

Understanding Electrochemistry Concepts using the Predict-Observe-Explain Strategy

Sevilay Karamustafaoğlu
Amasya University, TURKEY
Rachel Mamlok-Naaman
Weizmann Institute of Science, ISRAEL

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The current study deals with freshman students who study at the Department of Science at the Faculty of Education. The aim of the study was to investigate the effect of teaching electrochemistry concepts using Predict-Observe-Explain (POE) strategy. The study was quasi-experimental design using 20 students each in the experimental group (EG) and control group (CG). An Open-Ended Test (OET) and Multiple Choice Test (MCT) were used as pre- and post-test respectively. The POE was used to treat the experimental group, post test scores showed a statistically significant difference in performance by the EG, which had less misconception. The results of this study suggest that using The POE strategy is conceptual understanding.

Keywords: electrochemistry, chemistry learning, predict-observe-explain strategy

INTRODUCTION

One of the main goals of education is that students should learn how to use the data which they gather for the interpretation of events and experiences. In the past three decades, 'meaningful learning' has been strongly advocated by science educators (Novak, 2002; Tsai, 1998, 1999). Among educators, there seems to be a growing recognition of the need to refocus on students' learning outcomes derived from meaningful learning and their conceptual understanding of scientific ideas (Black, 2005; Chi, Slotta & Leeuw, 1994; Venville, Dawson, 2010). It is suggested that constructivist-oriented instruction or strategies can promote students' meaningful learning (Chiu, 2007; Kearney & Treagust, 2001; Tsai, 1998, 1999). Therefore, many teaching strategies have been suggested in order to improve student performances in science learning, e.g., concept mapping (Kinchin, 2000; Schmid & Telaro, 1990), the learning cycle (Lawson, 2001), cooperative learning strategies (Soyibo & Evans, 2002), and conceptual change instruction (Alparslan et al., 2003). Moreover, science educators have proposed that the integration of multiple teaching strategies could promote students' conceptual learning in science classrooms (Bean et al, 2001;

Correspondence: Sevilay Karamustafaoğlu,
Amasya University, Faculty of Education, Primary Education
Amasya, Turkey
E-mail: sevilayt2000@yahoo.com
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Odom & Kelly, 2001).

White and Gunstone (1992) have promoted the predict-observe-explain (POE) procedure as an effective strategy for eliciting and promoting discussions of students' science conceptions. This strategy involves students in predicting the results of an experiment demonstration, explaining their prediction, observing the demonstration, and finally explaining any discrepancies between their prediction and their observation. Whether used individually or in collaboration with other students, POE tasks can help students explore and justify their own individual ideas, especially in the prediction and reasoning stage. If the observation phase of the POE task provides some conflicts with the students' earlier predictions, reconstruction and revision of the initial ideas are possible (Searle & Gunstone, 1990; Tao & Gunstone, 1999).

In the past, the POE strategy was widely used for science education at secondary and high school levels as a tool for teaching and assessment (Kearney, Treagust, Yeo, & Zadnik, 2001; Palmer, 1995; White & Gunstone, 1992). Palmer (1995) also argued that POE could be a suitable technique for primary school science. In summary, POE strategy is regarded as a constructivist-oriented learning strategy to promote students' conceptual learning (White & Gunstone, 1992). Consequently, in this study, it was combined with small group cooperative learning activities and used to promote the scientific knowledge of the students.

The 'predict-observe-explain' (POE) strategy requires students to carry out three tasks:

Task 1: A physical situation is demonstrated to the students who are then required to predict the result of a specific change to the physical situation. Students are also asked to explain their prediction.

Task 2: When the students conduct the experiment, the students are asked to describe what they see.

Task 3: Students are required to reconcile any conflict between prediction and observation.

White and Gunstone (1992) pointed a number of issues in using POEs within the classroom:

- It is important that students are presented with situations which they feel are relevant and real, and are able to make a prediction based on some personal reasoning. The POE strategy is unlikely to be of much value if students engage in pure guessing.
- It is necessary to have a classroom where students feel free to give their opinions at appropriate times. The manner in which predictions with reasons are made can vary but it is important to get some commitment from every student before the observation stage.
- It is important that the class views are summarized and fed back to the students during the prediction stage. In this way students, on the one

State of the literature

- Prospective teachers should know the electrochemistry concepts related to their daily life and should teach them to their students without misconceptions.
- If the prospective teachers are not guided properly, they can forget concepts about chemistry and electrochemistry. As a result, they cannot be an effective teacher throughout their teaching experiences.
- The curriculum of the prospective science teachers should provide activities similar to POE (Prediction- Observation- Explanation). Otherwise, they cannot improve and apply these skills in their classrooms.

