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# THE EFFECT OF INTERACTIVE COMPUTER ANIMATION AND SIMULATION ON STUDENTS' ACHIEVEMENT AND MOTIVATION IN LEARNING ELECTROCHEMISTRY

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**ABSTRACT**

Electrochemistry is difficult to learn due to its abstract concepts involving macroscopic, microscopic, and symbolic representation levels. Studies have shown that students can visualize and improve their understanding of chemistry by using interactive computer animation and simulation. This study reports the effect of interactive computer animation and simulation module named "Interactive Electrolysis of Aqueous Solution" (IEAS) developed to aid students in learning electrolysis. A pre and post-test control quasi-experimental design was carried out to investigate the effects of the IEAS on students' achievement and motivation in electrochemistry topics. This study involved 62 16-years-old male students from two different secondary schools. Pre and post electrochemistry achievement tests (EAT) and pre and post- Instructional Material Motivation Surveys (IMMS) were used. For EAT, using one-way ANOVA, it shows that there was a significant difference in the post-test mean score in this study on the understanding of the electrolysis concept between students in the treatment and control groups [$F(1, 60) = 5.15$, $p < 0.05$]. The qualitative results also provided evidence that the students in the treatment group had a better conceptual understanding than the control group, especially at the microscopic representation level. For the IMMS test, there was a significant difference between the treatment and control groups in terms of the mean score of the post motivation IMMS test where $p < 0.05$ in chemistry learning [$F(1,59) = 266.89$, $p < 0.05$]. Thus, it can be concluded that IEAS has an impact on enhancing the students' understanding of the electrolysis concept, and the students are more motivated to learn electrochemistry.



Keywords: animation; chemistry; electrochemistry; simulation

## INTRODUCTION

Chemistry is an important subject in daily life because every substance or object is related to chemical processes. Therefore, it is essential to learn chemistry. Students find it difficult to learn the topics such as electrochemistry due to its abstract concepts. Electrochemistry is known as the process of conversion of chemical and electrical energy that occurs in electrolysis and voltage cells. According to Sesen & Tarhan (2013), electrochemistry is difficult for most students and causes negative feedback. The difficulty of the topic is the main cause of the decrease in students' achievement. Students in South East Asia and Asia-Pacific, like Indonesia, Malaysia, and Japan, seem to experience difficulties in electrochemical topics (Rahayu et al., 2011; Osman & Lee, 2014). These studies show that Indonesian, Japanese, and Malaysian students share similar difficulties in learning electrochemistry concepts, such as having alternative conceptions

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in electrolytic cells, electron flows, voltage cells, and electrode polarities. In a study by Doymus et al. (2010), it is reported that students often misunderstand the topics in electrochemistry at the molecular level to a considerable extent and possibly could not understand them at all. The terms such as oxidation and reduction make the topics even more difficult. In a study by Ahmad & Lah (2013) and Ahmad et al. (2019), they identify differences in students' everyday understanding of electrochemistry and the curriculum; thus, designed teaching that contains practical activities at a fine grain size could address the students' conceptual understanding of this topic.

There are many methods of teaching electrochemistry to enhance students' conceptual understanding as reported in the literature, such as using inductive teaching (Surif et al., 2019), verbal questioning (Iksan & Daniel, 2015), contextual teaching and learning (Prihastyanti et al., 2020), scientific animation (Al-Balushi et al., 2017), and computer animation (Osman & Lee, 2014). These methods share a similar perspective in which they promote active learning strategies. Active learning strategies utilize hands-on approaches such as jigsaw technique, inquiry-based learning, project-based learning, problem-based learning, and animation techniques, which have increased students' knowledge and conceptual understanding compared to teacher-centred learning (Madar & Hashim, 2011). In the 21st century teaching and learning, students are no longer into lecture-based but prefer interactive learning using technology (O'Neal et al., 2017), especially for abstract content that involves microscopic entities. Seels & Glasgow (1998) define interactive animation as a collection of images, lines, text, or other objects forming elements that provide visual animation (motion effect) and audio (voice) that can create an attractive environment. Animation and simulation using ICT can help students visualize and improve their understanding of chemistry (Doymus et al., 2010). In computer animation or simulation, the chemical processes in electrolysis can be visualized, such as the change of colour and the mass of electrodes (Osman & Lee, 2012).

In learning electrochemistry, students must understand the macroscopic, microscopic, and symbolic entities when they learn chemistry (Johnstone, 1993). The intertwined relationships provide a comprehensive view of studying chemistry, where these three representations will improve students' understanding of specific complex topics in chemistry. Students often have difficulties explaining at the microscopic and symbolic levels. Thus, interactive computer animation and simulation convert the abstract concept to a more concrete concept so the students can visualize the whole process at all three levels of representation (Rodrigues et al., 2001). Thus, the students studying electrochemistry using multimedia techniques should have higher achievement than conventional methods (static images) (Sanger & Greenbowe, 1997a, 2000; Karsli & Calik, 2012). For instance, at the microscopic representation level, it requires visualization where the students need to depict the movement of ions and electrons during the electrolysis process (Eilks et al., 2012). The students might distinguish between what happens at the anode and cathode if they use computer animation and simulation. They must also convert specific processes into formulas and chemical equations, such as half equations that show the product at the anode and cathode (Acar & Tarhan, 2007).

