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IMPACT OF INTERACTIVE MULTIMEDIA MODULE WITH PEDAGOGICAL AGENTS ON STUDENTS' UNDERSTANDING AND MOTIVATION IN THE LEARNING OF ELECTROCHEMISTRY

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ABSTRACT. The Electrochemistry topic is found to be difficult to learn due to its abstract concepts involving macroscopic, microscopic, and symbolic representation levels. Studies have shown that animation and simulation using information and communication technology (ICT) can help students to visualize and hence enhance their understanding in learning abstract chemistry topics. As a result, an interactive multimedia module with the pedagogical agent (IMMPA) named the EC Lab (Electrochemistry Lab) was developed in order to assist students in the learning of Electrochemistry topics. A non-equivalent pretest–posttest control group design investigation was carried out in order to gauge the effect of the IMMPA EC Lab on students' understanding and motivation in the learning of Electrochemistry. Some 127 Form Four students from two secondary schools in one of the districts in Malaysia were involved in the study. Each school had one treatment group and one control group taught by the same Chemistry teacher. Instruments involved were a pre- and posttest, a pre- and post-motivation questionnaire, and the IMMPA EC Lab. Results showed a significant difference between the control groups and treatment groups in the understanding of concepts in the learning of Electrochemistry.

KEY WORDS: electrochemistry, interactive multimedia module, pedagogical agent

Introduction

Chemistry is the science of matter concerned with the composition of substances, structure, properties and interactions between them. Chemistry should be taught at three representational levels, macroscopic, microscopic, and symbolic (Johnstone, 1993). Macroscopically, the chemical process can be observed and sensed by our sensory monitoring. The arrangement and movement of particles and the interactions between them can be explained at the microscopic level. All the chemical processes involved can be represented by symbols, numbers, formulae, and equations symbolically. Chemistry is taught at upper secondary level for science stream students in Malaysia. The themes for the Chemistry

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syllabus are: (1) Introducing Chemistry, (2) Matter around us, (3) Interaction between chemicals, and (4) Production and management of manufactured chemicals.

The Learning of Electrochemistry

Electrochemistry is a study of the inter-conversion of chemical energy and electrical energy that occurs in electrolysis and voltaic cells (Tan, Loh & Tan, 2007). Previous studies (Bojczuk, 1982; Lin, Yang, Chiu & Chou, 2002; Roziah, 2005) have shown that the topic is difficult to learn because the concepts are abstract. We conducted a needs assessment (Lee & Kamisah, 2010), and the results also showed that both teacher and students found that the topic is one of the most difficult topics to be learnt in the syllabus. Students often encounter misconceptions in the learning of this topic (Garnett & Hackling, 1993; Garnett & Treagust, 1992b; Garnett, Garnett & Hackling, 1995; Hamza & Wickman, 2008; Lee & Mohammad, 2009; Lee, 2008; Lin et al., 2002; Sanger & Greenbowe, 1997a, b). Macroscopically, students need to study the concepts of electrolytes and non-electrolytes, the electrolysis process, and voltaic cells. Microscopically, they need to understand the movement of ions and electrons during the electrolysis process. Besides that, they also need to transform the process into chemical formulae and equations symbolically. Students face difficulties in understanding the abstract chemical processes especially at the microscopic and symbolic levels (Garnett & Hackling, 1993; Garnett & Treagust, 1992b; Garnett et al., 1995; Hamza & Wickman, 2008; Lee & Mohammad, 2009; Lee, 2008; Lin et al., 2002; Sanger & Greenbowe, 1997a, b). Generally, some common misconceptions or problems faced by students in learning Electrochemistry are: (1) students are always confused between the flow of current in the conductors and in the electrolytes; (2) they cannot identify the anode and cathode/positive and negative terminals in the cell; (3) they cannot describe and explain the process happening at the anode and cathode; (4) they mix up the oxidation and reduction process at the electrodes; and (5) they are unclear about the concept of an electrolyte (Lee & Kamisah, 2011; Lee & Mohammad, 2009; Lee, 2008). These misconceptions were related to the understanding of Electrochemistry concepts at the three representational levels. The relationships between the misconceptions and the three representational levels are presented in Table 1.

The students' major problem in learning abstract chemistry topics is the ability to visualize the concepts, that is, to form a mental image or picture in the mind (Lerman, 2001). Chemistry is a visual science (Wu &

TABLE 1

Misconceptions in electrochemistry and relations with three representational levels

Misconceptions	*Representational level*
The flow of current in the conductors and in the electrolytes	Macroscopic, microscopic
Identify the anode and cathode / positive and negative terminal	Macroscopic
Process happening at the anode and cathode	Macroscopic, microscopic, and symbolic
Oxidation and reduction process	Microscopic, symbolic
Concept of electrolyte	Microscopic, symbolic

Shah, 2004). In educational practice, difficulties in visualization are applicable to one or more of the following situations: (a) the experiment is too long or too short; (b) the dimensions of the examined object are too small or too large; (c) the environment of the experiment is not accessible; (d) the parameters of the experiment or its effects are not directly available to the observer's senses; (e) there is a need for multiple revisions of the experiment; (f) the experiment is difficult to arrange or revise effectively; (g) the experiment is dangerous; (h) the experiment is too expensive; etc. (Burewicz & Miranowicz, 2002). In the context of Electrochemistry, the dimension of the examined objects (movement of particles) is too small, and the parameters of the experiment are not directly available to the observer's senses where the changes of the process are at the microscopic level. Hence, the teaching and learning of Electrochemistry should be aided with the use of a multimedia module. This enables the students to visualize the abstract chemical processes by using the application of multimedia elements in the module.

