiatives launched in many sectors, including science education, as well as the focus on human development and economic diversity to ensure the prosperity of future generations. This strategy aspires to enhance science- and technology-based innovation to fulfill national aspirations and to address international challenges (National Innovation Strategy, 2015). However, it is difficult to achieve such strategic goals without enhancing students' understanding of physics as the foundation of planning, industry, and technology.

In the UAE context, the 2017 grade 12 physics textbook identifies 12 possible misconceptions related to the electrical potential of spherical conductors; these include the learner expecting the electrical voltage inside the conductor to equal zero; that a body without charge is also equal to zero;

that when the voltage is equal, the distribution of the charges is equal; and finally, that the closer the charges are to each other, the greater the potential energy (Ministry of Education, 2017, pp. 30–39).

In the UAE, students start learning physics as a separate subject in grade 10, in which they study 10 units on mechanics. One of the mechanics units focuses on potential energy and the conservation of energy. In the grade 11 and 12 physics curricula, units on electricity and magnetism are included. Grade 11 students study electrical energy and current energy in physics, with a focus on direct current circuits and resistance (Ministry of Education, 2017).

Literature Review

Misconceptions are encountered in physics at all educational levels. Many misconceptions have been identified on a variety of topics and they are not easy to change, as they are affected by learning in other related subjects (Eman, 2017). Student misconceptions in physics are caused by many factors, including prior knowledge, textbooks, lack of information, the complexity of chemical concepts, and ineffective communication.

The present study focuses on conceptual understanding and misconceptions of students. Thus, constructivism is chosen as a guidance framework for the present research. Patton (2002) stated that the human world is unlike the natural, physical world and hence must be studied in a different way. The constructivism perspective states that students build their own view of reality based on interactions with the external world and individual experiences. Knowledge is “constructed” in the mind of the learner (Tessman, 2009). Thus, learners who were taught the same information may have different understandings of the task depending on their backgrounds of prior knowledge and beliefs.

Overcoming existing misconceptions requires some kind of conceptual change has to occur in the student’s mind. Each theory of conceptual change explains misconceptions in different ways; these theories offer particular ways for removing or clarifying misconceptions. Thus, the initial student knowledge about to-be-learned material has to be evaluated carefully. In fact, the evaluation is important for learning and if misconceptions are not recognized early, students will fail to understand much of the new material, and they will give a false impression that they have learned something about science (Chi, 2005).

Learning and accepting the new ideas in science that challenge a person’s world view is a beginning of conceptual change. Thus, learning may occur in three various ways as stated by Chi (2008). First, when a student has missing or no prior knowledge and the learning process consists of adding new knowledge (Chi, 2008). Second, a learner may have some correct prior knowledge, but it is incomplete. In both missing and gap filling conditions, knowledge acquisition is of the enriching kind (Chi, 2008). Third, a student may have acquired ideas, either in school or from daily experience that are in conflict with to- be-learned (Chi, 2008).

In fact, the goal of conceptual changes theories as stated by Ohlsson (2009) *“is to understand and propose the way to overcome…stubborn resistance to change”* (p. 68).

The concepts of electricity are not easy to understand since they are not directly observable, and macroscopic patterns appear from unobservable phenomena (Chi, 2005). McDermott & Shaffer (1992) found out some common misconceptions about electricity in university physics students. One of those misconceptions is that students have beliefs that a battery is a source of constant current. Those beliefs might refer to as *“perhaps the most pervasive and persistent difficulty that students have with DC circuits”* (McDermott and Shaffer, 1992, p. 997). Additionally, other misconceptions included the failure to understand that an ideal battery maintains a constant potential difference between its terminals, the belief that current is consumed, distinction between potential and potential difference, and misunderstanding the concept of a complete circuit (Streveler, Litzinger, Miller & Steif , 2008, p. 288).

A developmental sequence of misconceptions in students’ models of electrical current flow was reported by Shipstone (1984). He stated the primitive model (Sink Model) that is often accepted by young children. This model showed that a single wire connection between battery and a device allows the device to work.

Andre and Ding (1991) found that children moved through a sequence of four models: the clashing currents model, the lessening current model, the shared current model, and the correct model. In Lessening current model, current flows in one direction around the circuit, becoming gradually weakened as it goes so that later components receive less while the shared current model, current is shared between the components in a circuit; however, current is not conserved. In the scientific correct model, current flows around the circuit and the amount flowing in the source is the same as the amount flowing out.

