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Enhancing Electroplating Conceptual Understanding Through Predict-Observe-Explain (POE) Method Supported by Simulations: an Analysis of Student Responses

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Abstract. This study aimed to determine the impact of the Predict-Observe-Explain (POE) method, supported by simulations of high school students' conceptual understanding of electroplating. To achieve this goal, an experimental design was employed to determine the effects of the POE method, supported by simulations. The research was carried out with a sample of 15 students, comprising 5 females and 10 males. The analysis of the students' responses at the prediction, observation, and explanation stages of the two selected POE activities revealed that they had misconceptions regarding the anode-cathode electrode and the connection of electrodes. Furthermore, students' responses indicated that there was confusion between the galvanic cell and electrolytic cell or a lack of information about the anode-cathode electrode connection points. Despite this, the simulations used in the study were deemed clear, comprehensible, and effective as the students provided correct answers during the observation stage of the activities. In the explanation phase of POE activities, students attributed the differences between their predictions and observations to a lack of knowledge.

Keywords: Conceptual Understanding, Predict-Observe-Explain, Simulation

1 Introduction

The teaching materials significantly support learning processes in the teaching environment. One of these teaching materials is simulations. Interactive simulations can increase student achievements by making the learning process more interactive. In addition, in many studies [1, 2, 3,4] conducted in recent years, it has been seen that activities carried out with the constructivist approach have a positive effect on students' conceptual understanding. For this reason, a teaching-learning process prepared with a constructivist approach-based Predict-Observe-Explain (POE) activity is expected to have a positive effect on students' conceptual understanding. This study investigated the effect of the POE method supported by simulations of students' conceptual understanding of electroplating.

1.1 Electrochemistry

Students found it difficult to understand science and chemistry [5,6]. The fact that chemistry includes abstract subjects causes students to have difficulty in mental visualization and interpretation [6]. Finley et al. [7] and Johnstone [8] emphasized

especially electrochemistry among the subjects that students have difficulty in chemistry. Butts and Smith [9] revealed that students have more misconceptions because of their difficult understanding of topics such as electrochemical battery, oxidation-reduction reactions in the subject of Electricity and Chemistry.

Bar et. al. [10] revealed that the difficulties experienced in understanding the concept of electrolysis in high school are carried to university and these difficulties continue in university education. Sia et. al [11] conducted a study to examine high school students' understanding of the concept of electrolysis. For this purpose, they used a test tool called "Electrolysis Diagnostic Instrument (EDI) and analyzed students' answers to questions about electrolysis. In light of these findings, the researchers observed that high school students had a general understanding of the basic principles of the electrolysis process but were unable to explain the chemical reactions that occur during electrolysis.

A review of the literature revealed that students have various misconceptions about electrochemistry. For example, Sanger and Greenbowe [12,13] revealed some misconceptions regarding electrolysis and battery reactions in their studies. Some of these misconceptions are as follows: "In electrochemical batteries, the cell is the anode, and which cell is the cathode is decided according to their physical locations. In electrolysis, reduction reactions occur at the anode, and oxidation reactions occur at the cathode. Furthermore, Yılmaz et al. [14] aimed to reveal students' misconceptions about electrochemistry in another study they conducted. In this study, students were asked: "In electrolytic cells, oxidation occurs at the cathode and reduction at the anode. Oxidation and reduction events are independent of each other.'

This study aims to address students' possible misconceptions and incorrect or incomplete learning about electrolysis, as revealed by research in the literature, and to investigate the possible effects of the POE method supported by simulations in eliminating these misconceptions. In this context, this study makes important contributions to the literature.

1.2 **Predict - Observe – Explain**

Predict-observe-explain (POE) is a learning method that includes the stages of prediction-observation-explanation of the event or situation that occurs in an activity applied to students. In the first stage of POE, the prediction stage, students predict the outcome of the event based on its causes. In the second stage, students are expected to take notes about their observations, and in the last stage, the explanation stage, they are expected to speculate on whether there are similarities and differences between their predictions and observations, and if there are differences, the reasons for these differences [15]. In recent years, POE has been mostly used in concept teaching and to reveal misconceptions [16].

