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Research Article

Identify Students' Misconceptions on Electrolysis using Two-Tier Diagnostic Test

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Abstract
In the literature, lack of conceptual understanding makes it difficult for students to relate chemistry to their learning experience, leading to misconceptions. Misconceptions are defined as phenomena where students have concepts that differ from scientific concepts. Misconceptions will affect how students construct scientific knowledge in the next learning material. Therefore, the study of this misconception is an important concern in the field of education. The purpose of this study was to identify students' misconceptions on electrolysis material. The instrument used in the study was a two-tier diagnostic test consisting of 10 questions at the first level and supporting reasons at the second level. The questions contained in this instrument are taken from previous research. This study used a qualitative descriptive approach involving 55 students from class XII Analytical Chemistry in one of the vocational high schools in Cilegon City. The results showed that out of a total of 55 students, there were students who understood the concept as much as 34%, students who experienced misconceptions as much as 30.73%, students who understood partially as much as 9.82% and students who did not understand the concept as much as 25.45%.

Keywords: Electrolysis, Misconceptions, Two-Tier Diagnostic Test

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1. INTRODUCTION

By its nature, chemistry deals with macroscopic as well as sub-miscroscopic which are both explained by the use of symbols. The model of thinking in chemistry consists of three levels, namely macro, relating to observable phenomena (sensory); micro, including atoms, molecules, ions, etc. as well as symbolic consisting of formulas, equations and graphs. Integrating these three levels of thinking models is important to make it easier for students to understand chemistry (Jaber & BouJaoude, 2012).

In the process of learning chemistry, students often have difficulty integrating all three models of thinking (macro-micro-symbolic), so chemistry is considered difficult material. Lack of conceptual understanding makes it difficult for students to relate chemistry to their learning experience, leading to misconceptions (Dindar & Geban, 2016).

Misconceptions are defined as phenomena where students have concepts that differ from scientific concepts. Misconceptions can be caused by the learning methods used (Barke et al., 2009), students' lack of understanding of chemical concepts they learned before, textbooks, language terms used by teachers and students (Hadinugrahaningsih et al., 2020), and the use of scientific language that is rarely used in everyday life (Sheppard, 2006). Students are constantly interacting with their environment, so they will gain some knowledge, skills and experience. As students learn new concepts, they will construct newly learned knowledge with the knowledge, skills and experience they gained from previous interaction activities. This constructing activity in some cases can lead to the development of concepts that contradict scientific facts referred to as misconceptions (Kiray & Simsek, 2020).

Misconceptions will affect how students construct scientific knowledge in the next learning material. Therefore, the study of this misconception is an important concern in the field of education (Ozmen, 2004). One of the benefits of examining student misconceptions is that it reminds teachers of students' difficulties in conceptualizing material and as an effective strategy to improve classroom teaching. Before teaching a concept, the teacher must know what the student knows and the possible misconceptions brought by the student during the lesson so that the teacher can choose the right strategy to prevent these misconceptions (Pinarbasi, 2007, Ozmen, 2004).

According to Suparno (2013), to minimize the occurrence of misconceptions, namely by identifying the occurrence of misconceptions that can be done by teachers or researchers. Misconceptions among students should be identified so that action to help students change them with more scientific concepts can be taken. One instrument that can measure students' understanding of concepts and confidence is a tiered multiple-choice diagnostic test. These instruments classify into three categories namely: two-, three-, and four-level multiple choice. The basic principle of diagnostic tests is that teachers must consider the intuitive knowledge that students have built if they want to understand students' thoughts related to the concepts of science that have been taught. (Ardiansyah, 2018).

To identify misconceptions in electrolysis material, this study uses a two-tier diagnostic test instrument. The test has been considered an effective assessment tool for determining students' conceptual understanding as well as alternative conceptions (Treagust, 1988). This diagnostic test consists of the first level containing a question as a content of the material and the second level consists of three to four possible reasons for the answer given in the first level (Treagust, 2006). In Treagust's (1988) study for diagnostic assessment, a two-level test is considered correct if the student's choice at the first level and at the second level is equally correct.

Many literatures have examined misconceptions in various scientific fields, for example in the field of chemistry, identifying student misconceptions on acid-base material (Pinarbasi, 2007), stoichiometry (Dahsah & Coll, 2007), solution chemistry (Adadan & Savasci, 2012), electrochemistry (Pickles & Tarhan, 2006), and others.