Contribution of this paper to the literature

- This study found that the experimental group who received POE activities was more successful than the traditional group about learning some electrochemistry concepts. POE contributes to the experimental group on meaningful learning.
- This study contributes to the teachers and researchers to use POE in different subjects that they teach in the classrooms. This paper encourages them to benefit from POE and to realize the learning.
- The students of the prospective science teachers who use POE in their teaching can learn chemistry easily. They can integrate their skills with their daily life. They enjoy the chemistry and do not get bored in classes. This meaningful learning lasts a long time in their mind.

hand, do not feel they are alone in their thinking and, on the other hand, they come to appreciate that different views can exist among their peers.

- During the observation stage, emphasis needs to be placed in gaining agreement by all students as to what is actually seen. Observations by students may not be uniform as their observations are influenced by their predictions. To ensure that students make the correct observation the POE is designed so that observations are made as directly as possible (Ebenezer, Chacko, Kaya, Koya, & Ebenezer, 2010).
- POEs are easier to set up and can be used frequently. However, it is most important that the POEs do not always provide discrete events for the students. This can lead students to develop a negative approach towards this strategy which may result in predicting an outcome contrary to their personal reasoning. Otherwise, they will not be engaged in critical thinking, which is what you want them to do. Therefore, we should include POEs where many of the students are likely to find their predictions in line with their observations. Such POEs still have value as students need to provide an argument about why something should occur before it happens.
- POEs provide valuable information to guide the sequencing and presentation of the content.

Over the last 20 years, research has identified many of the difficulties which students have in understanding chemistry concepts (Abraham, Grzybowski, Renner & Marek, 1992; Çalık & Ayas, 2005; Özmen, 2004; Pınarbaşı & Canpolat, 2003; Zoller, 1990). Electrochemistry plays an important role in different types of curricula, textbooks, and everyday life. Research has shown many problems students are faced with understanding electrochemistry (Yılmaz, Erdem & Morgil, 2002).

Garnett and Treagust (1992) reported that high school students ranked electrolysis as the most difficult chemistry concept, while over 50 % of Okpala and Onocha's (1998) sample (n= 4344 11th graders) regarded electrolysis as one of the most difficult concepts in physics. These findings are not surprising because electrolysis, like many other chemical concepts is an abstract concept. Ogude and Bradley (1994) reported that 80 % of a sample of first-year university students exhibited a poor understanding of electrolysis. They also reported that '... the common error was that during electrolysis, an electric current breaks the electrolyte into positive and negative ions' (Ogude & Bradley, 1996, p: 1146). Another interesting idea was that 'anodes, like anions, are always negatively charged' (Sanger & Greenbowe, 1997a, p: 384). Sanger and Greenbowe also reviewed 10 introductory college chemistry textbooks to identify possible origins for these misconceptions. They reported many misleading or erroneous statements including the notion that electrons can flow through electrolyte solutions or that electrodes are negatively or positively charged to explain ion and electron flow.

Many studies have demonstrated that students who are taught science using activity-based methods express significantly better attitudes to science and science achievement than those who are taught using the lecture method (Archibong, 1997; Niaz, 2002; Stohr-Hunt, 1996; Tsai, 2001). Several articles have described teaching models designed to overcome students' alternative concepts in electrochemistry. Sanger and Greenbowe (1997b, 2000) investigated the effects of computer animations of the process occurring at the particle level in electrolyte cell and, in comparison, instruction aimed at changing students' conceptions of current flow. Students who attended the chemistry course took part in the investigation, and were evaluated using written exams. The authors reported that conceptual change strategies had positive effects on dispelling students' misunderstanding. In another

study, Huddle, et al (2000) practically demonstrated cell reactions to the EG after which the EG had significantly greater ability to show practical level than the CG. After this treatment, the experimental groups, when compared with the control group, had 'a significantly greater ability....to show what was occurring at the microscopic level in an electrolytic cell'. Niaz (2002, p: 432) used 'teaching experiments' to help students better understand electrochemical process. He argued that 'teaching experiments would have to be designed for particular aspects of a problem situation in order to facilitate conceptual change'. Özkaya (2002) studied how prospective teachers studying chemistry at university understood electrochemical concepts such as cell potential and equilibrium in galvanic cells. He also stated that the origins of learning difficulties to 'failure to acquire adequate conceptual knowledge (Özkaya, 2002, p: 436).