The Use of Information and Communication Technology in Teaching and Learning

The use of Information and Communication Technology (ICT) is the aiding of understanding and explanations of concepts, especially visualizing abstract concepts and processes (using models, simulations, games, digital video, and multimedia adventures) (Oldham, 2003). Application of multimedia in education through the World Wide Web, compact disc read-only memory (CD-ROMs), digital versatile disc (DVD), and virtual reality can help students visualize abstract concepts, especially in the learning of Chemistry. The use of multimedia creates the environment where students can visualize the abstract chemical processes via animation and video at the macroscopic, microscopic, and symbolic levels (Bowen, 1998; Burke, Greenbowe & Windschitl, 1998; Rodrigues, Smith & Ainley, 2001; Russell, Kozma, Jones, Wykoff, Marx & Davis, 1997). Studies (Doymus, Karacop & Simsek, 2010; Gois & Giordan, 2009; Lerman & Morton, 2009) have been carried out, and the results have shown that animation and simulation using ICT can help students to visualize and, hence, enhance students' understanding, in learning abstract Chemistry topics.

In the context of Electrochemistry, the use of multimedia elements like graphics and videos can show the students the observations of the electrolysis process. For instance, the color change during the electrolysis process can be shown by video macroscopically, and the mass difference of the electrodes before and after the electrolysis process support the observation. The animation showing the moving of electrons and ions in the electrolytic cell presents the electrolysis process at the microscopic level. Students can visualize the entire electrolysis process and understand how the inter-conversion of chemical energy and electrical energy occurs in electrolysis and a voltaic cell. The transformation of the oxidation and reduction process into a chemical equation can be shown by the text and presented to the students. Hence, students can make the relationship between the microscopic electrolysis process and symbolic representation of an equation.

Although the use of multimedia modules is able to assist students in visualizing the abstract concepts and enhance the Electrochemistry learning (Hasnira, 2005; Karsli & Çalik, 2012; Sanger & Greenbowe, 2000), the rate of using multimedia modules in the schools is still very low (Lee & Kamisah, 2010). Teachers are not interested in using the modules available in the market in the learning process because they have found that these modules are too formal, not interesting, and do not follow the syllabus (Norsiati, 2008; Roziah, 2005). Besides, students were found to have low motivation in the learning of Chemistry (Juriševič (2009); Kamisah, Zanaton & Lilia, 2007; Zanaton, Lilia & Kamisah, 2006), due to the abstractness and difficulty of the subject. Furthermore, students lack sufficient metacognitive awareness and comprehension monitoring skill to make effective choices (Hill & Hannafin, 2001; Land, 2000). They lack the skills to find, process, and use information and ideas. Students as novice learners do not always make connections to prior knowledge or everyday experiences in ways that are productive for learning (Land, 2000). As a result, pedagogical agents (PAs) are designed to facilitate learning in computer-mediated learning environments (Chou, Chan & Lin, 2003; Craig, Gholson & Driscoll, 2002; Johnson, Rickel &

Lester, 2000; Moundridou & Virvou, 2002; Predinger, Saeyor & Ishizuka, 2009; Slater, 2000). The use of PAs in the interactive multimedia module in this study makes the module different from the modules available in the marketplace.

Pedagogical Agents in the Interactive Multimedia Modules

PAs are animated life-like characters that show human characteristics in terms of appearance such as changes in facial expressions, gestures, and body movements when interacting with the users. Users can communicate with the agent via speech or on-screen text. The appearance of PAs is varied in terms of gender (male or female), realism (cartoon and realistic), and ethnicity (African-American and Caucasian) (Baylor, 2005). Normally, PAs are designed as experts (Baylor, 2005; Baylor & Kim, 2004; Chou et al., 2003; Hayes-Roth, Maldonado & Moraes, 2002; Kim, Baylor & PALS Group, 2006; Kizilkaya & Askar, 2008; Moreno, Mayer & Lester, 2000; Moreno & Mayer, 2005) who are knowledgeable in specific areas to provide guidance to students. However, there are also PAs which act as co-learners (Chou et al., 2003; Kim et al., 2006; Maldonado & Hayes-Roth, 2004; Maldonado, Roselyn Lee, Brave, Nass, Nakajima, Yamada, Iwamura et al., 2005; Xiao, Stasko & Catrambone, 2004) or motivators (Baylor, 2005; Baylor & Kim, 2004; Kizilkaya & Askar, 2008). The co-learners or motivators accompany the students and encourage and motivate them to be involved in the learning process.

PAs in a multimedia module serve to enhance students' metacognitive awareness of what they know and what they should know for the topic being studied. One strategy for providing metacognitive guidance involves embedding support, or scaffolds for procedural, strategic, or metacognitive control (Land, 2000). This guidance and support is provided by the PAs in the module. The PAs in a multimedia module could remind students of some related concepts learnt before in the previous sub unit so that students can make connections between the concepts learnt and the new concepts. Besides that, PAs could do revision with students in the early part of the new sub-unit to ensure that students still remember the concepts learnt before. PAs could make learners aware of the opportunities presented to them, provide advice for the learners on the tools to be used, and explain the functionalities of the tools in an open learning environment (Clarebout & Elen, 2007). For instance, PAs remind students to click on certain icons in the multimedia module to bring students to some important section in the module. Hence, students will not miss out the important part in the module. Apart from that, PAs that act as low-competency co-learners were found to be able to enhance students' self-efficacy, confidence, and motivation toward unfamiliar but important domains (Kim et al., 2006). In general, PAs in the learning material can increase students' learning effectiveness and motivate them to interact more frequently with agent-based educational software and enhance their motivation to continue learning (Atkinson, 2002; Baylor & Kim, 2004; Lester, Converse, Kahler, Barlow, Stone & Bhogal, 1997; Moreno et al., 2000; Moundridou & Virvou, 2002). Hence, an Interactive Multimedia Module with Pedagogical Agents (IMMPA) with the differing roles of PAs, named the EC Lab, was developed in order to assist students in the learning of Electrochemistry.