Bilir et al. [17] examined the effect of activities including POE, STEM, 5E learning model, concept cartoons, and virtual experiments on pre-service teachers' images of atoms and atomic models. The results revealed a positive effect on the images of pre-service teachers about atomic models. In another study conducted by Alkan et al. [18], it was concluded that POE-supported activities on hydrocarbons were effective in increasing the chemical achievement. Karadeniz et al. [19] examined how these activities affected students' metacognitive awareness with worksheets they developed

using the predict-observe-explain strategy related to the ninth-grade unit of chemistry, the states of matter. The metacognitive awareness of the group to which the POE activity was applied increased their metacognitive awareness in all sub-dimensions except for two. Karamustafaoğlu and Naaman [20] investigated the effectiveness of teaching electrochemistry concepts using the POE strategy in their study with first-year pre-service teachers. In the study, it was concluded that there was a significant difference in the experimental group, and that POE improved conceptual understanding. This study investigated the effect of POE activities on conceptual understanding.

1.3 Purpose of the Study

This study aimed to investigate the effect of the Predict-Observe-Explain (POE) method supported by simulations on improving the conceptual understanding of metal plating experiments on electrolysis in senior high school chemistry students.

2 METHOD

2.1 Research Model

In this case study, a qualitative research method was used. A case study examines one aspect of an event in detail [21,22,23]. Case studies have revealed the effect of elapsed time on the subject and differences in opinions on the subject [23]. Punch [24] emphasized that this research method enables us to understand the situation in more depth by revealing information that may be overlooked.

2.2 Participants

The sample of this study consists of fifteen 12th grade students studying in a private high school in the 2023-2024 academic year. Five of these students were female and ten were male. Of the fifteen students, one female and five male students were 18 years old, and nine students were 17 years old.

2.3 Data Collection

The POE worksheets developed by the researchers were used as data-collection tools.

This study examined students' conceptual understanding of electroplating topics related to electrolysis in 12th grade chemistry courses. POE worksheets, supported by simulations, were used to reveal their conceptual understanding. The questions in the POE worksheets were prepared in accordance with the objectives of the Chemistry and Electricity unit of the 12th grade secondary chemistry course.

Before the data collection phase, the students were informed of the Predict-Observe-explain teaching method.