In Ahmad & Lah (2013) and Ahmad et al. (2019), students' difficulties in learning electrochemistry are divided into two main areas that cannot generate detailed explanations of the chemical event and cannot relate the macroscopic, sub-microscopic, and symbolic entities or any of the two entities. The main reason students misunderstanding this topic is because students cannot relate to the existence of positive ions and negative ions. It causes them to write incorrect formulas and chemical equations. It could be said that students' main problem in studying abstract concepts of chemistry is their ability to visualize concepts in a mental model (Supasorn, 2015). Computer animation and simulation can depict the movement of ions and electrons in electrolysis cells at the microscopic representation level. Thus, students can visualize the whole process and understand how to convert electrical energy to chemical energy in the electrolysis process. In another study by Akpoghol et al. (2016), computer animation with music has positively impacted students' retention in electrochemistry topics.

Another critical aspect of learning chemistry is motivation. This aspect is to ensure the effectiveness of learning outcomes. Highly motivated students appear to put in more learning work, perseverance, and success in classroom practises and assignments than low motivated students (Wolters & Rosenthal, 2000; Yustina et al., 2020). The consequences of students' misunderstanding about electrochemistry have made students demotivated in studying electrolysis topics. According to Deci & Ryan (1991), interest is a motivating factor that encourages the students to learn. So when students do not have interest, they are not motivated to learn (also in Mumba et al., 2018). In the electrochemistry topic, when the teaching content focuses more on the theory, this can create low motivation and low achievement in students' learning (Widodo, 2017). Thus, many efforts have been made to enhance students' motivation to learn electrochemistry, especially in designing the appropriate instructional materials for this topic (Chen & Liao, 2015). In the educational line, the educators at all levels are encouraged to use active learning strategies so that the students are more interested in classroom learning. The activities are designed to engage students in high-order cognitive processes when presented with new concepts or open-ended questions, help them develop connections, and ultimately construct their knowledge (Sandi-Urena et al., 2012).

This study aims to identify interactive computer animation and simulation effects on students' achievement and motivation in learning electrochemistry. The specific objectives of this study are to identify the differences between students in the treatment and control groups in their mean scores for the achievement test in some aspects of electrochemistry and the motivation questionnaire. This study investigated a small number of students of two classes in two schools. Thus, the finding cannot be generalized to the fact that the typical classroom teaching and learning may be unsuitable for improving students' conceptual understanding in the three levels of representation in learning chemistry when connecting the macroscopic, sub-microscopic, and symbolic representations. This study utilized the computer animation and simulation module, which was developed to enhance students' conceptual understanding of some aspects of electrochemistry.

## METHODS

This study used a quasi-experimental design to examine the effects of interactive computer animation and simulation in understanding electrolysis (achieve concepts) and students' motivation in chemistry learning. This study also utilized pre-test and post-control groups (Gay et al., 2011), requiring pre and post-test testing for control and treatment groups. As the schools had classes streamed according to academic achievement, it was impossible to carry out this study using the actual experimental design (true experiment). A total of 62 sixteen-year-old male students from two secondary schools are selected as the study sample. Both schools were Band Two (2) schools that have exemplary academic achievement. Two chemistry teachers from two different schools were involved in this study. The classes selected from each school, one treatment group and one control group from the two schools, had similar characteristics in the individual achievement of the previous national examination for 15 years-old students where all of the students achieved Grade A and B in science and mathematics subjects. Those grades were referred to their achievement in their PT3 (National examination for Form 3). This selection is to minimize the effect of internal threats for this design. For the experimental design, Cook & Campbell (1979), the selection of subjects or samples would be one of internal threat. Thus, the result from their PT3 was used as the benchmark that they were equal in terms of cognitive ability. Before the test, the students were divided into two groups at random as control group (N = 31) and treatment group (N = 31). All the respondents had the basic knowledge of electrolysis as they had learned the basic concept of electrolysis when they were in Form Two. Each group was taught by a different chemistry teacher who has had more than ten years of experience teaching chemistry.

The study took about three weeks. In the first phase, the students in the treatment group were shown the interactive computer animation and simulation using interactive electrolysis of aqueous solution (IEAS) software. In contrast, the students in the control group were exposed to other multimedia approaches (e.g. PowerPoint). The activities for both groups were shown in Table 1.