Objectives of the Study

The researcher designed and developed the IMMPA EC Lab and carried out the study for several objectives as listed below:

a. Identify the difference between the control and treatment groups in terms of mean score for the achievement test.
b. Identify the difference between the control and treatment groups in terms of mean score for the motivation questionnaire.

METHODOLOGY

Research Design

The study is a non-equivalent pre-test/post-test control group design (Campbell & Stanley, 1963). Normally, schools in Malaysia will arrange the classes according to students' achievements and subjects selected. Hence, it was impossible to run the study using true experimental designs. So, the researcher picked whole classes of students as samples for the study. Four classes were chosen from two secondary schools with some similar characteristics among the students. There were two groups of samples: a treatment group and a control group. Two classes were selected as the control group, and another two classes were selected as the treatment group. Samples in the treatment group learnt the Electrochemistry topic using the IMMPA EC Lab developed by the researcher. On the other hand, Electrochemistry was to be taught by a Chemistry teacher using the traditional method for the students in the control group.

Sample of the Study

The selection of samples was based on certain criteria. For instance, overall students' achievement in the Lower Secondary Examination

(Peperiksaan Menengah Rendah, PMR); the ratio of female and male students; the experience of the Chemistry teacher who taught the classes; and finally, the number of computers in the computer laboratory. Finally, 127 (50 males and 77 females) Form Four students (16 years old) from two secondary schools in one of the districts in Malaysia were involved in the study. The students were from four classes, with two classes randomly selected as control groups and another two classes as treatment groups. There were 24 males and 39 females in the control group, and 26 males and 38 females in the treatment group. Each school had one treatment group and one control group taught by the same Chemistry teacher. Both teachers had more than 20 years of experience in teaching Chemistry. The students then completed the specific entry test to test their basic skills that would be applied in the learning of Electrochemistry. The purpose of the specific entry test was to identify students' specific entry competencies related to proton number, nucleon number, arrangement of electrons, chemical formulae, and chemical equation. This was to ensure that students were homogenous in terms of entry behaviors. Independent-samples *t* test results showed that both groups had no significant difference on specific entry test means and that they were homogeneous in terms of entry behaviors (Kamisah & Lee, 2012). To avoid the participant effect, the researcher implemented the single-blind experiment (Jackson, 2003) where the students in the treatment group were unaware about the treatment being done on them. The details of the samples are summarized in Table 2.

Materials

Achievement Tests. Materials utilized in the study were the achievement tests, motivation questionnaire, and the IMMPA EC Lab. The achievement tests were administered in the form of a pre-test and post-test before and after the intervention. There were two structured

TABLE 2

Descriptive information of samples

	Schools		*Groups*		
Details	*SMKL*	*SMKTM*	*Control*	*Treatment*	*Total*
Number of students	54	73	63	64	127
Male	17	33	24	26	50
Female	37	40	39	38	77
Ratio of male to female	1:2.18	1:1.21	1:63	1:1.46	
Teacher's experience (years)	>20	>20	>20	>20	

questions in the achievement test. The questions tested knowledge on the electrolytic cell and voltaic cell concepts at the macroscopic, microscopic, and symbolic levels (Table 3). Macroscopically, the students needed to identify the anode and cathode in the cell and describe the observations at both electrodes during the electrolysis process. Microscopically, they needed to draw the ions that existed in the electrolyte and the direction of the flow of the electrons in the circuit. Symbolically, they had to represent the oxidation and reduction process at the electrodes by writing the half-equations. The distributions of items according to the concepts tested and their representation levels are presented in Table 4. Questions in the pre-test and the post-test were similar in terms of the difficulty level and the concepts tested. The only difference was in the types of electrodes and electrolyte used in the cells. A reliability analysis was carried out, and the Cronbach Alpha was 0.65 for the pre-test and 0.71 for the post-test. All the questions in the achievement tests were developed by the researchers, referring to the previous studies by Lin et al. (2002) and Lai (2003). The questions in the tests followed the Chemistry syllabus and were checked by lecturers and teachers to maintain the content validity of the instruments. The pre-test was administrated to both groups to identify students' existing knowledge before they studied the Electrochemistry topic. Besides that, the pre-test could be used to measure the degree of improvement after instruction was completed (Morrison, Ross & Kemp, 2007). Then, the post-test was administered after the interventions to evaluate the amount of gain on measures of achievement. The post-test results from the two groups could also be used to compare the effectiveness of interventions being done in the study.

TABLE 3

Sample items and related representational level

Items	*Representational level*
Predict any color change in the solution that may occur in the beaker after electrolysis has been carried out for 50 min?	Macroscopic
Imagine that you can see the particles in the electrolyte. Draw and label all the ions that exist in the beaker at the A area before the reaction begins.	Microscopic
Write the ionic equations (half equations) showing the reactions taking place at the anode and cathode.	Symbolic

TABLE 4

Distributions of items in the achievement test

	Distributions of items		
Concepts	*Electrolytic cell*	*Voltaic cell*	*Representation level*
The flow of currents in the conductors and in the electrolytes	c (i), c (ii)	c (i), c (ii)	Microscopic
		k, l (i), l (ii), m (i), m (ii)	Macroscopic Microscopic
Identifying anode and cathode	a (i), a (ii), b	a (i), a (ii), b	Macroscopic
	e (i), e (ii), f	e (i), e (ii), f	Microscopic Symbolic
Identifying process at anode and cathode	j	j	Microscopic
	i (i), i (ii), k (i), k (ii), k (iii), k (iv), k (v), k (vi), l (i), l (ii), l (iii), l (iv), l (v), l (vi)		Macroscopic Microscopic
		i (i), i (ii)	Macroscopic
Oxidation and reduction process	g (i), g (ii)	g (i), g (ii)	Symbolic
	h	h	Microscopic
Concept of electrolyte	d	d	Microscopic Symbolic