Purpose of the study

The study investigated the effect of teaching electrochemistry concepts (cathode, anode, positive and negative poles, electrolysis, and transport of electric charges in electrolyte solution in electrochemistry) to University freshmen students using POE. The related literature on electrochemistry (Garnett & Treagust, 1992; Ogude and Bradley, 1994; Özkaya, 2002; Sanger & Greenbowe, 1997b) provides us with an extensive list of university freshmen's alternative conceptions in electrochemistry concepts. There is a need for instructional strategies based on the meaningful learning of electrochemistry concepts. Thus, activities to teach electrochemistry concepts based on the POE strategy were developed and their efficiency was investigated.

METHODOLOGY

Research design

In this research, quasi-experimental design was used. Experimentally and control groups were selected randomly. The groups can be said equal as there was no difference between them related to the pre-test grades. For the testing of the hypothesis, it is observed whether there is any difference in both groups from pre-test to post-test (Cohen, Monion & Morrison, 2000; Creswell, 1994; Shadish, Cook & Campbell, 2002; Yin, 2009). Pre-test/post-test experimental design was used to compare the effectiveness of using the prediction-observation-explanation strategy and traditional instruction. Pre-test was disseminated prior to the intervention in order to compare the students' levels of understanding in both groups. The students in the experimental group were exposed to the POE strategy, while the students in the control group were instructed through traditional instruction. For the control group, teaching of conceptions on electrochemistry was realized in the lab using deduction lab approach. In such an approach, the teacher is more active. The subject and the concepts are taught theoretically by the teacher. After the intervention, a post-test was administered to both groups. The experimental design of the study is given in Table 1.

Table 1. The Experimental design of the research

Groups	Pre-tests	Teaching Strategy	Post-tests
Experimental Group	Multiple choice test Open-ended test	POE Strategy	Multiple choice test Open-ended test
Control Group	Multiple choice test Open-ended test	Traditional Strategy	Multiple choice test Open-ended test

Participants

The study consisted of students in Turkey from two separate university freshmen of science (28 boys, 12 girls). The university freshmen were randomly divided into two groups: Experimental group (EG) (n=20; 13 boys, 7 girls), and control group (n=20; 15 boys, 5 girls). Both groups were taught by the same chemistry teacher.

Instruments

Two tests were developed to determine the students' understanding level of selected fundamental electrochemistry concepts namely: the cathode, anode, minus, plus, electrolysis, galvanic cell, and transport of charges in electrolyte solution. One of the tests included 15 open-ended questions developed from the studies of Sanger and Greenbowe (1997b). The validity of the test was provided by the researchers and the experts. For this purpose, two chemistry educators, one science educator, three chemists and five chemistry teachers were consulted. This test is called "Electrochemistry Open-ended Test (OET)". The other test consisted of 11 multiple choice questions. The data obtained from the questions were developed by the researcher who used the study published by Schmidt, Marohn, and Harrison (2007). The validity of the test was provided by the examination of two chemistry educators, one science educator, three chemists and five chemistry teachers. The reliability of the Electrochemistry Multiple Choice Test (MCT) based on KR-21 was 0.78. There are two conditions for KR-21 reliability. The first one is the grading of test 1-0. The second one is the usage of KR-21 when the item difficulty index is unknown. KR-21 is calculated based on the arithmetical average of the test.

Treatment

This study was conducted over a three weeks period. The chemistry course was scheduled as four class hours per week. Before the treatment, OET and MCT were administered to the students in the experimental and the control groups as pre-tests. Students were given one class hour to complete the tests.