Electrochemistry is one of the chemical materials taught to students in high school / vocational / equivalent. Electrochemistry is classified as one of the toughest topics in chemistry for students, both at the school level as well as the university level. In general, students will have difficulty mastering it. One of the main reasons why misconceptions occur on this topic, because students need higher thinking skills covering the three levels of representation, as mentioned earlier. The movement of electrons cannot be seen and some students have to visualize the movement of those electrons. Students must understand the movement of ions and electrons during the electrolysis process, and be able to convert the processes that occur into chemical equations and formulas (Sia, 2010).

Based on literature studies, students also have difficulty studying electrolysis material because they cannot observe and imagine what happens at the microscopic level in electrochemical reactions (Yochum &; Luoma, 1995). The misconceptions related to electrolysis matter have been widely reported in several research literatures including: negatively charged anodes that attract cations while the cathode is positively charged so that they attract anions (Garnet &; Treagust, 1992), electrons are transferred from the cathode to the anode by ions in solution (Sanger &; Greenbowe, 1997).

Based on this background, the purpose of this study is to identify misconceptions of students in class XII on electrolysis material using the Two Tier Diagnostic Test.

2. RESEARCH METHODOLOGY

2.1 Research Design

This study used a qualitative descriptive approach to identify student misconceptions using a two-tier diagnostic test instrument on electrolysis material. The test instrument consists of 10 questions of true and false statements at the first level and supporting reasons at the second level. The questions contained in this instrument are taken from previous research, conducted by Sia et al. (2012).

2.2 Participants

The subjects of this study were class XII students majoring in Analytical Chemistry (KA) at one of the SMKN in Cilegon as many as 55 students divided into 2 classes, namely XII KA 1 and XII KA 2 who had studied electrolysis material in class XI.

2.3 Data Analysis

The stages of this study, namely (1) conducting a literature review to determine student misperceptions on electrolysis material in general, (2) looking for two-tier diagnostic test instruments in accordance with the misconceptions found in the first step, (3) distributing instruments to students, 4) analyzing the data obtained, and 5) making conclusions. Data analysis was carried out by calculating the percentage of students who experienced misconceptions by following the answer pattern as in table 1.

Table 1. Item Analysis Criteria in Two Tier Diagnostic Test (Costu et al., 2007)

Category				Points	Information
First Level		**Second Level**			
True	-	True	(B-B)	3	Understand
False	-	True	(S-B)	2	Partial Understanding
True	-	Not Answering	(B-T)	2	Partial Understanding
True	-	False	(B-S)	1	Misconception
False	-	Not Answering	(S-T)	0	Don't Understand
False	-	False	(S-S)	0	Don't Understand
Not Answering	-	Not Answering	(T-T)	0	Don't Understand

3. RESEARCH RESULTS

Student misconceptions on electrolysis material that were successfully identified using a two-tier diagnostic test are presented in Table 2. Of the 10 questions given to students, the largest percentage with the category of students understanding concepts are found in questions number 1, 7 and 8; The largest misconception student categories are 2, 5 and 6; And the category of students who do not understand the biggest concepts is found in questions number 3, 4 and 9. In question number 10, the number of students who understand the concept and the students who misunderstand the concept are the same. In this study, the biggest student misconceptions will be discussed in numbers 2, 5 and 6.

Table 2. Identify Student Misconceptions on Electrolysis Material

Concept/ Question No.		E-Process				E-Products			EE	AE		% Average
		1	**2**	**6**	**9**	**3**	**4**	**5**	**7**	**8**	**10**	
Understand	F	27	16	19	6	13	12	12	21	42	18	34
	%	49.1	29.1	34.55	10.9	23.64	21.8	21.8	38.18	76.37	32.73	
Partial Understanding	F	1	10	3	2	5	14	5	7	1	6	9.82
	%	1.8	18.18	5.45	3.64	9.1	25.46	9.1	12.73	1.8	10.9	