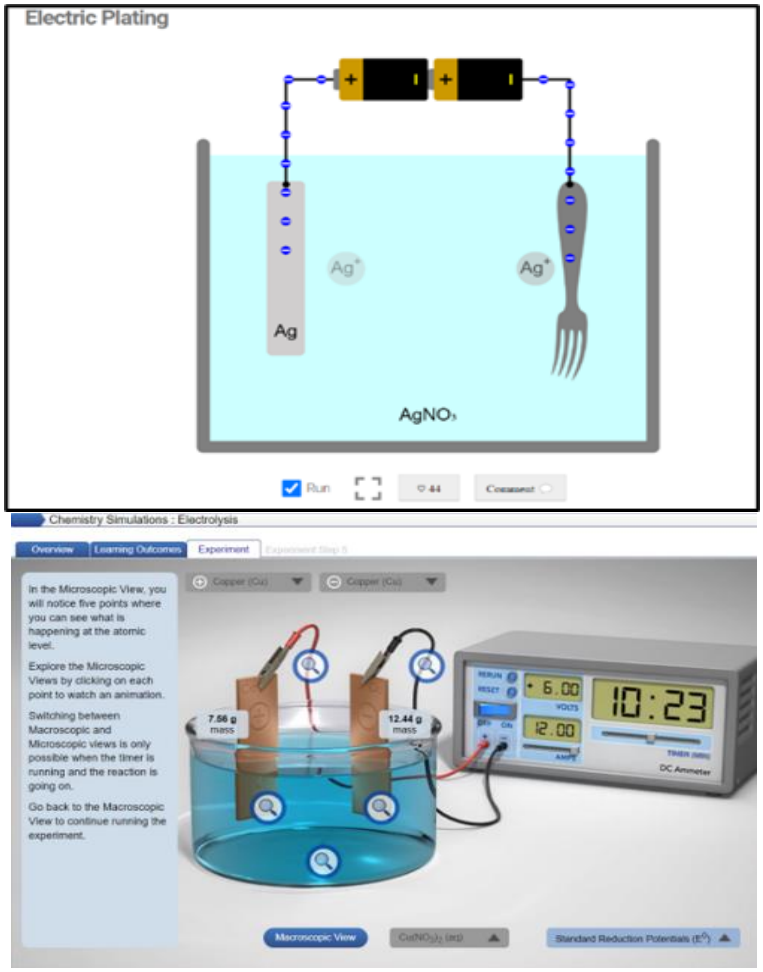


Fig. 1. Screenshots of simulations used for two selected POE events.

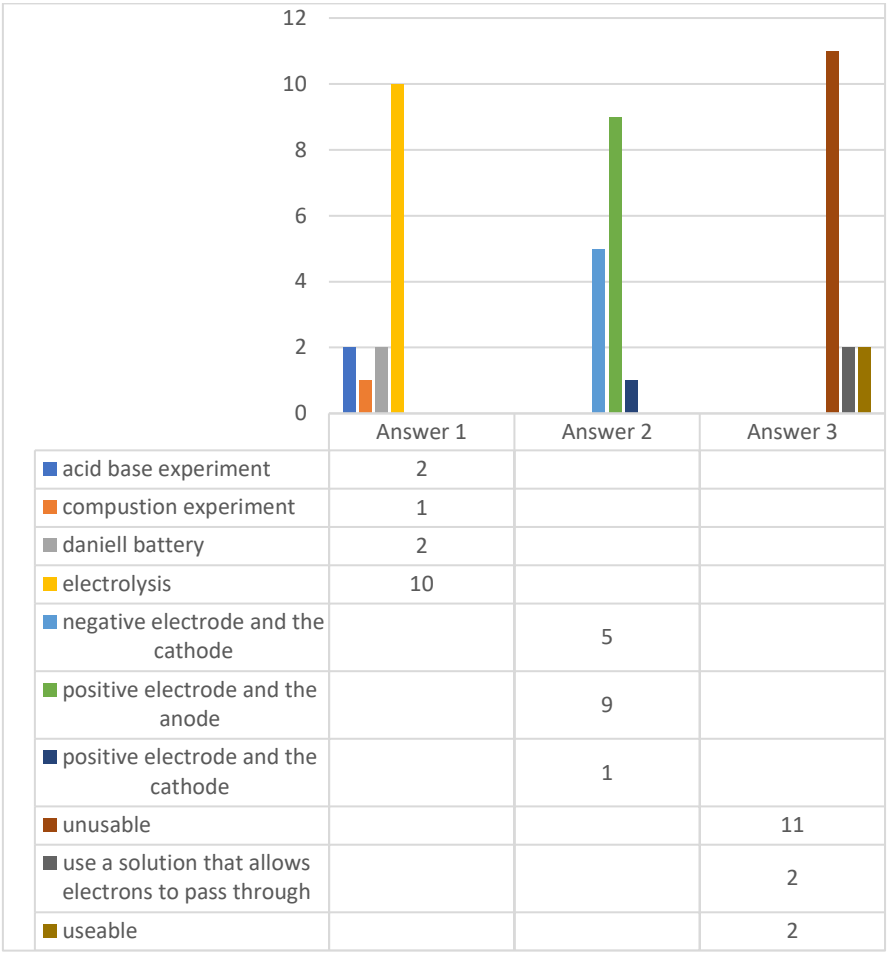
2.4 **Data Analysis**

The students' responses at the prediction, observation, and explanation stages of two of the selected POE activities used within the scope of the study were analyzed using content analysis. The purpose of the content analysis is to determine the general orientation of the selected study topic [25]. Content analysis also provides ideas for future studies on this topic [26]. Content analysis also contributes to improving the publication policy of research and providing ideas to researchers [27]. In the Javalab Science Simulation and Pearson POE activities, student responses at the prediction-observation-explanation stages were tabulated and analyzed**.**