Another study conducted by Nasr, Hall, and Garik (2003) about students' understanding of linear circuits. They found out that "*students seem to conflate the field-concept of voltage with the substance-concept of charge and to construe voltage as a measure of a quantity of charge" (*p. 27).

The common students' misconceptions about electricity and electrical circuits are stated by different researchers. For example, students failed to differentiate between concepts of current, energy, power, and potential difference (McDermott & Shaffer, 1992). Then, a belief that current flow is a sequential process that has a beginning and the end (Picciarelly et al., 1999). Next, a belief that current gets used up as it flows through the elements in a circuit (Picciarelly et al., 1999; McDermott & Shaffer, 1992). Also, a belief that the current through a given circuit element is not affected by the circuit modification introduced after the element (Picciarelly et al., 1999). After that, a belief that a battery is a constant current source (Picciarelly et al., 1999; Cohen et al., 1983). Additionally, there were misinterpretations of Ohms law (Picciarelly et al., 1999; Cohen et al., 1983). Moreover, students failed to recognize that an ideal voltage source maintains constant potential differences between its terminals (McDermott & Shaffer, 1992). Furthermore, students had difficulty at identifying series and parallel connections (McDermott & Shaffer, 1992).

Al Kaabi (2014) conducted a study in the UAE to explore the misconceptions of grade 11 female students concerning concepts related to heat. The researcher used a three-tier multiple-choice test. The study found that most grade 11 female students expressed misconceptions about heat as a physical phenomenon and more than half of the students expressed misconceptions about heat equilibrium. The study recommended engaging students in an interactive way in science classrooms and simplifying the required content knowledge (Al Kaabi, 2014).

In Indonesia, a descriptive qualitative study was carried out by Setyani et al. (2017) to assess student conceptions and perceptions of a simple electrical circuit. The results showed that the students had alternative conceptions, and their conceptions were found to be affected by prior learning experiences, language, and inferences related to the following concepts:

1. A high-voltage wire has a potential difference, and it can cause electric shocks.

2. A conducting wire has a current that produces voltage and causes electric shocks.
3. The potential difference and resistance in a circuit are influenced by the electric current.
4. A thin filament causes a lamp to have less resistance, so it has a stronger current (Setyani et al., 2017, p. 11).

A study conducted in Thailand by Kamcharean and Wattanakasiwichb (2016) diagnosed the misconceptions of Thai and Lao university freshman students in thermodynamics using a TTMC test. The study found that most students answered the content-tier questions correctly but chose incorrect answers for the reasoning tier. The reason for the incorrect responses was incorrectly relating pressure to temperature when presented with multiple variables (Kamcharean & Wattanakasiwichb, 2016).

In Libya, Elwan (2011) found that students also had difficulties applying their scientific knowledge related to heat and temperature to everyday situations. For example, the students gave different answers to a question on the relative insulating properties of aluminum foil and wool (Elwan, 2011). In addition, the research study of Elwan (2008) showed that students had many misconceptions related to speed, velocity, acceleration, and position. Further instances of student misconceptions collected by teachers and documented as follows: doubling the speed of a moving object doubles the kinetic energy; the only "natural" motion is for an object to be at rest and the motion of an object is always in the direction of the net force applied to the object; and the terms "distance" and "displacement" are synonymous and may be used interchangeably, and thus the distance an object travels and its displacement are always the same (Elwan, 2011). Also, Elwan (2004) found that students had many misconceptions related to force and Newton's laws.

A study conducted in Turkey by Eryılmaz (2010) developed and validated a three-tier test to assess student misconceptions of heat and temperature. The students were asked to compare the heat and temperature of different-sized desks made from the same materials, and equal-sized desks made from different materials. Furthermore, the students were asked about the relationship between heat and temperature in these contexts. The results showed that the percentage of the participants' misconceptions varied between 5% and 48% for bachelor's students, 4% and 49% for master's students, and between 7% and 40% for doctoral students, depending on whether the participants manifested the misconception in every situation or in at least one situation.

In sum, misconceptions are caused by many factors, including prior knowledge, textbooks, teachers, curricula, lack of information, the complexity of chemical concepts, and ineffective communication. Some misconceptions were identified by Al Kaabi (2014) concerning heat as a physical phenomenon and heat equilibrium. Eryılmaz (2010) assessed student misconceptions concerning heat and temperature of different-sized desks made of the same materials and equal-sized desks made of different materials. Kamcharean and Wattanakasiwichb (2016) diagnosed student misconceptions of thermodynamics and incorrect conceptions relating of pressure to temperature when presented with multiple variables. Setyani et al. (2017) identified misconceptions related to high-voltage wires, electric shocks, and the potential difference and resistance in a circuit influenced by an electric current. Finally, student misconceptions are identified related to speed, velocity, acceleration, and position. All these studies grant this study some common insights like the importance of identifying the misconceptions by tier tests and device strategies to tackle them in order to enhance science literacy.