One week after the administration of the pre-tests, instruction related to electrochemistry concepts started in both of the groups; namely control and experimental groups. The teachers of both the groups were the same. The students in the control group were instructed through traditional methods. The teacher provided instruction through lecture and discussion as students took notes and asked questions. Moreover, the teacher solved quantitative problems related to electrochemistry concepts (galvanic and electrolytic cell concepts). Meanwhile, the experimental group students carried out the sessions according to the POE strategy.

The pilot study

The researcher developed five POE activities for the concepts about electrochemistry found in the literature to eliminate misconceptions to provide more effective learning (Garnett and Treagust, 1992). These activities were applied to the upper grade science students as a pilot study. In the pilot research, upper grade students were investigated, as they often accomplish their lessons in the lab. The second reason is to see if POE causes any problems during the application.

The teacher observed that the students were highly motivated to participate in the activities during the study. After a four hour study, the teacher interviewed the students and they responded:

- We found the activities more enjoyable and quite different than the ones in the previous year.

- The activities also lead us to think using different points of view, brain storming, critical thinking, etc.
- It was very interesting to see whether our guesses were right or wrong in the end.
- We enjoyed studying with our friends in pairs or in groups.
- The activities were manageable enough for us to succeed; therefore, they attracted us.
- In the end, they expressed that they understood the electrochemistry concepts more effectively, and more importantly they eliminated their misconceptions.

The face validity of the activities was ensured by using five field experts. By this way, the scientific and pedagogical problems that could arise were eliminated.

These activities developed were conducted on the experimental group. Below is a sample POE activity given.

POE Strategy

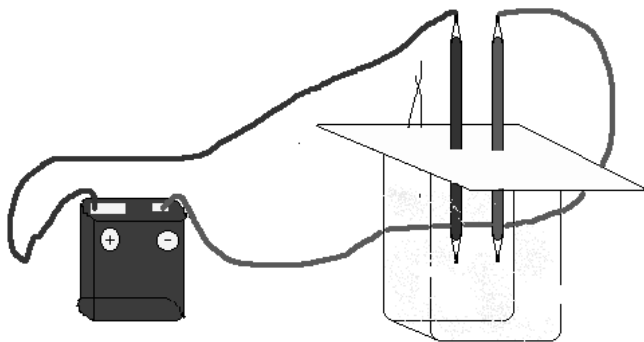
One of the activities of using the POE strategy to teach electrochemistry concepts is given below. The chemistry lab is designed in the U-shape with groups of five. There are a total of 20 students in each homogeneity group. On each table the necessary equipment for the experiment is provided. When the students take their seats in the lab, they are asked the following questions to determine their preconceptions and each group notes their answers and predictions. The questions are as follows:

Predict

- Is pure water a mixture or a compound? Why / why not?
- What are the decomposition methods of mixtures and compounds? Which method can pure water be decomposed with?
- Can we decompose the water to its main elements with a pencil? How can we realize this? Please explain the reasons for your prediction.

At the onset, students were told that they would do an experiment, they were asked to predict what would happen and they provided reasons for their predictions. The experiment was done, and the students wrote down their predictions and observations.

At this stage, the teacher drew the mechanism on the blackboard (The students also had the same mechanism on their worksheets). The students were asked the following questions, and wrote down their predictions with explanations:



- What is the purpose of this mechanism?
- In your opinion, which pencil has (+) electrode?

- In your opinion, which pencil has (-) electrode?
- Predict which pencils are anode and cathode.
- Can pencil ends conduct the electricity? Why?
- Predict where the H₂ and O₂ gases will appear.
- In your opinion, which gas will appear more intensively? Predict it. Write down your predictions on your worksheets.

Observe and Explain

At this level, the students were asked to build up the mechanism above, using the materials on their table.

Experiment

Let's decompose water!

Purpose: To decompose water to its main elements through electrolysis.

Concepts: Element, compound, electrolysis.

Materials: Two sharpened pencils, 9-volt batteries, electrical wire, a jar, scissors, tape, a cardboard, a ruler, and some sodium carbonate.

Introduction:

Water is composed of oxygen and hydrogen. Hydrogen is flammable and oxygen supports combustion. As a compound composed of these elements, however, water has totally different features and is drinkable. Some compounds can be decomposed by electrolysis. As an example, oxygen and hydrogen can be obtained by the electrolysis of water.