Concept/ Question No.		**E-Process**				**E-Products**			**EE**	**AE**		**% Average**
		1	**2**	**6**	**9**	**3**	**4**	**5**	**7**	**8**	**10**	
Mis	F	16	28	26	18	12	10	30	7	5	18	30.73
conception	%	29.1	50.9	47.27	32.73	21.8	18.18	54.55	12.73	9.1	32.73	
Don't Understand	F	11	1	7	29	25	19	8	20	7	13	25.45
	%	20	1.82	12.73	52.73	45.46	34,56	14.55	36.36	12.73	23.64	
Not Answering	F	0	0	0	0	0	0	0	0	0	0	0
	%	0	0	0	0	0	0	0	0	0	0	
Total		55	55	55	55	55	55	55	55	55	55	100

Note: E-Process = Electrolysis Process, E-Products = Electrolysis Products, EE = Effects of Electrolysis, AE = Application of Electrolysis

4. DISCUSSION

The benchmark used in complete learning is the level of ability per student, not per class. Students who are able to achieve competency standards can proceed to the next material, while students who have not reached competency standards must make improvements in order to fully master the material. However, sometimes students are found who experience misconceptions. Teachers can identify student misconceptions by using diagnostic test instruments. The test instruments used should use diagnostic tests in the form of multiple choice, reasoned multiple choice, open essay or closed essay. The test instrument is arranged based on learning indicators, so that later the teacher can find out the parts where students experience misconceptions so that teachers can immediately follow up on these misconceptions.

Factors that can cause misconceptions in electrochemical materials, namely insufficient prerequisite knowledge, incorrect interpretation of student language, use of various definitions and models, and use of various concepts and formulas that are more memorization than to understand and analyze a problem and chemistry textbooks can also cause misconceptions due to the use of inappropriate language to explain concepts in electrochemistry (Asnawi et al., 2017).

The sources that cause students to experience misconceptions include teacher teaching methods and textbooks that students use as learning references. The difference between students who experience misconceptions and those who do not understand concepts is that students who experience misconceptions tend to believe in the understanding they build from everyday experiences that cannot be scientifically proven, while students who do not understand concepts are those who cannot explain an event accompanied by scientific facts because they do not have scientific knowledge (Fitriza et al., 2020).

The reason why the topic of electrochemistry is considered difficult by students is because the concept involves three representative levels, namely macroscopic, microscopic and symbolic. Macroscopically, students need to learn the concepts of electrolyte and nonelectrolyte, electrolysis process and voltaic cell material. Microscopically, students need to understand the movement of ions and electrons during the electrolysis process, besides that students also need to understand the reaction process and the symbolic suppression of chemical reactions. Based on the results of research from Osman and Lee (2013), teachers can display an animation or interactive multimedia by utilizing ICT so that it can help students to visualize material that is considered abstract so that it is easier for students to understand. Other literature explains that using conceptual change text can overcome students' misconceptions on electrochemical cell material. The conceptual change text attempts to activate students' preconceptions, reminding students of possible alternative ideas that contrast with scientifically accepted conceptions through the use of examples and explanations. There are four conditions that must be met in order for conceptual change to occur so that students do not experience misconceptions: 1) there must be dissatisfaction with existing concepts, 2) new concepts must be clearly understood, 3) new concepts presented initially must make sense 4) new concepts must satisfy certain conditions (Yuruk, 2007).

1. Question Item Number 2

In question number two, a picture is presented about the relationship of polarity of the voltage terminals to determining the location of the anode and cathode. In the first level students are asked to determine the location of the anode and cathode by paying attention to the polarity of the voltage terminals using batteries, while in the second level, students are asked to explain the movement of ions and the flow of electrons in the electrolysis of the MgO melt. Based on the data that has been analyzed, it can be seen that as many as 16 students were identified as understanding concepts, 10 students had partial understanding, and as many as 28 students experienced misconceptions on this topic. Students can answer in the first level about the effect of the polarity of the voltage terminals on the location of the anode and cathode but in the second level students cannot explain the exact reasons related to the concept of ion movement and the direction of electron flow.