Methodology

Participants

The sample of this study consisted of 200 participants selected randomly from 10 UAE public high schools, including five boys' schools and five girls' schools. 100 grade 12 boys and 100 girls participated in the TTMC testing. The grade 12 students are 17-18 years old.

Study Design

The study employed a quantitative research method and an exploratory survey design. A TTMC test was given to the students as a post-test following the completion of a unit of study. The unit is about the electrical potential for a spherical conductor and it covers 6 main learning outcomes tackling the value of a charged particle and the number of electrons, a capacity of a conductor, the distribution of charges of both spherical and conical conductor, calculating the electrical voltage and the force that affects a charged particle inside an electrical field.

Instruments

The two-tier electrical potential misconception test comprised 12 items, and each question consisted of two tiers to assess the students' understanding of the electrical potential of spherical conductors. The first tier was the content tier, consisting of a conventional multiple-choice question with four choices. The second tier was the reasoning tier, which presented four reasons for the given answer to the content tier response. The 12 items covered the six learning outcomes of the unit of study, as described in "The Research Context" section. The weights of the questions are the same as they covered the learning outcomes.

The validity of the testing instrument was established by asking three science teachers, three science supervisors, and two university professors of science education to review the questions of the two-tier electrical potential misconception test considering the learning outcomes of the unit.

To ensure the reliability of the results of the TTMC test used in the present study, Cronbach's alpha coefficient was measured. The alpha coefficient of all 12 items of tier one was calculated (.72), and was found to be the same for the tier-two questions (.70). For both tiers, the alpha coefficient was (.74). In fact, the reliability ranged between low and medium; however, this instrument was reliable, and its internal consistency scores are acceptable.

Data Collection and Analysis

The students were given the two-tier electrical potential misconception test after studying the unit; this test was used by the science instructor as a formative assessment. The tests were collected and sent to the researcher, who corrected the test and asked another teacher to review it to ensure the correctness of the marking process. In addition, the researcher made a matrix of knowledge and misconceptions for the responses and assigned numbers to each item, as follows:

Table 1

Matrix of Knowledge and Misconceptions

Tier 1	Tier 2		
Correct	Correct	2	Scientific
Correct	Not correct	1	Misconception
Not correct	Correct	0	Misconception
Not correct	Not correct	0	Misconception

The data were checked to ensure that there were no obvious errors, inconsistencies, or instances of double coding. Next, the data was coded and each variable was assigned a number. Then, the descriptive statistics of frequency and the percentage of misconceptions were calculated. Finally, an independent samples *t*-test analysis was conducted to compare the mean scores of the male and female students.

Results

To answer the two research questions concerning whether the students understood the concepts related the electrical potential of spherical conductors and the nature of their identified misconceptions, data were collected from the TTMC test. The data are presented below in table2.

Table 2

Frequency and Percentages of Responses to Tier 1 and Tier 2 Questions

Questions	Tier 1		Tier 2	
	Incorrect Freq. & %	Correct Freq. & %	Incorrect Freq. & %	Correct Freq. & %
1. An electron moves north when it is set free in a regular electrical field. What is the direction of this field?	80 (40%)	120 (60%)	84 (42%)	116 (58%)
2. Which point can be surrounded by a zero electrical field effect?	82 (41%)	118 (59%)	87 (43.5%)	113 (56.5%)
3. By what factor does the value of a charged point's field intensity increase when the distance from it is doubled?	104 (52%)	96 (48%)	105 (52.5%)	95 (47.5%)
4. To which of the following four points illustrated below should the (q) charge move from its current position for it to increase its electrical potential energy?	65(32.5%)	135 (67.5%)	73 (36.5%)	127 (63.5%)