Electrolysis is a chemical process. This method is widely used in industry. Oxidized elements like iron can be covered with non-oxidized elements by electrolysis. For instance, an iron spoon is covered with chrome or silver.

Procedure:

Cut the wires to length of 20 cm. Strip the ends insulation to a length of 3 cm and connect them to the (+) and (-) poles of the 9 volt battery.

Make a circular shape at the end of each wire.

Add sodium bicarbonate to the half-filled jar with water and dissolve it.

Place a cardboard to the top of the jar.

Pierce the cardboard and immerse the pencils into the water (label pencils and water on the diagram).

Connect the circular ends of the wires to the pencil leads outside the jar.

Observe what happens at the immersed pencils.

Evaluation:

What is the purpose of the experiment?

In your opinion, is the end of the pencil an electric conductor?

What did we obtain by decomposing water? Tell us about the process?

Which one of the gases is oxygen or hydrogen?

At which pencil can you see more bubbles?

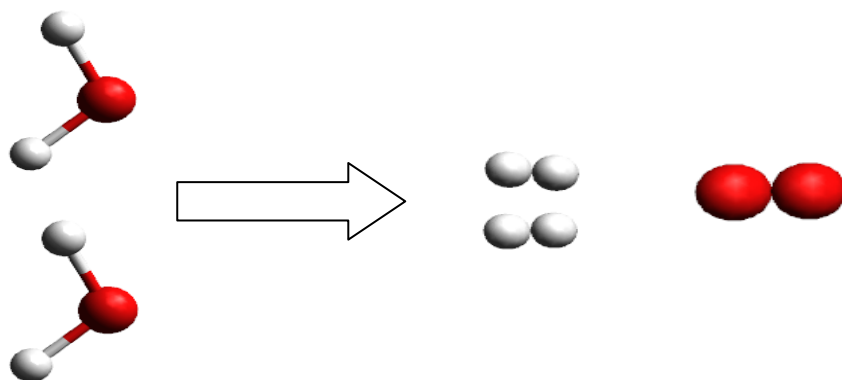
When a compound is decomposed by electrolysis, can elements be decomposed to simpler structures?

Note:

When you connect the wires connected with a battery to the pencil, the electric current passes from the battery to the pencil and from the pencil to the water. When the current passes into the water, you can see bubbles at the ends of the pencils. These bubbles are oxygen and hydrogen gases. To understand which one is oxygen or hydrogen, you should look at the poles of the battery. You can see oxygen at the (+) pole and hydrogen at the (-) pole. Each water molecule consists of one oxygen and two hydrogen atoms. When the electric current travels through water molecules, they are decomposed into oxygen and hydrogen atoms and let more hydrogen atoms out.



The diagram shows the above formula.



two volumes of water

two volumes of hydrogen

one volume
of oxygen

Compare your observation with your prediction. Are they in agreement or disagreement?

Justify them:

Finally, students in each group discussed their answers to?questions after which they each wrote down their final reasons and explanations.

Similar to the above mentioned POE activity, four more POE activities related to electrochemistry concepts were conducted on the experimental group students. These studies lasted for three weeks. One week after the treatment, OET and MCT were administered as the post-test to both control and experimental groups at the same time.

For the control group, teaching of conceptions on electrochemistry was realized in the lab using deduction lab approach. In such an approach, the teacher is more active. The subject and the concepts are taught theoretically by the teacher.

Data analysis

Electrochemistry Multiple Choice Tests (MCT) and Electrochemistry Open-ended Tests (OET) were administered to both EG and CG as pre-tests and post-tests. The analyses of pre-test and post-test scores were found via independent groups t-test

to find out whether there is any difference between the performance of the groups. The analyses were done by using SPSS, and the results were evaluated at the significance level of .05. The reason using this analysis is to compare the scores of the groups that formed according to a variable related to independent variable. In this study, it is seen that there is not any significant difference between the pre-test scores of control and experimental groups. Considering that the groups are not affected by the used pre-tests, independent sample t-test is applied.

RESULTS AND DISCUSSION

Data collection tools (MCT and OET) were applied as pre-tests before exploring the efficiency of teaching some electrochemistry concepts by POE strategy and by the traditional approach. The findings were evaluated with SPSS. These results, which were gathered from MCT pre-test application, are presented in Table 2.