3 FINDINGS

3.1 **Findings from Javalab-Electric Plating**

In the prediction phase of the POE activity in which Javalab- Electric Plating simulation was used; ten out of 15 students gave the correct answer electrolysis to the question “What kind of experiment should be used to perform metal plating with the above equipment?” (see Fig. 2). This result shows that most students understood the purpose of the electrolysis experiment. This question was used to reveal students' prior knowledge. Although most of the students answered the first question correctly, nine students answered the question “To which electrode should the fork be connected in the beaker?” as the anode or a positive electrode. One student answered +, that is, the cathode electrode (see Fig. 2). This result shows that the student confused the galvanic cell setup with the electrolysis setup or that he/she did not have knowledge of the connection points of the anode and cathode electrodes. In the prediction phase of the POE activity, eleven students answered the question, “Can one of the Cu $(NO_3)_2$ and $Ni(NO_3)_2$ solutions be used instead of $AgNO_3$ in the experimental vessel? Why?" Eleven students answered,”” It cannot be used. Because it must have silver in it.", 3 students answered, it can be used.’ and two students answered, ‘Any solution that will allow the passage of electrons should be used.’ (see Fig. 2). Eleven students understood why the electrolyte solutions were used in the electrolysis experiments. It was revealed that two students who answered “can be used” did not understand the role of electrolyte solutions in the experimental setup and the other two students had misconceptions that electrons are transferred from one electrode to another through electrolyte solution.



	Answer 1	Answer 2	Answer 3
acid base experiment	2		
compustion experiment	1		
daniell battery	2		
electrolysis	10		
negative electrode and the cathode		5	
positive electrode and the anode		9	
positive electrode and the cathode		1	
unusable			11
use a solution that allows electrons to pass through			2
useable			2

Fig. 2. Javalab- Distribution of students' answers to the questions in the estimation phase of the Electric Plating POE Activity

In the observation phase of the POE activity, it was asked “To which electrode was the fork connected in the beaker? Which electrode did the Ag^+ ions move? What kind of change did you observe in the mass of the Ag electrode?” They answered all the questions correctly by giving answers to the cathode-negative electrode decrease (see Fig. 3).

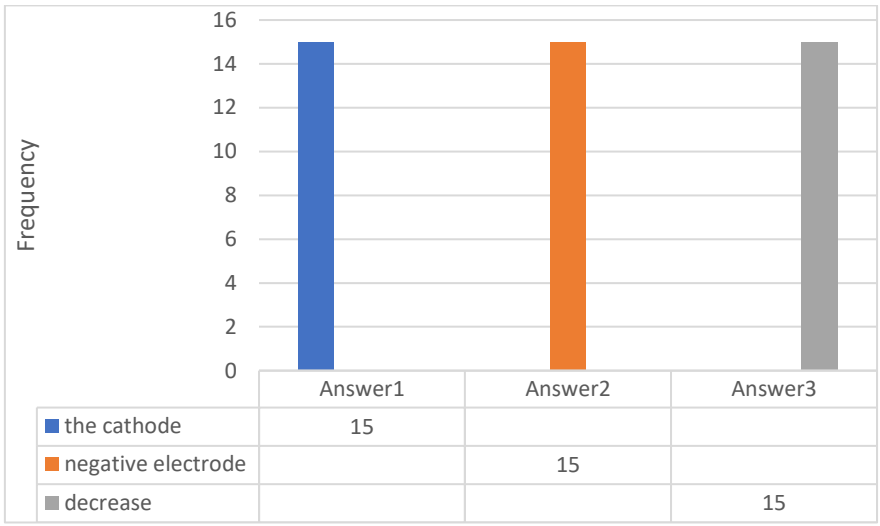


Fig. 3. Distribution of students' answers to the questions in the observation phase of Javalab-Electric Plating POE Activity

In the observation phase of the POE activity, eleven of the students answered the question "In the experiment, did electrical energy turn into chemical energy or chemical energy turn into electrical energy?" Four students answered that chemical energy was converted into electrical energy (see Fig. 4).