Motivation Questionnaire. The motivation questionnaire is a Likert scale questionnaire. There are three sub-dimensions involved, namely, Adhered Value, Expectancy Components, and Affective Components. Adhered Value consists of three subscales, namely intrinsic goal orientation, extrinsic goal orientation, and task value. On the other hand, Expectancy Components consist of control of learning belief and self-efficacy for learning and performance. Affective Components involve test anxiety. There were 28 items in the questionnaire with a Likert scale provided, where 1 is Strongly Disagree, 2 is Disagree, 3 is Not Sure, 4 is Agree, and 5 is Strongly Agree. Distributions of items and some sample items in the related subscales are presented in Table 5. Items in the questionnaire had been taken from the study of Sadiah and colleagues (2009) which were translated from the instrument used by Pintrich & DeGroot (1990). In this study, the researcher used the motivation section only and changed the scale from seven points to five points. The validity and reliability of the translated questionnaire was checked by Sadiah and colleagues (2009), and the overall internal reliability was measured at 0.838. However, we still conducted the pilot study (Lee & Kamisah, 2011), and the

TABLE 5

Distributions of items in the motivation questionnaire

Sub-dimension	*Distributions of items*	*Sample items*
Adhered value		
Intrinsic goal orientation	1, 13, 19, 21	I prefer course material that arouses my curiosity, even if it is difficult to learn.
Extrinsic goal orientation	6, 9, 27	Getting a good grade is the most satisfying thing for me right now.
Task value	8, 14, 20, 23, 24	Understanding the subject matter of this course is very important to me.
Expectancy components		
Control of learning belief	2, 7, 15, 22	It is my own fault if I don't learn the material in this course.
Self-efficacy for learning and performance	4, 5, 10, 12, 17, 18, 26, 28	I believe I will receive an excellent grade in this class.
Affective components		
Test anxiety	3, 11, 16, 25	I have an uneasy, upset feeling when I take an exam.

Cronbach's Alpha for the questionnaire was 0.87. The items in the pre-motivation questionnaire and post-motivation questionnaire were the same. The two sets of questionnaires were given to the samples before and after the interventions to evaluate the difference in motivation level among the students.

IMMPA EC Lab. The IMMPA EC Lab was developed by the researcher by using a combination of two instructional design models: the Kemp Model and Gerlach and Ely Model. The reasons for using the combination of these two models were because they are classroom-oriented models (Gustafson & Branch, 1997) with their own strengths. The Kemp Model describes elements, not "step, stage, level, or sequential item" in an instructional design (Kemp, Morrison & Ross, 2004). All the processes of designing, developing, implementing, and evaluating can be done concurrently and continuously. The Gerlach and Ely Model is suitable for the novice instructional designers who have knowledge and expertise in a specific context (Qureshi, 2001, 2003, 2004). This model is classroom-oriented and is suitable for teachers at secondary schools and higher education institutions. Hence, the researcher combined the two models as the instructional design model to develop the IMMPA EC Lab.

There are two PAs in the IMMPA EC Lab, namely Professor T and Lisa. Professor T is a 60-year-old male PA who acts as an expert in Electrochemistry. He gives accurate information and explains new concepts to the students. Professor T speaks slowly in a formal way with few body gestures and facial expressions. On the other hand, Lisa is a 15-year-old female youth who speaks with an energetic voice. She is a learning companion in the IMMPA EC Lab. She learns together with the students and provides motivation and encouragement to the students to complete the tasks and exercises in the module. Students are free to choose the PA they want to accompany them in the learning of Electrochemistry when using the IMMPA EC Lab.

The main menu for the IMMPA EC Lab consists of the tutorial, experiment, exercise, quiz, memo, and game. There are five sub-units in the IMMPA EC Lab: (1) Electrolytes and Non-electrolytes, (2) Electrolysis of Molten Compounds, (3) Electrolysis of Aqueous Solutions, (4) Voltaic Cells, and (5) Types of Voltaic Cells. All the information delivery for the sub-units are presented in the tutorial session. The experiment session consists of five experiments in Electrochemistry. The students are guided by the PAs to carry out the experiments in the chemistry laboratory, and they need to apply scientific process skills and manipulative skills in order to carry out the investigations. There is a session named "Micro-world" (Fig. 1) in the IMMPA EC Lab. When students click on the magnifying glass button,

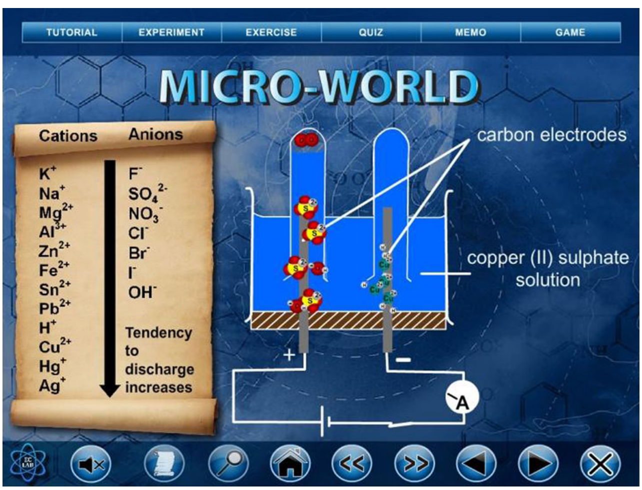

Figure 1. Micro-world in the IMMPA EC Lab showing the electrolysis process at the microscopic level