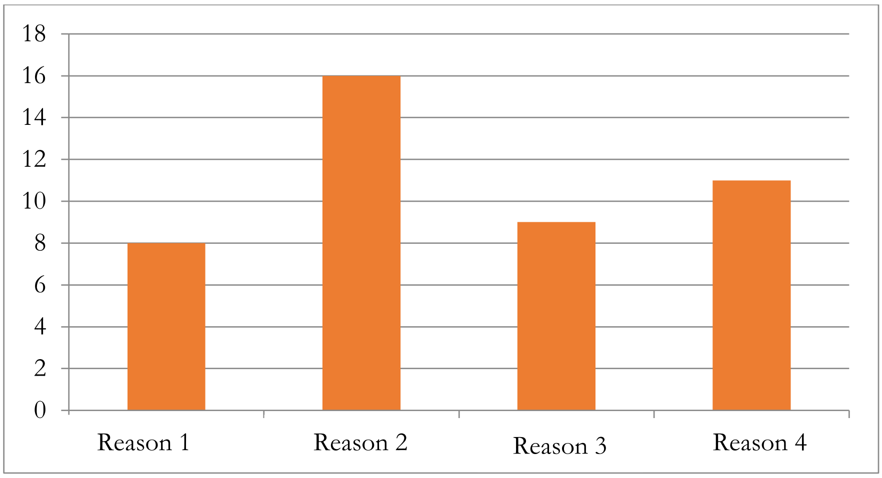

Figure 1. Student Answers Identified Misconceptions

Reason 1: Positive ions move to the anode and accept electrons

Reason 2: The negative ion travels to the anode and gives electrons (correct answer)

Reason 3: Positive ions move to the cathode and give away electrons

Reason 4: Negative ions move to the cathode and receive electrons

Then, as many as 1 student did not understand the concept of the influence of voltage terminal polarity on the location of the anode and cathode and the direction of electron flow. This may be because students have forgotten the material about electrolysis because this material is taught in class XI in the second semester while this test is given to class XII students in the second semester.

The results of research conducted by Osman and Lee, (2013) found that students could not explain the influence of polarity of voltage terminals on the location of the cathode and anode. When asked about voltaic cells and electrolysis cells, they confused the terminals of voltaic cells and electrolysis. In electrolysis, both the electrochemical cell terminals of the anode and cathode are connected to an external source that supplies the energy needed to produce a non-spontaneous reaction. When the energy source used is a battery, the image of the electrode terminal can be seen in figure 2. In electrolysis, electrons will enter the negative electrode, because there are no free electrons in the electrolyte and electrons cannot accumulate for long at the interface, a reduction reaction will occur that will use electrons at the interface. Therefore, the negative electrode in an electrolysis cell is the cathode and vice versa the positive electrode is the anode (Lefrou et al., 2009).

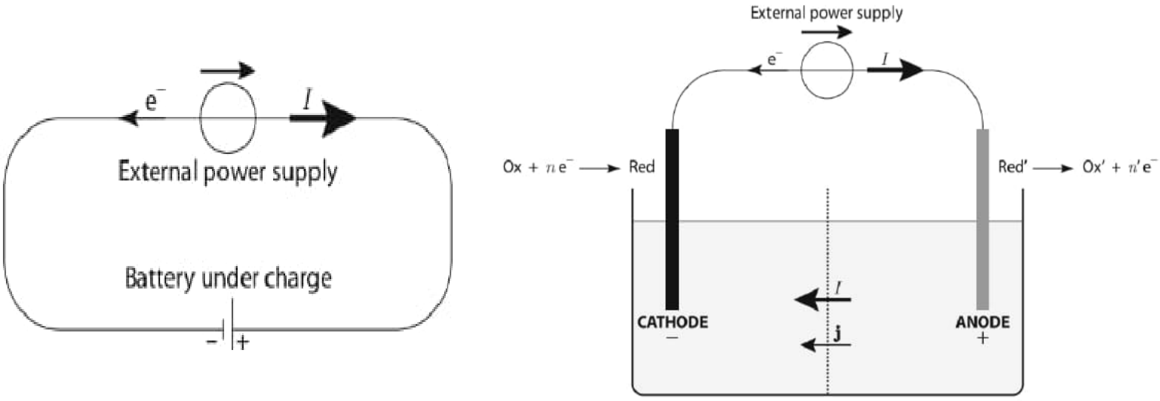

Figure 2. Electrode Terminals Using Batteries
Source: Electrochemistry: The Basics, With Examples

Research conducted by Osman and Tien (2017), found that as many as 55.6% of students experienced misconceptions when they were asked to explain the direction of electron flow in electrolysis cells. Students tend to draw the flow of electrons in the electrolyte or they reverse the direction of electron flow. Students assume that electrons flow in the electrolyte to complete the circuit.