**Table 1.** Students' Activities

| Research Method | | |
|---|---|---|
| **Week** | **Treatment Group** | **Control Group** |
| 1 | Explanation to the teacher on interactive animation teaching, IEAS and pre-test | Explanation to the teacher on PowerPoint and pre-test |
| 1 | Pre-test motivation | |
| 2 | Teacher Teaching<br>(Topics - Electrolysis in molten) | Teacher Teaching<br>(Topics - Electrolysis in molten) |
| 3 | IEAS<br>(Topics - Electrolysis in aqueous solution) | PowerPoint<br>(Topics - Electrolysis in aqueous solution) |
| 4 | Post-test motivation | |

The teacher who used IEAS in the treatment group was trained for a week to ensure the materials were used as planned. The IEAS was designed and adapted from the University of Iowa based on the education system in Malaysia. This software was also certified by a chemistry teacher with 20 years of teaching experience. The IEAS was designed to guide students, and this module covered three factors of the electrolysis process in an aqueous solution. The IEAS works by providing students with an image or mental image of the molecular process at the macroscopic, microscopic, and symbolic levels.

Additionally, the IEAS increases student's metacognitive awareness of what they know and what they need to know for the topic they are studying. One of the strategies is embedded support and scaffolding for metacognitive strategy, procedure, or control (Land, 2000). In general, IEAS can improve the effectiveness of students' learning process and motivate students to continue learning. Hence, IEAS has been developed to help students in electrolytic learning.

The first page of IEAS consists of a labelled aqueous solution. This page has three aqueous and colourless solutions: hydrochloric acid, copper (II) sulphate, and iron (II) chloride. This page also shows the ions that move freely within each solution so that the students can understand the relationship between free ions and the flow of electricity (see Figure 1).

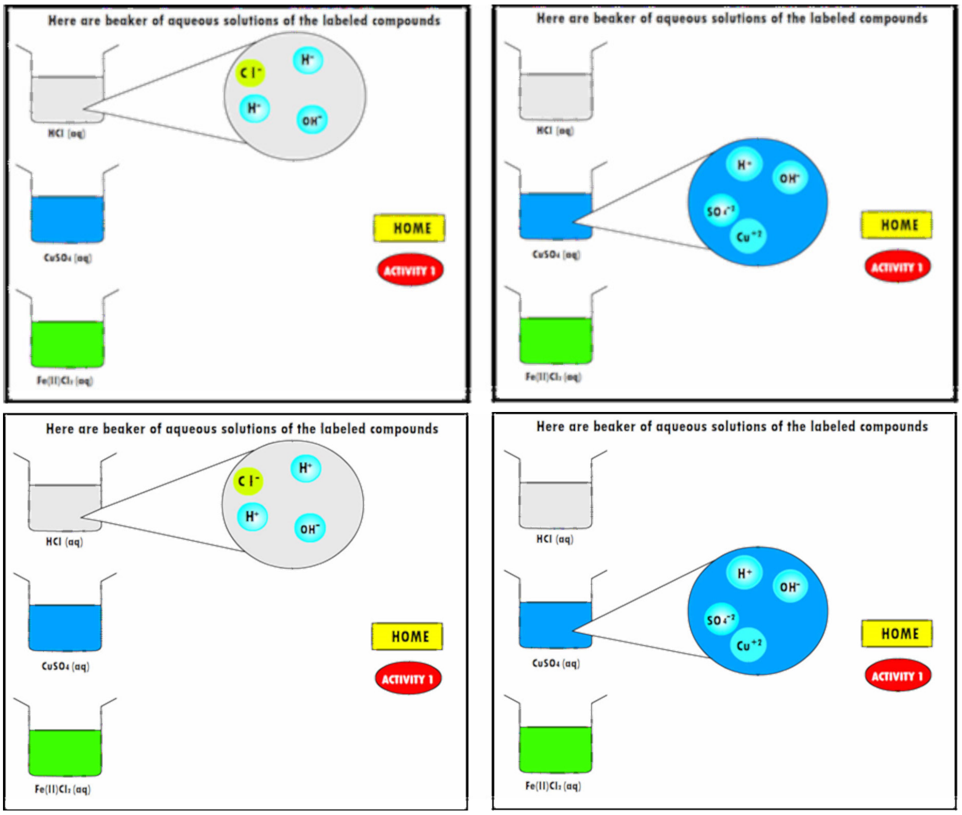


**Figure 1.** Interactive Electrolysis of Aqueous Solution (IEAS)

The model above consists of three electrolysis processes in aqueous solutions. IEAS encompasses three factors that affect the ionization of the electrolysis process in aqueous solutions. The first and second factors describe the electrolysis process occurring in electrolysis cells at the microscopic level and focus on the half-reactions to carbon electrodes and ionic transfer. In comparison, the third factor of the electrode type is used to focus on the half-reaction in the copper electrode. In addition, IEAS illustrates the colour change on the metal surface (plating material). It also describes the electrolysis of copper (II) sulphate, hydrochloric acid, the formation of air bubbles, deposition, and colourless gases produced on the anode and cathode. Figure 2 shows the micro world in IEAS, which shows the electrolysis process at the microscopic representation level.