they will be shown the moving of electrons and ions at the microscopic level. This Micro-world session describes the detailed process which happens in the cell during the electrolysis process. Hence, students will be able to understand the process that happens in both electrodes during the electrolysis process and avoid misconceptions. After the information delivery process, the students do some exercises to enhance their understanding of the concepts learnt in the *Practice makes perfect* session. A Quiz is given at the end of every sub-unit consisting of multiple choice questions, structured questions, and essays. The Memo is created to give some hints and tips on the learning of some of the Electrochemistry concepts. For instance, mnemonics are given to help the students in memorizing the list of anions and cations in the Electrochemical Series (Fig. 2). There are four activities in the game session to let the students relax after the learning process.

The complete flow of each sub-unit follows the five phases in the learning process created by Needham (1987). The five phases are orientation, elicitation of ideas, restructuring of ideas, application of ideas, and review. In the IMMPA EC Lab, the *Think about it* session is the orientation phase. The PAs in the IMMPA EC Lab show some familiar pictures to the students. These pictures are related to the concepts to be learnt in every sub-unit. Then, in the *Do you still remember* session, the PAs reminds the students of some concepts that they have learnt before. Those concepts are related to the new concepts to be learnt in the sub-unit. Next, in the *Give me your ideas* session, the students are given the chance to give their ideas regarding some activities that are related to the concepts to be learnt. PAs motivate and help students to

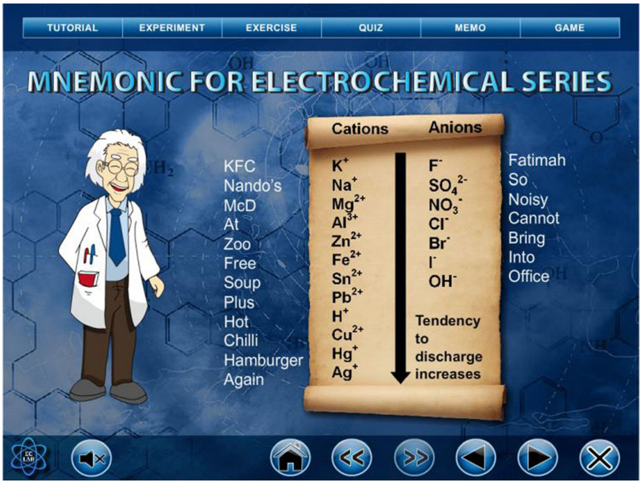

Figure 2. The mnemonic in the Memo helping students to memorize the electrochemical series

give ideas and take part in the activity. Then, in the *Are you sure* session, the students need to give some ideas and make some guesses or predictions on some outcomes of the situations. In order to examine their ideas, guesses, and predictions, the students need to carry out some investigations in *Let's do it* or watch related videos in *Show time* sessions. PAs help students to carry out some experiments in order to find out the answers for their predictions. In these two sessions, the students are exposed to conflict situations if their ideas, guesses, or predictions are different from what is being shown in the experiments or videos. Hence, conceptual change should happen here, and the students need to modify, extend, or replace their existing ideas. Then, reinforcement of the constructed ideas is done in the *Practice makes perfect* session. The students apply the concepts learnt in new situations and examples. Lastly, a *Before and after* session is created to enable the students to reflect upon the extent to which their ideas have changed. The students need to answer certain activity questions again and compare their prior answers to the new answers. *Testing yourself* and *Challenge yourself* sessions contain multiple choice questions, structured questions, and essay questions to let the students evaluate themselves on the concepts learnt. PAs will give feedback on the answers given by the students in the multiple choice questions and remind them to check their answers for structured and essay questions by clicking on the *SOS* button provided.

Procedure

The study was carried out in the schools using Chemistry periods during the normal school hours. Two Chemistry teachers were involved in the study. The same Chemistry teacher handled both the treatment and control groups in one school. The teacher used the traditional "chalk and talk" method to teach the control group and the IMMPA EC Lab module for the treatment group during the teaching and learning process of Electrochemistry.

Samples in both the treatment and control groups were given 1 h to answer the pre-test. After that, they needed to answer the motivation questionnaire in about 15 min. In the next meeting (Chemistry periods), students in the treatment groups went to the computer lab to study the Electrochemistry topic using the IMMPA EC Lab. The user manual was given to the students, followed by a briefing on how to use the IMMPA EC Lab. Then, students were told the sub-unit to be learnt on that day to ensure that every student learnt the same sub-unit. Then, students were free to explore the first sub-unit in 80 min. They put on the earphones to listen to the script delivered by the PAs. Teachers acted as facilitators and helped students if they faced any problems during the learning process with the IMMPA EC Lab. On the other hand, students in the control groups were taught by their teacher using the traditional method. Each meeting was about 80 min (two periods), and students learnt one sub-unit in each meeting either with their teacher or with the IMMPA EC Lab.

Students learnt the second sub-unit in the next meeting. The teaching and learning process for a treatment groups was carried out in computer laboratory, but unlike the control groups, they used the Chemistry laboratory to study Electrochemistry. Sub-unit three consisted of three experiments in studying the factors that determine the ions discharged at the electrodes. Students therefore needed to attend three meetings to complete sub-unit three in the IMMPA EC Lab. As a result, the third, fourth, and fifth meetings were conducted in the Chemistry laboratory. Students needed to carry out the experiments to investigate the three factors that determine the ions to be discharged at the electrodes. Students learnt sub-unit four in the sixth meeting. There was an experiment regarding simple voltaic cell in the unit. Hence, students conducted the experiment in the Chemistry laboratory. For the seventh meeting, students explored sub-unit five in the IMMPA EC Lab about types of voltaic cells. Students in the control groups were given notes and lectures for the same sub-unit.