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5. If the electrical field intensity at point A, illustrated below, equals to zero, which of the following is true?	138 (69%)	62(31%)	143 (71.5%)	57(28.5%)
6. If the electrical voltage, at a point set in an electrical field of two charged points, equals zero, which of the following is true?	136 (68%)	64(32%)	141 (70.5%)	59(29.5%)
7. When a small alkaline ball balances in a regular electric field, this indicates that:	144 (72%)	56 (28%)	151 (75.5%)	49 (24.5%)
8. Given that the mass of a drop of oil is 1g, calculate the value of its charge under an electrical field intensity of 120 N/C.	147(73.5)	53(26.5%)	164 (82%)	36 (18%)
9. One of the following is not true regarding the conical conductor showed below, which has an electrostatic balance:	173(86.5%)	27 (13.5%)	174 (87%)	26 (13%)
10. The conductor illustrated below was charged with a negative. Which of the following is true about the conductor?	107(53.5%)	93 (46.5%)	107 (53.5%)	93 (46.5%)
11. Which of the following portions in not equal to zero for uncharged & isolated spherical conductors?	153(76.5%)	47(23.5%)	160 (80%)	40 (20%)
12. A positive charge point was set near the surface of a spherical conductor that is connected to the earth. Which of the following effects does the conductor have?	90 (45%)	110 (55%)	91(45.5%)	109 (54.5%)

The first three items target the concept of interpreting the force that affects a charged particle inside of an electrical field. Table 2 shows that the percentages of the students who understood the content of the concept in tier one were 60% for the first question, 59% for the second question, and 48% for the third question in tier one. In tier two, they were 58% for the first question, 56.5% for the second question, and 47.5% for the third question. For miscomputations in tier one, approximately 40% to 52% had incorrect responses for the first three questions, while approximately 42% to 56.5 % of the students had incorrect responses in tier one.

Questions 4 to 6 targeted the learning outcomes related to comparing the energy required to move a charge from one point to another and the change in the potential energy. It was observed that many of the students understood the content of the concept in tier one (67.5%) in question 4, while the number was observed to be less in tier two (63.5%). For questions 5 and 6, approximately 29% of the students understood the content (tier one) and reason (tier two) of the topic. For miscomputation, the percentage in tier one was 32.5%, whereas the percentage was higher in tier two (36.5%) for question 4. For the misconceptions of questions 5 and 6, the percentages were approximately 70% in both tiers.

Questions 7 and 8 targeted the concept of the value of a charged particle and the number of electrons. It was found that more than one-fourth of the students understood the content of the concept, with a lower percentage answering correctly in tier two. For miscomputation, the percentage in tier one ranged from 72% to 73.5%, whereas the percentage was higher in tier two (75.5% to 82%).

Questions 9 and 10 targeted the distribution of charges for both spherical and conical conductors. It was found that few students understood the content of the concept in tier one (13.5%) of question 9, while this percentage was lower in tier two (13%). For question 10, less than half of the students understood the content and the reason for it. The percentage in tier one was 86.5%, whereas the percentage was higher in tier two (87%) in question 9 on conical conductors. For question 10, the percentage was 53.5% for both tiers.

Question 11 targeted the factors that the capacity of a conductor depends on. It was found that less than one-fourth of the students understood the content of the concept in tier one (23.5%), while this percentage was even lower for tier two (20%). For miscomputation, the percentage in tier one was 76.5%, whereas the percentage was higher in tier two (80%).

Question 12 focused on calculating the electrical voltage for a spherical conductor set in either a field of charge or a field of another charged conductor. It was found that more than half of the students understood the content of the concept in tier one (55.5%), while this percentage was slightly less for tier two of the question (54.5 %). For miscomputation, the percentages in tier one (45%) and tier two (45.5%) were nearly the same.

Table 3

Independent Samples T-Test Mean Scores for Male and Female Students

Questions	Male		Female		t	df	Sig. (2-tailed)
	Mean	SD	Mean	SD			
1	0.26	0.68	0.72	0.97	-3.91	198	0.00
2	0.32	0.74	0.48	0.86	-1.41	198	0.16
3	0.28	0.70	0.24	0.65	0.42	198	0.68
4	1.42	0.91	1.12	0.10	2.22	198	0.03
5	1.06	1.00	1.12	0.10	-0.42	198	0.67
6	1.10	1.00	1.22	0.98	-0.86	198	0.39
7	0.98	1.01	0.92	1.00	0.42	198	0.67
8	0.06	0.34	1.08	1.00	-9.63	198	0.00
9	1.06	1.00	0.80	0.99	1.85	198	0.07
10	0.54	0.89	0.64	0.94	-0.77	198	0.44
11	0.80	0.99	1.46	0.90	-4.97	198	0.00
12	0.42	0.82	0.30	0.72	1.10	198	0.27

Concerning RQ3, “Is there any significant difference between male and female grade 12 students in terms of misconceptions in physics?,” no significant differences were found between male and female students for eight test items, while significant differences were found for four test items. Female students performed better than male students on three test items, while male students scored higher on only one test item.