2. Question Item Number 5

At the first level is presented a statement of the product of sulfuric acid electrolysis using an inert electrode and at the second level students are asked to give reasons for the answers chosen in the first level. Based on the data that has been analyzed, it can be seen that as many as 12 students were identified as understanding concepts, 5 students had partial understanding, 30 students had misconceptions and as many as 8 students did not understand concepts. This misconception occurs because students can answer at the first level about the electrolysis product of dilute sulfuric acid using an inert electrode but at the second level students cannot explain the exact reason related to the reaction that occurs from the electrolysis. The following is a graph of the distribution of answers of students who experience misconceptions.

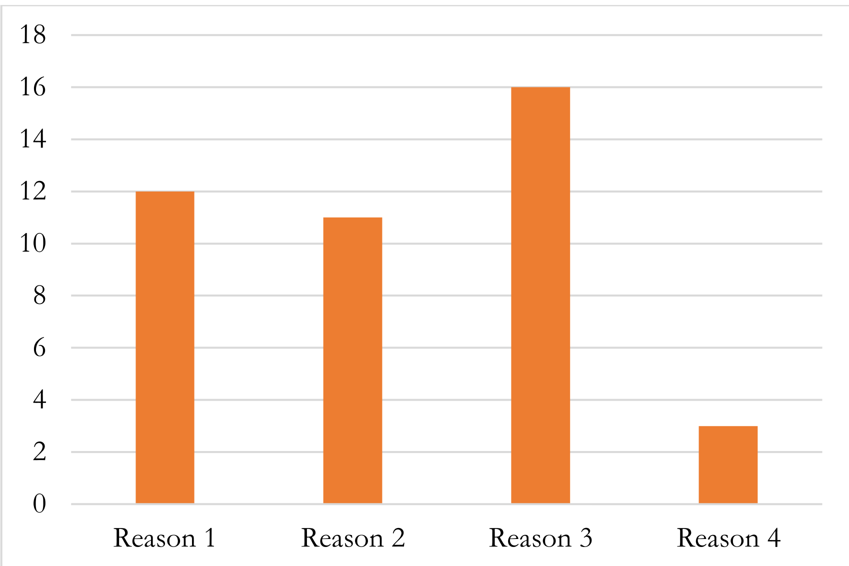

Figure 3. Student Answers Identified Misconceptions

Reason 1: Sulfate and hydrogen ions are selectively released (correct answer)

Reason 2: Sulfate and hydroxide ions are selectively released

Reason 3: The electrolyte consists of hydrogen ions and oxygen ions

Reason 4: Hydrogen and hydroxide ions are selectively released

The same research was conducted by Asnawi et al. (2017) that students identified misconceptions related to the determination of anodes and cathodes in electrolysis cells and products resulting from the electrolysis process. Misconceptions that occur in students can affect learning outcomes because learning objectives are not achieved so that they can reduce the quality of education (Nisa &; Fitriza, 2021). Therefore, the misconceptions identified above can be used as a reference for teachers to plan future learning strategies to minimize the occurrence of misconceptions so as not to inhibit students from receiving new knowledge in the next learning process and can be used as a source of information when remedial so that teachers can correct wrong concepts into right.

3. Question Item Number 6

In question number six, a statement is presented that in order to purify impure copper plates using a solution of copper(II) sulfate, pure copper must be used as the cathode. Students are asked to choose whether the statement is true or false. Then, students were asked to choose a reason from the answers they chose. Based on the data that has been analyzed, it can be seen that as many as 19 students were identified as understanding concepts, 7 students did not understand concepts, 3 students had partial understanding, and as many as 26 students experienced misconceptions.

Students who experience this misconception, can answer correctly in the first level regarding the statement that to purify impure copper plates using a solution of copper(II) sulfate, pure copper must be used as the cathode. However, in the second level students cannot explain the exact reason for the electrolysis event that occurs based on this statement. The following is a graph of the distribution of answers of students who experience misconceptions.