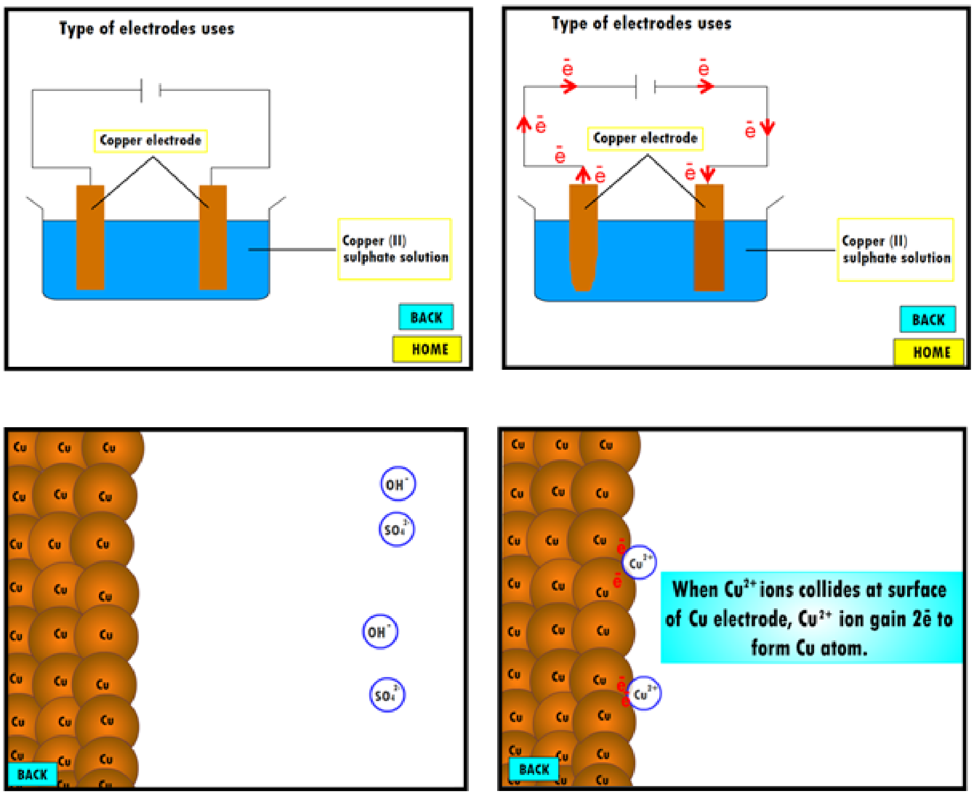


**Figure 2.** The Micro World in IEAS

The instrument for the achievement test was the Electrolysis in aqueous solution Achievement Test (EAT). It contains two sets of electrolysis understanding tests administered as pre-test and post-test. The questions in the EAT understanding test were to assess students' concepts at the macroscopic, microscopic, and symbolic representation levels (see Table 2). Both sets of tests used the same questions but had different arrangements.

**Table 2.** Sample Item and Level of Chemical Representation

| Item | Chemical Level |
|---|---|
| Predict the change in the colour of the solution in the beaker after electrolysis is extended to 45 minutes. | Macroscopic |
| Draw all the ions present in the electrolyte before the reaction occurs. | Microscopic |
| Write an ionic equation (half equation) at the reaction at the anode and cathode responses. | Symbolic |

The items in EAT were adapted from the national examination questions. The students were required to answer the questions and give a reason for the answer. The test consists of two objective questions and five open-ended questions. For example, Item 3 and 4 (a) (ii) are for the macroscopic representation level where the students list the ions in the electrolyte. For the microscopic representation level, the students were required to draw ions at the anode and cathode. Next, for the symbolic representation level, the student wrote the half-equation for both the electrodes (see Table 3).

The score for EAT was as objective questions in which the correct answer was given one (1) mark, and the wrong answer and no answer were given zero (0). The open-ended items were categorized as correct (1) mark when students were able to clearly express and reflect clearly, zero (0) marks when students used false ideas and alternative concepts on related topics, and zero marks when the student did not provide any explanation. The maximum score for this test was 21 marks, and the minimum score was 0.