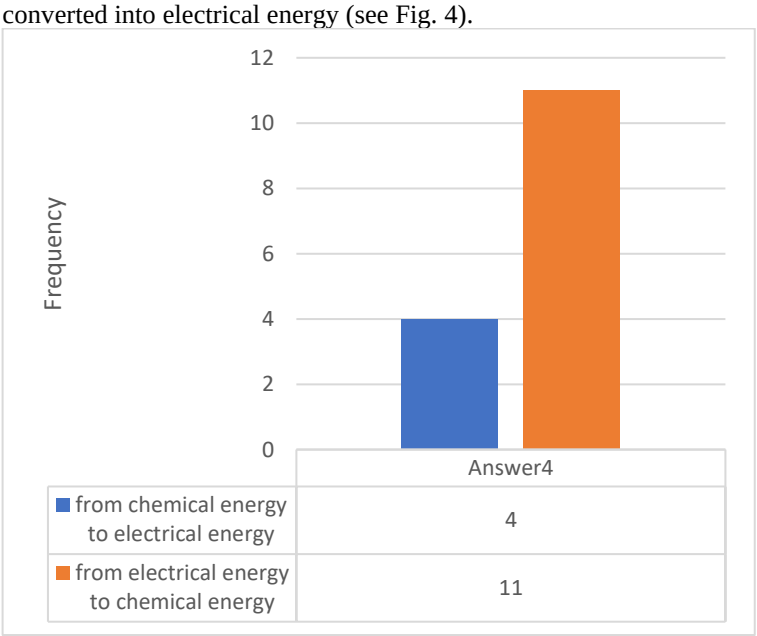


Fig. 4. Javalab- Distribution of students' answers to the questions in the observation phase of the Electric Plating POE Activity

In the explanation phase of the POE activity in which Javalab-Electric Plating simulation was used, students gave the following answers: “I thought that the mass of the anode would increase, and the mass of the cathode would decrease.” “I did not know to which electrode the electrodes were connected.” “I was confusing the anode and cathode electrodes. The students stated that the differences between their predictions and observations were due to their lack of knowledge of electroplating.

3.2 **Findings from Pearson- Electrolysis TGA Activity**

The first question asked in the prediction phase of the Pearson-Electrolysis TGA activity was “What kind of experiment should be used to perform metal plating with the above equipment?.” All students answered “electrolysis” to this question (see Fig.5). These answers revealed that students understood the purpose of the electrolysis experiment. In addition, while ten students gave correct answers in the first experiment simulation, fifteen students gave correct answers in this experiment simulation, indicating that students' conceptual understanding improved, and they grasped the electrolysis experiment. In the prediction stage of the activity, 8 students answered the question “To which electrode should the object to be coated with metal be connected in the test container?” as the + electrode, that is, the anode (see Fig.5). This result shows that students have misconceptions about cathode and anode electrodes. The last question in the prediction phase of the activity consisted of two fill-in-the-blank questions. These questions are "After the experiment starts, I expect the mass of the anode to .... [increase/decrease/remain the same]." "I expect the mass of the cathode to .... [increase/decrease/remain the same] after the experiment starts." While filling in the blanks, five of the students gave the answers “increase/decrease” (see Fig.5). This result shows that students could not learn the reactions occurring at the cathode and anode electrodes.