After completing the sub-units in the Electrochemistry topic, students needed to answer the post-test and motivation questionnaire in the next meeting. As usual, students in both the control and treatment groups were given 60 min to answer the post-test and 15 min to answer the motivation questionnaire. All the pre-tests, post-tests, and motivation questionnaires were collected and analyzed. The achievement tests were checked following the answer scheme prepared by the researcher. A correct answer was given one point, while a zero point was given to the wrong answer or a blank answer. The pre-tests and post-tests were used to analyze students' achievement levels while the motivation questionnaire was used to analyze students' motivation levels in the learning of Electrochemistry. The results were compared between the treatment and control groups to identify the effectiveness of the IMMPA EC Lab in increasing students' knowledge and motivation in the learning of Electrochemistry.

Results and Discussion

Achievement Tests

A series of paired-sample *t* tests were conducted to evaluate the impact of the interventions on the students' scores in the achievement test. There was a statistically significant increase in test scores from pre-test (M = 4.46, SD = 3.52) to post-test [M = 35.9, SD = 18.44, $t(62) = 12.57$, $p < 0.05$] for the control groups. On the other hand, students' achievement in the treatment groups also showed a statistically significant increase in test scores from the pre-test (M = 7.11, SD =4.00) to the post-test [M = 46.01, SD = 29.94, $t(63) = 11.03$, $p < 0.05$]. The eta squared statistic (0.50) for both groups indicated a large effect size. Although the overall results for the post-test were better compared with the pre-test for the groups, 52.4 % and 43.75 % from the control groups and treatment groups, respectively, still failed the post-test. The results for the post-test ranged from 4.26 % to 61.70 % for the control groups and 2.13 % to 93.62 % for the treatment groups. Both groups showed significant increased results for the achievement test from the pre-test to post-test, indicating that students' knowledge in Electrochemistry increased after they had gone through the interventions. However, the results for the post-test for the treatment groups were higher than the control groups. Table 6 shows the mean scores for the post-test between the control groups and treatment groups. An independent-samples t test was conducted to compare the post-test results for the treatment and control groups. There was a statistically significant difference in scores for the treatment (M = 46.01, SD = 29.94) and the control groups [M =35.90, SD = 18.44; $t(105.06) = 2.30$, $p = 0.05$]. This showed that students who learned Electrochemistry with the IMMPA EC Lab were achieving higher results compared with the control groups who learned Electrochemistry using the traditional method. Hence, the IMMPA EC Lab developed in the study was proven to have the ability to increase students' knowledge in the learning of Electrochemistry. This is parallel with previous studies (Hasnira, 2005; Karsli & Çalik, 2012; Sanger & Greenbowe, 2000) where students learning Electrochemistry with animations and simulations in a multimedia module would gain higher achievements compared with the traditional method.

Questions in the test consisted of items testing Electrochemistry concepts at the macroscopic, microscopic, and symbolic levels. Students

TABLE 6

Post-test mean scores for the control and treatment groups

Group	*N*	*Mean*	*SD*	*t value*	*Sig (two-tailed)*
Treatment	64	46.01	29.94	2.295	0.024**
Control	63	35.90	18.44		

**α = 0.05

needed to understand the whole process that happens during electrolysis at both electrodes. Overall, students' results in answering questions at the macroscopic levels were similar between the two groups. For instance, the majority of the students (84.1 % from the control groups and 89.1 % from the treatment groups) could identify the anode and cathode for Item 1 (a). For Item 2 (a), 61.9 % students from control groups and 87.5 % students from treatment groups could identify the positive and negative terminals for the voltaic cell. For Item 1 (i), they were able to predict the color change of the electrolyte after the electrolysis process had been carried out for some time. However, students from the treatment groups were found to be more scientific in giving explanations to their answers for the color change based on the Electrochemistry concept at the microscopic level. Half of the students from the treatment groups explained that the color of the electrolyte changed from blue to light blue because the numbers of Copper (II) ions in the electrolyte reduced when Copper (II) ions were discharged at the cathode. By comparison, only 34.9 % students from the control groups could give such an explanation at the microscopic level. Students in the treatment groups had learnt the Electrochemistry via the IMMPA EC Lab where they could see the electrolysis process at the macroscopic and microscopic levels. The combination of multimedia elements in the ICT such as graphics, animation, and audio in explaining the movement of ions and electrons promoted conceptual understanding (Barak, 2007; Phillips, Norris & Macnob, 2010). Furthermore, the application of the five Needham phases which have similarities with the Learning Cycle Approach suggested by Gabel (2003) enabled the students to produce better content achievement, improved thinking skills and to have more positive attitudes towards science. The complete conceptual understanding of Electrochemistry enabled the students to describe the electrolysis process at the macroscopic, microscopic, and symbolic levels.

Students from the treatment groups had better conceptual understanding compared with the control group especially at the microscopic level (Kamisah & Lee, 2012). Item 1 (c), (i) tested students on the concept of the flow of currents in the conductors and in the electrolytes at the microscopic level. Students needed to draw the direction of the flow of electrons in the electrolytic cell during the electrolysis process. There were 70.3 % of students from the treatment groups who answered the item correctly compared with 55.6 % of students from control groups who got the answer correct. Students tended to draw the flow of electrons in the electrolyte (Garnett & Treagust, 1992a; Hamza & Wickman, 2008; Lee & Kamisah, 2011; Lee & Mohammad, 2009; Lee, 2008), or they reversed the direction of the flow of electrons. Students assumed that the electrons flowed in the electrolyte to complete the circuit (Lee & Mohammad, 2009; Lee, 2008) as shown in the Fig. 3. For Item 2 (c), which tested students on the same concept in a voltaic cell, almost half of the students from both groups could draw the correct direction of flow of electrons in the cell. But only 9.5 % of students from the control groups could give the scientific reason to explain the flow of electrons from Zinc metal to Copper metal. Comparatively, 43.8 % of students who had studied Electrochemistry using the IMMPA EC Lab were able to explain the difference between Zinc and Copper metal in terms of electro-positivity due to the position of metals in the Electrochemical Series.