**Table 3.** Items in the EAT Achievement Test

| Concept | Items | Level |
|---|---|---|
| | Electrolytic Cell | |
| Current flow in conductors and electrolytes | 5b | Microscopic |
| Identify anode and cathode | 3b (i), 4b (i), | Macroscopic |
| Identify the process in anode and cathode | 3b (iv), 3c (ii), 3d, 4b (iii), 6 | Macroscopic |
| | 2, 3b (ii), 3c (i), | Microscopic |
| Oxidation and reduction process | 3b (iii), 4b (ii) | Symbolic |
| Electrolyte concept | 1, | Macroscopic |
| | 3a, 4a (ii), 5a | Microscopic |

The Instructional Material Motivation Survey (IMMS) pre-test and post-test were given to both groups to compare the level of motivation to study students' motivation in learning electrochemistry. The research instruments were adapted from Song & Keller (2001). Keller made a motivational prescription based on the synthesis of previous studies on psychological motivation (Keller, 1983; Reigeluth, 2018). This questionnaire is designed to assess the teaching of materials influencing student motivation or how motivated students engage in learning (Dempsey & Johnson, 1998; Rodgers & Withrow-Thorton, 2005; Green & Sulbaran, 2006; Bolliger et al., 2015). The IMMS questionnaire had 36 items (see Table 4). Four categories were used: (i) attention, (ii) relevance, (iii) confidence, and (iv) satisfaction. Relevance and confidence both have nine items, satisfaction has six items, and attention has 12 items. This questionnaire was measured by a 5-point Likert scale, which refers to Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. The questionnaires in this study consist of two parts. Part A involved students' demographic profiles such as gender, age, race, family income, and PT3 (science and mathematical) test results. While part B contained motivation items which were randomly arranged: (i) attention (item: 2, 8, 11, 12, 15, 17, 20, 22, 24, 28, 29, 31), (ii) relevant (item: 6, 9, 10, 16, 18, 23, 26, 30, 33), (iii) confidence (item: 1, 3, 4, 7, 13, 19, 25, 34, 35), and (iv) satisfaction (item: 5, 14, 21, 27 , 32, 36). Items 3, 7, 12, 15, 19, 26, and 34 are reverse items expressed negatively. Item 29 and 31 were recoded as previously suggested by Józsa & Morgan (2017) by selecting the old (negative) and new value (corresponding opposite value) for the variables. For instance, in a 5-point Likert scale, the positive items are scored 1, 2, 3, 4 and 5. Then the negative items should be rescored as 5, 4, 3, 2, and 1. The total score of IMMS is 180. The closer the mark to 180 will show higher motivation.

**Table 4.** IMMS Test Items

| Dimension | Question No | Item |
|---|---|---|
| Attention | 2 | There was something that caught my attention at the beginning of the lesson. |
| | 8 | These materials attracted my attention. |
| | 11 | The quality of writing helped to impress me. |
| | 12 | The electrolysis lesson is so abstract that it makes me stay focused. |
| | 15 | The page of this material seems unattractive. |
| | 17 | The way information is arranged in the pages helps keep my attention. |
| | 20 | The electrolysis concept stimulates my curiosity. |
| | 22 | Repetition in electrolysis causes me to be bored. |
| | 24 | I have learned the things I did not expect. |
| | 28 | The diversity of passages, exercises, illustrations and others helped me to keep our attention. |
| | 29 | The writing style of this material is boring. |
| | 31 | There are many words on this material page, and it annoys me. |

| Dimension | Question No | Item |
|---|---|---|
| Relevant | 6 | I am clear how the content of this material relates to my existing knowledge. |
| | 9 | There are stories, pictures, or examples that have shown me that this material is vital for some people. |
| | 10 | Completing electrolysis lessons is crucial to me. |
| | 16 | I like the content of the materials. |
| | 18 | There is an explanation or an example of how to use knowledge with the concept of electrolysis. |
| | 23 | The content and style of writing this material give an impression that the content is of good quality. |
| | 26 | Electrolysis does not suit me because I already know some of these concepts. |
| | 30 | I can relate chemistry to what I see, do or think about my life. |
| | 33 | The electrolysis is helpful to me. |
| Confidence | 1 | The first day I learned electrolysis, I think it is easy. |
| | 3 | This material is harder to understand than I expected. |
| | 4 | After reading the introduction, I am sure I know what I am going to study in electrolysis. |
| | 7 | There is too much information on this page, and difficult for me to pick and remember important notes. |
| | 13 | I am sure I can understand electrolysis after trying hard. |
| | 19 | Exercise in electrolysis is too difficult. |
| | 25 | I am sure I will pass the test after working hard. |
| | 34 | I only understand a little bit of electrolysis. |
| | 35 | The content of this material enhances my confidence in the electrolysis lesson. |
| Satisfaction | 5 | I feel very satisfied after the finish the exercise of electrolysis. |
| | 14 | I enjoy learning electrolysis and want to know more about this concept. |
| | 21 | I am delighted to learn electrolysis. |
| | 27 | Feedback or comments after electrolysis exercises make me appreciated it. |
| | 32 | I am satisfied that I can complete the electrolysis lesson. |
| | 36 | I enjoyed studying with well-designed teaching materials. |

The students spent 15 minutes completing the IMMS motivation test. Using KR20, the Cronbach alpha value from the pilot study for IMMS was 0.97. According to Tavakol & Dennick (2011), acceptable alpha Cronbach values are 0.70 - 0.95. With the value of Cronbach alpha obtained high on reliability, this study can be continued with both instruments.