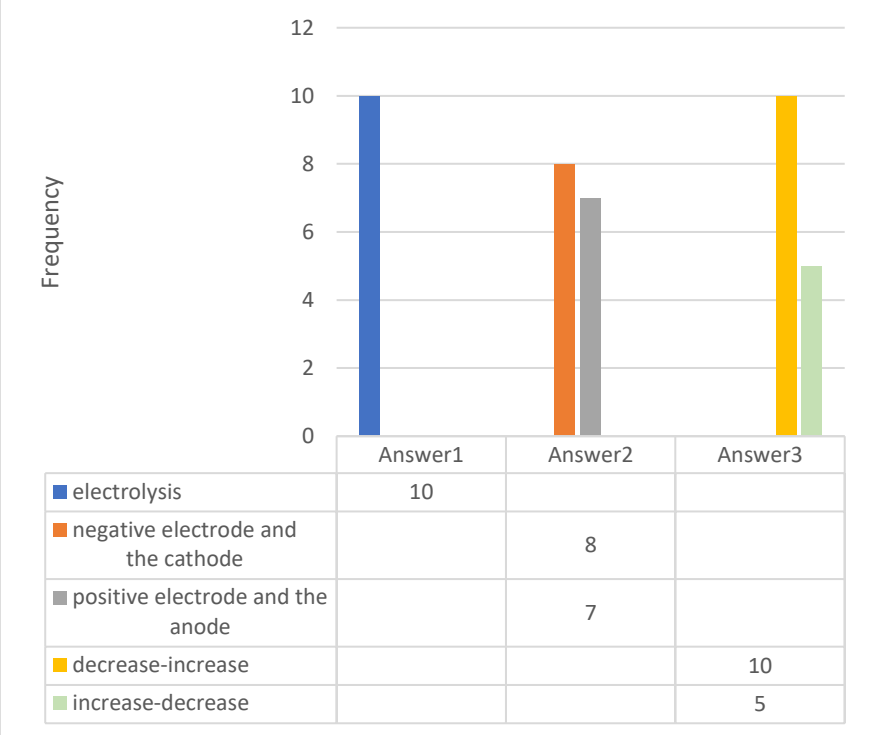


Fig. 5. Distribution of students' answers to the questions in the prediction phase of the Pearson-Electrolysis POE Activity

All answers to questions "Initial electrode masses = ……. Which electrode is the object to be plated with the connected metal? The mass of the anode in the experiment... [increased/decreased/remained the same] and the mass of the cathode after the experiment started … [increased/decreased/remained the same]" in the observation phase of the worksheet were accurate (see Fig.6).

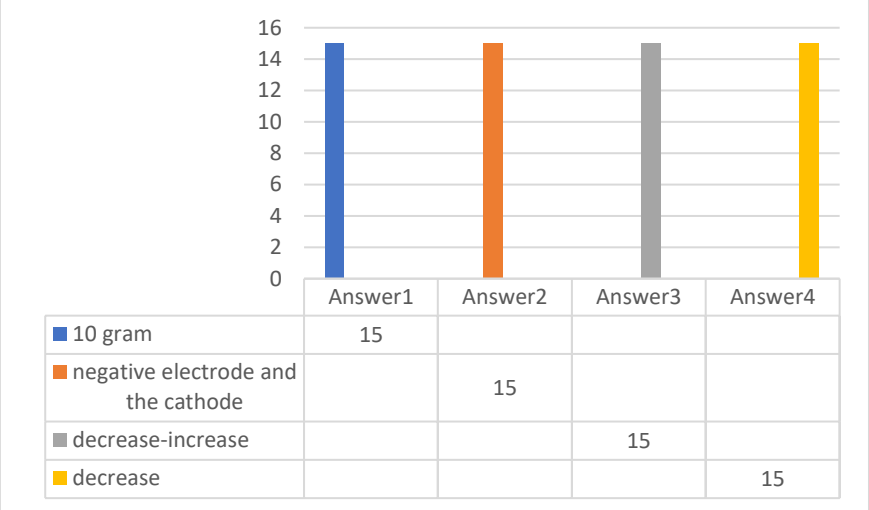


Fig. 6. Distribution of students' answers to the questions in the observation phase of the Pearson- Electrolysis POE Activity

At the explanation stage of the worksheet, 10 students stated that since they learned how the cathode and anode electrodes were determined in the simulation in the first Javalab Electric Plating POE activity, which electrode to connect the fork to, and which electrolyte was used during silver plating, they could easily distinguish similar questions in the prediction stage of this study, and that there was no difference between their predictions and observations. While explaining the reasons for the difference between their predictions and observations, the other five students said,' I did not fully understand the subject. I cannot distinguish between the anode and cathode in galvanic and electrolysis cells. I cannot predict the change in anode and cathode masses.