For understanding of the process that happened at both electrodes during the electrolysis process, more than 40 % of the students from both groups were able to list down all the ions that accumulated at both electrodes for the electrolytic cell. But when the electrolyte changed to a concentrated Copper (II) chloride solution (Item 11), only some students from both groups were able to give the correct observations at both electrodes at the macroscopic level. However, students from the treatment groups (e.g. ET 22 & ET33) could explain the reasons to the observations at the microscopic level, including describing the movements of ions and processes that happened at both electrodes. On the other hand, students from the control groups (e.g. KL29) tended to give a conclusion as a reason for the observation given.

Since the Cl^- ion is more concentrated than OH^-, the Cl^- ion is chosen for discharging to form chlorine gas (ET22).
Cl^- ions are selectively discharged as it is more concentrated even though it is placed higher in the electrochemical series (ET33).
The chlorine gas is produced (KL29).

Similarly, Item 2 (i) tested students on the concepts of the process that happened at both electrodes, which involve the positive and negative

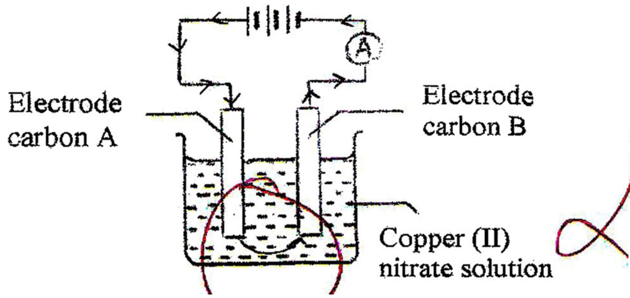

Figure 3. The flow of electrons in the electrolyte

terminals in a voltaic cell. Although the items were at the macroscopic level, surprisingly only 1.6 % and 7.9 % of students from the control groups could state the products at both terminals compared with 39.1 % and 31.3 % of students from treatment groups. Students were confused between terminals in the electrolytic cell and voltaic cell (Lee & Mohammad, 2009; Lee, 2008) causing them to give the answers following the terminals in the electrolytic cell. For Item 2 (j), which was asking the explanations for the products formed, 28.1 % of students from the treatment groups were able to describe the process that happened at both terminals at the microscopic level. On the other hand, only one student from the control groups was able to do so.

Results showed that students were still weak in understanding the concept of an electrolyte in a voltaic cell. Data showed that only 6.3 % of students from the control groups and 35.9 % of students from the treatment groups were able to draw all the ions that existed in the voltaic cell. Students assumed that water molecules were not involved in the electrolysis process (Garnett & Treagust, 1992b; Sanger & Greenbowe, 1997a; Lai, 2003; Lee & Mohammad, 2009; Lee, 2008), and hence, they did not draw the hydrogen ions and hydroxide ions from the water molecule in the electrolyte as illustrated in Fig. 4. Some of the students even drew the molecules, atoms, or wrong ions formulae in the electrolytes (Lee & Mohammad, 2009; Lee, 2008) showing that students had a poor understanding of the concept of ionization.

Overall, students from both groups were able to transform the oxidation and reduction process into half-equations, showing that they could answer the questions at the symbolic level. Although students from the control groups could give correct half-equations for both the electrodes and terminals, they were unable to explain the reasons for their answers. The teaching and learning of Electrochemistry using the traditional method in the control groups is a kind of passivelearning (Ausubel, Novak & Hanesian, 1978), where the students just accept the content presented to them. If students receive the content in an arbitrary, verbatim fashion that does not result in the acquisition of any meaning, the learning can be considered to be rote learning. Students just reproduce the content presented to them without any connection or assimilation of the relevant aspects into the cognitive structure. On the

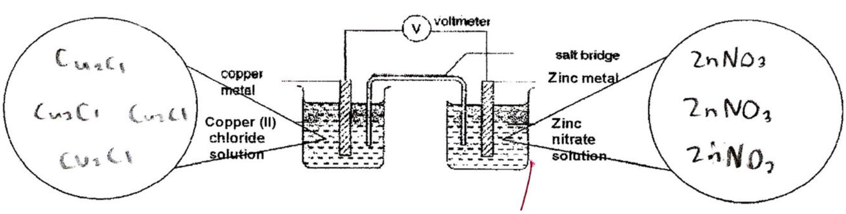

Figure 4. Molecules in the electrolyte

other hand, the learning of Electrochemistry using the IMMPA EC Lab with PAs enable the students to rearrange information, integrate it with existing cognitive structures, and reorganize the integrated combination in a way that promotes meaningful concept understanding. Hence, they can explain the selection of ions being discharged at both the electrodes and terminals based on the position of ions in the Electrochemical Series.

Overall, students' conceptions improved after the intervention, especially at the microscopic and symbolic levels. Comparisons of students' answers for some Electrochemistry concepts during the pretest and posttest are presented in Table 7.