## RESULTS AND DISCUSSION

The pre-test descriptive result shows that the students from both groups had a similar understanding of the concepts before the intervention. Table 5 shows the findings of descriptive analysis of achievement test scores for the control and treatment groups. The control group score for pre-test was M = 1.03, SD = 1.14, while the score for the treatment group was M = 1.19, SD = 1.25.

**Table 5.** Mean Pre-test Score of EAT Achievement Test for Control Group and Treatment Group

| Group | Pre-test | |
|---|---|---|
| | **Mean** | **SD** |
| Control | 1.03 | 1.14 |
| Treatment | 1.19 | 1.25 |

An independent sample t-test was used to compare the pre-test results between the control and treatment groups. The result shows that there was no significant difference in the mean score of the comprehension test on electrolysis between the control and treatment groups [t (60) = -5.31, p> 0.05]. These results indicate that students from both groups were similar in terms of initial understanding before the intervention. Table 6 shows the mean score of the post-test for the understanding of electrolysis concept for treatment group (M = 16.42, SD = 2.45) and control group (M = 14.94, SD = 2.70). The findings show that the mean score of the treatment group was higher than the control group.

**Table 6.** The Post Test Mean Score for the Concepts of Electrolysis in the Control Group and Treatment Group

| | Group | N | Mean | Standard Deviation |
|---|---|---|---|---|
| Post-test | Control | 31 | 14.94 | 2.70 |
| | Treatment | 31 | 16.42 | 2.45 |

Using the one-way ANOVA test, Table 7 shows that there was a significant difference in the post-test mean score on the understanding of the electrolysis concept between students in the treatment and control groups [F (1, 60) = 5.15, p <0.05]. Thus, it can be concluded that IEAS has an impact in helping to improve the students' understanding of the electrolysis concept.

**Table 7.** One-way ANOVA Test Mean Score for EAT Post-test for Control Group and Treatment Group

| | | Sum Sq. | Degree of Freedom | Mean Sq. | F Value | Sig. |
|---|---|---|---|---|---|---|
| Post-test | Between Group | 34.129 | 1 | 34.129 | 5.153 | 0.027 |
| | Within Group | 397.419 | 60 | 6.624 | | |
| | Total | 431.548 | 61 | | | |

In addition, the qualitative results also provided some evidence that students in the treatment group had a better understanding of concepts than control group, especially at the microscopic representation level. For item 5(a), students had to examine the concept of current conduction in conductors and electrolytes. The students were required to draw the direction of electron flow in the electrolyte cell during the electrolysis process. All students from the treatment group answered the items correctly compared to about 96.8% of the control group. The students drew the electrons in electrolytes (Hamza & Wickman, 2008) or reverse the direction of electron flow (Garnett & Treagust, 1992). The students in the control group depicted electrons to flow in electrolytes to complete the circuit (Sanger & Greenbowe, 1997b; Buty et al., 2004), as shown in Figure 3.

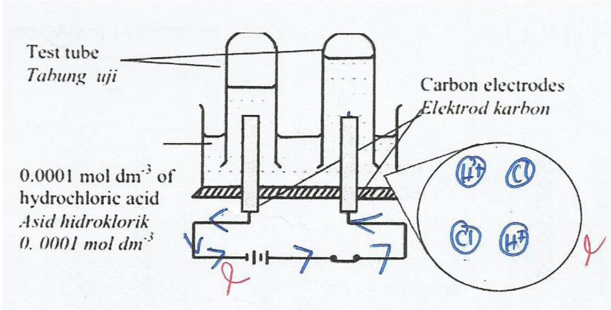


**Figure 3.** Electron Flow from the Electrolytes

More than 40% of students for both groups had successfully listed all the ions gathered on electrolytic cell electrodes to understand the processes on both electrodes during the electrolysis process. However, only a few students from both groups gave a correct observation at the microscopic representation level when a carbon electrode was converted to a copper electrode [Item 3 (d)]. However, students from treatment groups (e.g. TG22 & TG33) can explain observations at microscopic representation levels, including the movement of ions and processes on both electrodes. At the same time, the students from the control group (CG29) tend to give conclusions as a reason for observation (see below).

*Copper electrodes are inert electrodes, and copper will donate 2e- to $Cu^{2+}$ ions (TG22)*
*Copper will oxidize $Cu^{2+}$ ions (TG33)*
*Anod is thinning (CG29).*

The results show that the students in the control group were still weak in understanding the concept of electrolytes in electrolysis cells. The data obtained shows only 16.1% of students from the control group compared to 24.2% of treatment groups that could write all the ions present in the electrolysis cell. The students in the control group considered water molecules were not involved in the electrolysis process (similar to Lee & Arshad, 2008). Therefore they did not state hydrogen ions and hydroxide ions from water molecules in the electrolyte, as shown in Figure 4. Some control group students wrote molecules, atoms, or ions with the wrong chemical formula in the electrolyte (Chandrasegaran et al., 2007; Bong & Lee, 2016), showing that students had a weak understanding of the concept of ionizing and had difficulties in the symbolic representation.