In sum, the results of the TTMC test given to the students revealed that the students had correct responses for only two question items (1 & 6) in tier one above 60%, which is the passing mark in the high school grading system; moreover, students had correct responses in only one question item (4) in tier two above 60%. Overall, many students displayed multiple misconceptions concerning most of the test items in both tier one (scientific content) and tier two (scientific reasoning).

Discussion and Conclusion

Based on the findings of the present study, it can be concluded that most grade 12 students did not possess a good understanding of the electrical potential of spherical conductors in either scientific content knowledge or scientific reasoning. Additionally, most students had serious misconceptions concerning most concepts of the electrical potential of spherical conductors. This may relate to different factors, such as the method of instruction, the lack of practical lessons taught in a laboratory setting, or the fact that the students do not start physics classes until high school. Moreover, compared to other areas of science, physics concepts, such as force, motion, and physical and chemical changes, are often more abstract and thus more difficult for students to understand.

The methods used in the present study were similar to those of previous studies that used two-tier (Kamcharean & Wattanakasiwichb, 2013) or three-tier testing instruments (Al Kaabi, 2014; Eryilmaza,, 2010).

The findings of the present study were consistent with those of Eryilmaza, (2010). In other regards, the findings of the present study are unique in that no other researchers have investigated student knowledge and understanding of the electrical potential of spherical conductors. However, this present study partially was in line with some studies in the field of electricity since the concepts of electricity are not easy to understand since they are not directly observable, and macroscopic patterns appear from unobservable phenomena (Chi, 2005). In addition, it is similar to the findings of McDermott & Shaffer (1992) who found out some common misconceptions about electricity in university physics students especially the *persistent difficulty with DC circuit*. Additional similarity included the distinction between potential and potential difference, and misunderstanding the concept of a complete circuit (Streveler et al., 2008).

Another study conducted by Nasr, Hall, and Garik (2003) about students' understanding of linear circuits. They found out that "*students seem to conflate the field-concept of voltage with the substance-concept of charge and to construe voltage as a measure of a quantity of charge" (*p. 27).

Like the present study a belief that the current through a given circuit element is not affected by the circuit modification introduced after the element (Picciarelly et al., 1999). Besides, misinterpretations of Ohms law as found out by Picciarelly et al (1991).

Teachers should explain to students the nature of concepts (similar to the study of Chi, 2008) that can clarify students' misconceptions and provoke conceptual change. Teachers may transfer their misconception to students as people, regardless of their educational background and expertise level, hold various misconceptions about the natural world. The message to instructors is "do not make it worse". Sometimes, to simplify a new material, instructors attempt to use.

The findings of the present study present some implications for high school science educators, as the participants displayed many misconceptions and misunderstandings of various concepts in the high school physics curriculum. Thus, in order to remedy this situation, student misconceptions of the learning contents should first be identified, and then a remedial program that enhances student understanding should be implemented. To ensure that the students understand all the scientific concepts covered without doubt or ambiguity, projects, experiments, or tests using the two-tier model can be utilized.

In addition, high school science teachers require professional training on how to identify student misconceptions and develop strategies to provide them with accurate conceptual knowledge. In addition, teachers need to detect and correct these misconceptions immediately to ensure that they do not affect the students' subsequent learning. Teachers should also use various forms of formative assessment to identify and analyze misconceptions at an early stage. Furthermore, physics teachers should emphasize the use of the laboratory; practical, hands-on learning; demonstrations; as well as project-based tasks to deepen students' understanding of scientific knowledge. Physics teachers should also collaborate and share their students' misconceptions with one another through an initiative called the bank of physics misconceptions; this is a portfolio including all the expected misconceptions that students might encounter to ensure the correct concepts of physics. Finally, introducing basic physics concepts into elementary science classes will enable the gradual development and reinforcement of students' understanding of physics concepts. Expected misconceptions should be noted in student textbooks and teachers' guides and should be emphasized so that students and teachers understand their importance.

Grades based only on the results of multiple-choice test might not be the best indicator of students' real knowledge and conceptual understanding due to the high percentage of guessing. Teachers need to include oral or open-ended written exams where students exhibit their knowledge. These types of the questions are more accurate assessment.

Such a study should be carried out in depth and breadth to cover all the learning outcomes in the same grade and other grades to support science literacy and enhance the pedagogy of teaching and learning physics.

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