4 CONCLUSION AND DISCUSSION

Within the scope of this study, the answers given by the students at the POE stages (prediction, observation, explanation) in the worksheets containing the POE activities were analyzed in general. Considering that some students stated that their predictions and observations matched because they learned the correct ones after doing the first simulation-supported POE activity, it is seen that the lesson plans realized with simulations were effective on students' conceptual understanding. The fact that all the answers given by the students especially to the observation parts of the POE activities were correct shows that the simulations were clear, understandable, and instructive.

The findings of our study showed that although the students generally grasped the logic of electrolysis, they had difficulty in distinguishing between anode and cathode electrodes and understanding the function of the electrolyte. These findings support the findings of Sia et al. [11] that they understood the general framework of electrolysis.

The misconceptions revealed by Sanger and Greenbowe [12,13] and Yılmaz et al. [14] (e.g., deciding which cell is the anode and which cell is the cathode in electrochemical batteries according to their physical locations, reduction reactions at the anode and oxidation reactions at the cathode in electrolysis, thinking that oxidation reactions occur at the cathode and reduction reactions occur at the anode in electrolytic cells) were also found to be misconceptions encountered in the findings of this study. From this point of view, at the end of the study, it was determined that students had various misconceptions about chemistry and electricity.

In a study conducted by Bar et al. [10], although university students' knowledge of chemistry can be increased by course contents, especially those that include topics such as atomic physics, they can bring the misconceptions they acquired in high school to the university. This study, if conducted for high school students, may help to recognize misconceptions, and change the chemistry knowledge that will be carried to university as correct scientific knowledge.

Huri et al. [28] facilitated the conceptualization of the electrolyte concept with concepts in daily life by giving the example that coconut water is an electrolyte because it contains charged particles in water. Similarly, in this study, the examples in the introductory texts of the POE activities helped students associate electrolysis with contexts in daily life. In the worksheets, it was aimed to attract the student's attention by mentioning the reflections of the subject in daily life before proceeding to the POE stages. For this purpose, the following paragraphs were placed at the beginning of the worksheets; "Gold plating method is frequently used in many sectors such as electronics industry, jewelry, space, and aviation, but the usage areas of gold plating are not limited to these. It is also possible to see some objects and vehicles being plated with gold. For example, in Dubai, you can see many cars plated with gold in line with the special orders of customers." "Metals, which have many uses in daily life, become unusable over time due to environmental factors. In order to prevent corrosion, metals are coated with other metals that are more resistant to wear."

One of the students stated that there was no difference between his predictions and observations in his answer to the explanation stage of the Pearson -Electrolysis POE activity, in addition to this, he stated that he had a lot of fun while doing the activities and that he did not know that the subject of electrolysis was so much in daily life. From this point of view, simulations make learning more fun, and the daily life sections in the worksheet prepared by the researchers attract students' attention and enable them to associate the subject of electrolysis with daily life. In this study, students' opinions about Predict-Observe-Explain (POE) Method Supported by Simulations were not collected. In future studies, questions such as “Were the activities fun?,” “Were you interested in the simulations?” could be added to the worksheets to get all students' opinions on this subject.

Declarations

Funding. The authors did not receive support from any organization for the submitted work.

Conflicts of Interest. The authors declare that they have no conflict of interest.

Data Availability. The datasets generated during and/or analyzed during the current study are available from the corresponding authors on reasonable request.

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