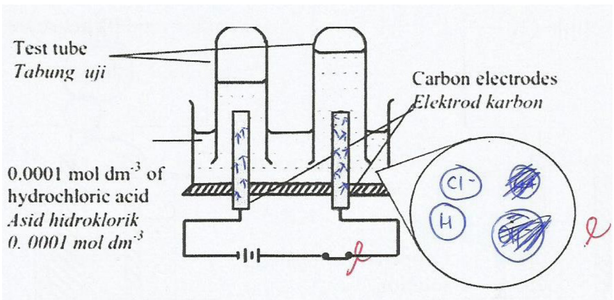


**Figure 4.** Molecules in the Electrolytes

Overall, the students from both groups converted the oxidation process and decreased it to the half equation. It shows that they could answer the question of symbolic representation level. Although the students from the control group could write the correct half equations for both terminals, they could not explain their answers. According to Karamustafaoğlu and Mamlok-Naaman (2015), teaching and learning electrochemistry using traditional methods are passive learning where the students only receive and memorize information. Thus, using IEAS to teach electrochemistry could assist the students in organizing information and integrating their existing cognitive schema for meaningful learning. Table 8 shows the comparison of the answers of the treatment group in pre and post-tests.

**Table 8.** Comparison of Answers in Pre and Post-tests of the Treatment Group

| Electrolysis Concept | Students' Answers | |
|---|---|---|
| | Pre-test | Post-test |
| The flow of current in the conductor and electrolytes [item: 5b] | Electrons get out from both electrodes<br>Electrons flow from electrolytes<br>Electrons flow from cathode to anode | Electrons flow from anode to cathode |
| The process in anode and cathode [item: 3a, 3b (ii)] | There is no presence of water molecules<br>Anions are collected at the cathode<br>Cations are collected at the anode | There are the presence of $H^+$ dan ion $OH^-$ ions<br>Anions are collected at the anode<br>Cations are collected at the cathode |
| The oxidation and reduction concept at the electrodes [item: 3b (iii), 4b (ii)] | Oxidation equation at the cathode<br>Reduction equation at the anode<br>Haff equation is incorrect/ incomplete | Oxidation equation at the anode<br>Reduction equation at the cathode<br>The half equation is accurate/ complete |
| The concept of electrolytes [item: 5a] | The ions for water molecules are not present in the electrolytes | $H^+$ dan $OH^-$ ions are present in the electrolytes |

Furthermore, IEAS in some sub-units shows the movement of ions during the electrolysis process. In Figure 5, the students in the treatment group could depict the process of receiving electrons in the cathode and donating electrons in the anode microscopically.

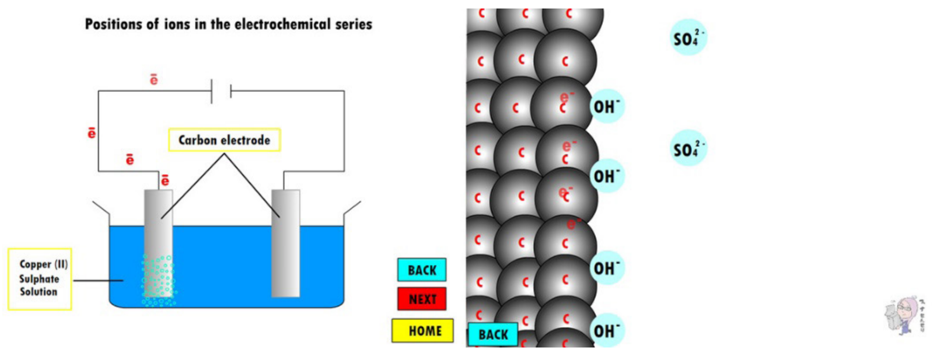


**Figure 5.** IEAS Showing the Electrolysis Process at Microscopic Representation

The students could create an overview of the process via animation in IEAS and connect the microscopic nature of matter. It is similar to a study reported by Özmen (2011), where the animation has an impact that enhanced students› conceptual change and understanding of the particulate nature of matter and its transformation.

The results of the motivation questionnaire are discussed in the following. Table 9 shows the descriptive analysis of motivation test scores for the control and the treatment groups. The score for the control group for pre motivation IMMS test was M = 87.65, SD = 6.59, whilst for the treatment group was M = 84.29, SD = 4.64. The result shows that the students in the control group had a higher mean score than the treatment group. Thus, the independence sample t-test was used to compare pre-motivation results between the control and treatment groups.