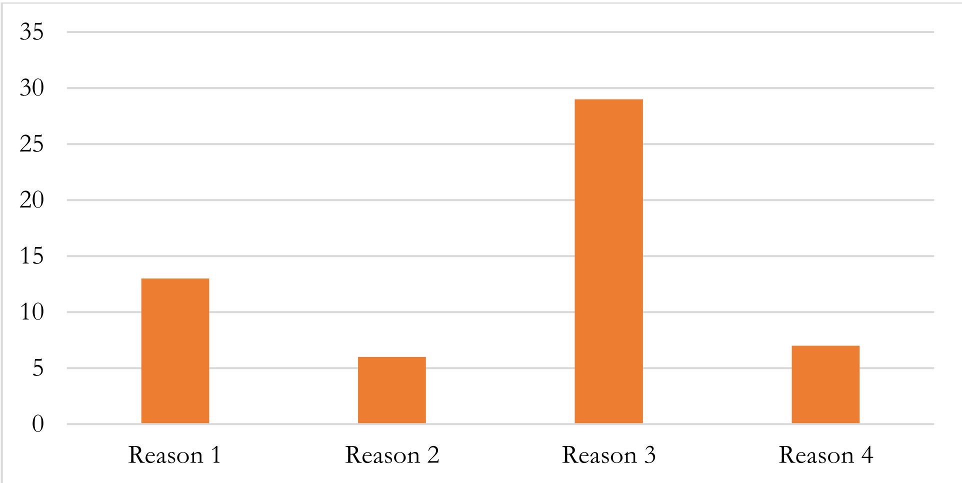

Figure 4. Student Answers Identified Misconceptions

Reason 1: Hydrogen ions are attracted to the cathode and selectively discharged

Reason 2: Hydrogen ions are attracted to the anode and selectively discharged

Reason 3: Copper(II) ions are attracted to the cathode and selectively discharged (correct answer)

Reason 4: Copper(II) ions are attracted to the anode and selectively discharged

In question number 6, at the first level students are asked to determine true or false statements regarding how to purify impure copper plates using copper (II) sulfate solution. The statement is correct, because to purify impure copper plates using a solution of copper (II) sulfate or ($CuSO_4$), pure copper must be used as the cathode. The one that acts as an anode is impure copper. Then, in the second level, students were asked to choose a reason from the answers they chose. Students who experience misconceptions do not realize that the correct reason is that the copper(II) ions are attracted to the cathode and selectively discharged.

According to McMurry & Fay (2004), copper purification is carried out by electrolysis of $CuSO_4$ solution, impure copper metal is used as an anode and cathode of pure copper. In impure Cu metal anodes, copper is oxidized with other metals that are easily oxidized such as zinc and iron. Other impurities that are not easily oxidized such as platinum fall under the cell as anode sludge, which is reprocessed into pure metal. At pure Cu cathodes, Cu^{2+} ions are reduced to copper metal, but other, less easily reduced metal ions remain in solution.

Here are the reactions that occur in the electrolysis:

Anode (oxidation): $Cu_{(s)} \rightarrow Cu^{2+}_{(aq)} + 2e^-$

Cathode (reduction): $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$

In this electrolysis, impure copper in the anode will undergo oxidation and dissolve as Cu^{2+} ions. Then, the Cu^{2+} ions will move towards the cathode and settle at the cathode as pure copper metal.

According to Widiyatmoko and Shimizu (2018), misconceptions in students can occur due to students' daily experiences with their environment, teacher factors, and textbook factors. Regarding the textbook factor itself, the results of research conducted by Jumbaendah and Raden Henni (2016) stated that there was a lack of electrolysis cell material in one of the chemistry textbooks handbook for students in grade 12. Based on this, the breadth of material both contained in textbooks and when teachers deliver material to students is one of the important things that must be considered to minimize or prevent misconceptions in students.

5. CONCLUSION

The results showed that out of a total of 55 students, there were 34% who understood the concept, as many as 30.73% had misconceptions, as many as 9.82% had partial understandings, and as many as 25.45% did not understand the concepts. Of the 10 two-tier diagnostic test questions given to students, the largest percentage of students understand concepts are found in questions number 1, 7 and 8; the largest misconception student categories are found in numbers 2, 5 and 6; and the category of students who do not understand the concept is found in questions number 3, 4 and 9. In question number 10, the number of students who understand the concept and the students who misunderstand the concept are the same. The misconceptions found are that students cannot explain, 1) the relationship between the polarity of the voltage terminals to determine the location of the anode and cathode, 2) the movement of ions and the direction of electron flow, 3) the products produced from the electrolysis of sulfuric acid using inert electrodes and 4) the purification of copper plates.

Conflict of Interest

We have no conflicts of interest to disclose.

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