When Table 2 was examined, it was found out that the mean scores that science education freshmen students got from the pre-test application of MCT were: 38.10 for the experiment group and 37.80 for the control group. The statistical comparison revealed that there were no significant difference between the conceptual understanding of the two groups ($t = .093$, $p = .927$). In order to study at university, students have to pass an exam. The students get the opportunity to study areas which they prefer, according to the scores which they get from an examination called Student Selection Exam (Öğrenci Seçme Sınavı - OSS). These scores don't show significant differences within the pre-requisites of each university department. The reason of insignificant difference among the success levels of science education freshmen students can be explained by this fact of the Turkish higher education system (OSS).

Table 3 presents the percentages of the students' answers to each item in the MCT pre-test and post-test application. As seen in Table 3, there is no meaningful difference between the answers of prospective teachers to the pre-test questions. As an example, 50 % of the experimental group students answered the 11th question correctly whereas 55 % of the control group students answered the same question correctly. When the post-tests were compared, the correct answer percentage of the experimental group students was more than the control group students. For example, 100 % of the experimental group students answered question 7 correctly, compared to the 85 % of the control group students.

Table 2. MCT results of the t-test on pre-test scores of experimental and control group students

Group	N	Mean	sd	df	t	p
Experimental	20	38.10	10.26	38	.093	.927
Control	20	37.80	10.24			

Table 3. Percentages of students' correct answers of MCT in pre-test and post-test

Item No	Experimental Group (%)		Control Group (%)	
	Pre-test	Post-test	Pre-test	Post-test
1	50	90	45	90
2	40	75	35	70
3	35	75	30	50
4	25	65	20	65
5	30	80	35	55
6	35	70	35	60
7	45	100	45	85
8	25	80	25	50
9	50	90	40	45
10	45	85	50	60
11	50	90	55	75

The comparison of the data obtained from the application of MCT as a post-test is given in Table 4. As Table 4 suggests, it is seen that the scores of the experimental group students who were taught according to the POE strategy are higher than those of the control group students who were taught using the traditional teaching strategy. There is a meaningful difference in favor of the experimental group at the rate of $t=4.909$ ($p<0.05$).

The reason of this difference can be explained with the POE strategy. In the literature, it is widely claimed that using the POE strategy which was developed for teaching concepts and conceptual learning, affects the students' success (Kearney, Treagust, Yeo, & Zadnik, 2001; Liew & Treagust, 1998). Moreover, by using the POE, the students become more active, they enhance their problem based-learning, which helps students learn difficult electrochemistry concepts, and the teachers experience collaborative teaching techniques, (Acar & Tarhan, 2007; Yürük, 2007).

OET consisting of open-ended questions was used as a pre-test and a post-test. This test was developed for students to interpret the concepts, conceptual learning and high level questions. When their answers are compared on the SPSS, an independent group's t-test is applied to see whether there are differences between their achievements. The obtained pre-test results are given in Table 5.

In Table 5, it is seen that there is no significant difference between the achievements of the control and the experimental group students relating to the electrochemistry test consisting of open-ended questions used as a pre-test ($t=.864$ for value $p>0.05$). The same result is in accordance with the results obtained from the multiple choice test used as a pre-test. Moreover, misconceptions of students are determined by evaluating this test with open-ended questions. These misconceptions are the same as the misconceptions that Garnett and Treagust (1992) mentioned in their studies.

Table 6 indicates some of the similar misconceptions determined both by this study and by Garnett and Treagust (1992).

The analyses of data of this test as a post-test indicate that the understanding electrochemistry concepts of the experimental group students are eliminated whereas those of the control group are not. Sanger and Greenbowe (1997a) suggested that the constructivist approach was effective in teaching electrochemical concepts. Similarly, the study of Lin et al. (2002) determined the difficulties of 9th, 12th grades and college students encountered while learning electrochemistry concepts. They suggested that in order to eliminate the misconceptions that the students have and to solve their learning problems, active learning and conceptual change approaches can be utilized. In this study, it is concluded that the POE strategy is effective in teaching electrochemistry concepts.