**Table 9.** Pre-test Motivation Mean Score for the Control Group and Treatment Group

| Group | Pre-IMMS Test | |
|---|---|---|
| | **Mean** | **SD** |
| Control | 87.65 | 6.59 |
| Treatment | 84.29 | 4.64 |

The descriptive analysis for the post-test shows in Table 10 shows the mean score of post motivation IMMS test of treatment group (M = 149.71, SD = 4.66) and control group (M = 130.77, SD = 4.51). It shows that the mean score of the treatment group was higher than the mean score of the control group.

**Table 10.** IMMS Motivation Post-test Mean Score between Control Group and Treatment Group

| Group | N | Mean | SD |
|---|---|---|---|
| Control | 31 | 130.77 | 4.51 |
| Treatment | 31 | 149.71 | 4.66 |

The findings in the independence sample t-test show that there was a significant difference in pre-motivation towards chemistry learning between the control and treatment groups [t (60) = 2.32, p <0.05]. Next, the ANCOVA analysis test was chosen because this study was in a quasi-experiment using unequal groups, i.e. pre-motivation scores between the two groups were unbalanced (Campbell et al., 1963).

**Table 11.** ANCOVA Results for IMMS Motivation Post-test for the Control and Treatment Groups

| Source | Sum Sq. | Degree of Freedom | Mean Sq. | F value | Significance |
|---|---|---|---|---|---|
| Pre Motivation Test (covariate) | 102.36 | 1 | 102.35 | 5.24 | .03 |
| Group | 5217.53 | 1 | 5217.53 | 266.89 | .00 |
| Total | 1158958.00 | 59 | | | |

The results of the analysis are shown in Table 11, where there was a significant difference between the control group and treatment in terms of min score of post motivation IMMS test where p <0.05 in chemistry learning [F (1,59) = 266.89, p <0.05].

From the findings, it can be concluded that IEAS could have an impact on improving students' motivation in chemistry learning. The items in the IMMS motivation test consists of four subscales: attention, relevance, confidence, and satisfaction. The students showed a high mean score in satisfaction between subscales, indicating that students were motivated when learning using IEAS. Furthermore, the confidence subscale was the second-highest mean score for the control and treatment groups. The students who were able to control their personal feelings and expectations to succeed had influenced their learning. The motivation test also indicates that students needed support from their teachers, especially in learning complex topics such as electrochemistry. Relevance is an influential factor in determining what students are motivated to learn or why they are willing to continue learning (Keller, 1983). It is the third-highest score for the control group and treatment. This result shows that students could apply chemistry in their daily lives. According to Keller (2008), students' motivation improves when knowledge of the lessons learned was significant. Similar to a study by Rosen (2009), this study shows that an animation-based online learning environment affects the transfer of knowledge and motivation for science and technology learning.

Attention refers to getting attention, building curiosity, and being constantly active in learning activities. It is a low mean score between the four subscales for the control and treatment. Item 20, "The concept of electrolysis stimulates my curiosity," has got the highest mean score, with the majority choosing "agree" and "strongly agree." The findings in this study are essential to show that students could apply chemistry in their daily lives. The results of this study were quite similar to Barak et al. (2011), where they use animated movies to promote students' explanation ability and their understanding of scientific concepts. Their findings report that students who studied science with animated movies developed higher motivation to learn science that shows interest and enjoyment when they can make connection with their daily lives compared to the control group. According to Keller (2008), student motivation improves when knowledge of the lessons learned is significant as their curiosity has stimulated their motivation. Thus, interest and motivation could bring an individual to success and lead them to achieve good results in their studies.

## CONCLUSION

Establishing conceptual links between macroscopic, microscopic, and symbolic representations is an essential part of chemistry learning. Thus, the students should form a mental model of the electrolytic processes to visualize the microscopic entities such as the movement of ions and electrons, which often causes confusion and difficulties in learning this topic. This mental model created by the students in the treatment group, especially on tangible concepts or phenomena in electrochemistry, helped them learn chemistry at the molecular level. The students who were exposed to electrochemistry using interactive computer animation and simulation showed higher achievement in electrochemistry topics than the control group who were exposed to the conventional methods. The reason is that interactive computer animation and simulation might assist the students' abilities to visualize dynamic interactions and predict the behaviour of submicroscopic entities. Even though using interactive computer animation and simulation involve some technical aspects that need to be handled by teachers, and the teachers might not prefer to use this method. However, interactive computer animation and simulation should be utilized in chemistry teaching to enhance students' conceptual understanding. When the students could overcome the difficulties in learning complex topics in chemistry, they are more motivated and interested in learning chemistry. In conclusion, this study shows that using interactive computer animation and simulation increased the students' score in the achievement test of electrochemistry and their motivation level compared to students who followed the regular classroom teaching methods.

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