The results obtained from the related test as a post-test are given in Table 7. As seen in Table 7, there is a meaningful difference in favor of the experimental group between the achievements of experimental and the control group students when OET is used as a post-test ($t=5.208$ $p<0.05$). This result indicates that teaching with the POE strategy is effective for electrochemistry concepts. White and Gunstone

Table 4. MCT results of the t-test on post-test scores of experimental and control group students

Group	N	Mean	sd	df	t	p
Experimental	20	81.65	9.1897	38	4.909	.000
Control	20	65.90	11.0210			

Table 5. OET results of the t-test on pre-test scores of experimental and control group students

Group	N	Mean	sd	df	t	p
Experimental	20	11.7500	9.0139	38	.864	.393
Control	20	9.4000	8.1654			

Table 6. Paraphrased list of common student misconceptions reported by Garnett and Treagust (1992b) with this study

No.	Common Student Misconceptions
1	Electrons enter the solution from the cathode, travel through the solutions and the salt bridge, and emerge at the anode to complete the circuit.
2	Anions in the salt bridge and the electrolyte transfer electrons from the cathode to the anode.
3	Cations in the salt bridge and the electrolyte accept electrons and transfer them from the cathode to the anode.
4	The anode is negatively charged and releases electrons; the cathode is positively charged and attracts electrons.
5	The anode is positively charged because it has lost electrons; the cathode is negatively charged because it has gained electrons.
6	The calculated cell potentials in electrolytic cells can be positive.
7	A salt bridge is absolutely necessary in a Galvanic cell to create electromotive force.
8	The electrolyte must contain the cation that corresponds to the electrode in a Galvanic cell.
9	There is no relationship between the calculated cell potential and the magnitude of the applied voltage.
10	No reaction will occur if inert electrodes are used.
11	In electrolytic cells, oxidation now occurs at the cathode and reduction occurs at the anode.
12	In electrolytic cells, water is non-reactive toward oxidation and reduction.
13	In electrolytic cells, the direction of the applied voltage has no effect on the reaction or the site of the anode and cathode.

Table 7. OET results of the t-test on post-test scores of experimental and control group students

Group	N	Mean	sd	df	t	P
Experimental	20	69.2500	14.6714	38	5.208	.000
Control	20	44.5000	15.3743			

(1992) have promoted the predict-observe-explain (POE) procedure as an efficient strategy for eliciting students' ideas and also for promote student discussion about their ideas in literature.

CONCLUSION AND IMPLICATION

In this study, the efficiency of the POE strategy in helping science education freshmen students to understand some electrochemistry concepts was researched. MCT and OET data collection tools were applied to the experimental and the control groups as a pre-test and a post-test. As a result of the statistical comparison of the data gathered from both data collection tools, it was found out that there was no significant difference between the experiment and the control groups in pre-tests, whereas there was a significant difference between them in favor of the experiment group from the post-test. Accordingly, we concluded that the POE strategy implemented on the experiment group affected the students' learning abilities of certain electrochemistry concepts. The POE strategy was effective to eliminate the misconceptions in literature and gathered from pre-test results. Especially, 'A salt bridge is absolutely necessary in a Galvanic cell to create electromotive force.' and 'The electrolyte must contain the cation that corresponds to the electrode in a Galvanic cell.' which were misconceptions in literature were eliminated by using the POE activities with the students in the experimental group. It is known from the literature that teaching through the POE strategy on teaching chemistry concepts is effective (Kearney, Treagust, Yeo, & Zadnik, 2001; Liew & Treagust, 1998; Thompson & Soyibo, 2002). The result also proved that the findings of the related study prevail.

Therefore, chemistry teachers are suggested to use the POE strategy that enforces the teaching of the constructivist teaching strategy of the POE. This technique, which suggested the students to be active in class and helps students better understand abstract chemistry concepts should be learned and used by all chemistry teachers.

According to the observations of the researcher during the application of the activities, it was noted that the interests and curiosity of the prospective teachers

have improved. They claimed that they performed the activities in an enjoyable environment. They thought about the questions that were asked to them at the prediction level and then, they compared their prediction with their observations. They accepted the new empirical knowledge and stated that permanent learning was realized.

As a result, it can be argued that using the POE strategy is an inevitable way to make science courses more interesting, to induce permanent learning, and to eliminate misconceptions. For those who study on this area should take it into account to give importance on POE strategy and such studies should be carried on.

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