The Micro-world in some of the sub-units shows the movements of ions in the electrolyte during the electrolysis process. Students can watch the process of gaining of electrons at the cathode and the releasing of electrons at the anode microscopically. They can visualize (Lerman, 2001) the whole process through the animations in the Micro-World. The IMMPA EC Lab makes the abstract concepts "concrete" because students

TABLE 7

Comparison of students' answers for the pretest and posttest

Electrochemistry concepts	*Pretest's answers*	*Posttest's answers*
The flow of current in the conductors and in the electrolytes [Item 1 c (i)]	Electrons flow in the electrolyte Electrons flow from the cathode to anode Electrons come out from both electrodes	Electrons flow from the anode to cathode
Process at the anode and cathode [Item 1 e (i), 1 e (ii)]	Anions accumulated at cathode	Anions accumulated at anode
	Cations accumulated at anode	Cations accumulated at cathode
	Absence of ions from water molecule	H^+ ions and OH^- ions are included in the answers
Concepts of oxidation and reduction process at the electrodes [Item 1 g (i), 1 g (ii)]	Oxidation equation at the cathode	Oxidation equation at the anode
	Reduction equation at the anode	Reduction equation at the cathode
	Wrong/incomplete half equations	Correct and complete half equations
Concept of electrolyte [Item 1 d]	Absence of ions from the water molecule in the electrolyte	H^+ ions and OH^- ions are present in the electrolyte

can watch the whole process visually at three representational levels (Bowen, 1998; Burke et al., 1998; Rodrigues et al., 2001; Russell et al., 1997). Hence, students learning Electrochemistry with the multimedia module will gain higher levels of achievement compared with the traditional method (Hasnira, 2005; Karsli & Çalik, 2012; Sanger & Greenbowe, 2000).

Motivation Questionnaire

The motivation questionnaire was used to assess the students' goals and value beliefs for Chemistry (especially Electrochemistry), their beliefs about their ability to succeed in the subject, and their anxiety toward the test and examination on Electrochemistry. Both groups answered a similar motivation questionnaire before and after the interventions. The paired sample t test was unable to show any significant difference between pre-motivation and post-motivation mean scores for both groups. The mean score for the control groups decreased from pre-motivation (M = 3.64, SD = 0.48) to post-motivation [M = 3.59, SD = 0.38; $t(62) = -0.98$, $p <$ 0.05]. On the other hand, the mean score for the treatment groups increased from the pre-questionnaire (M = 3.64, SD = 0.39) to the post-questionnaire [M = 3.68, SD = 0.39, $t(63) = 1.10$, p <0.05]. The eta squared statistic (0.50) indicated a small effect size for the both groups. Although the post-motivation mean score for the treatment groups was slightly higher than the control groups, the t test result as summarised in Table 8 was unable to show a significant difference between the groups.

Results from the independent samples t test show that there was no significant difference in post-motivation mean scores for the treatment (M = 3.68, SD = 0.39) and control groups [M = 3.59, SD = 0.38; $t(125)$ =1.43, p = 0.05]. The magnitude of the differences in the means was small (eta squared = 0.02). Items in the motivation questionnaire consisted of six subscales, namely intrinsic goal orientation, extrinsic goal orientation, task value, control of learning

TABLE 8

Post-motivation mean score for control and treatment groups

Group	*N*	*Mean*	*SD*	*tvalue*	*Sig (two-tailed)*
Treatment	64	3.68	0.39	1.429	0.156
Control	63	3.59	0.38		

belief, self-efficacy for learning and performance, and test anxiety. Students showed the highest mean score in extrinsic goal orientation (treatment groups, M = 4.16, SD = 0.61; control groups, M = 4.04, SD = 0.63), among all the subscales, indicating that they were trying to show to others that they could perform well in Chemistry. They expected to get a reward and praise from the parents and teachers if they got good grades in the subject. The examination-oriented education system in the country (Anthony, 2006; Keeman, 2007; Lim, 2011) causes the students to learn to get good grades in the examinations. For instance, item six "Getting a good grade in this class is the most satisfying thing for me right now," had a high mean score of 4.31 (SD = 0.72) with the majority of them agreeing (39.4 %) and strongly agreeing (45.7 %) with the statement. Results also showed that students were more extrinsically motivated than intrinsically motivated (Chang, 2005). Students were more concerned with the rewards and grades rather than enjoying and learning the Electrochemistry.

Control of learning belief obtained the second highest mean scores for the control and treatment groups with 4.01 (SD = 0.58) and 4.07 (SD = 0.59), respectively. With high control beliefs, students were confident in employing learning strategies to manage their learning and believed that this would bring about the desired results. As such, they may self-regulate more when their control beliefs are improved (Melissa Ng & Kamariah, 2006). Students believed that if they tried their best (Item 15, M = 4.24, SD = 0.70) and studied in an appropriate way (Item 2, M = 4.17, SD = 0.71), they would be able to learn and could understand the subject well.

Anxiety subscale measures students' nervousness and worried feelings towards examination. Students with a high anxiety level are not confident and are always worried about their academic results. Students who are not well prepared or who expect to fail are more likely to have higher anxiety than those students who are well prepared and expect to succeed (Shores & Shannon, 2007). Previous research showed that test anxiety is related to high extrinsic goal orientation (Kivinen, 2003) and the control of learning belief (Melissa Ng & Kamariah, 2006), and it was proven in this study. Extrinsic goal orientation and test anxiety for the treatment groups were found to be positively related to each other (r = 0.5, p <0.01). On the other hand, test anxiety was found to be positively related to the control of learning belief (r = 0.3, p <0.01). Students were more likely to worry about examinations if they believed that the attainment of the desired grades was not within their control (Melissa Ng & Kamariah, 2006).

Conclusion

The results from the study showed that the IMMPA EC Lab was able to increase the students' score in the achievement test in the learning of Electrochemistry. This is in parallel with previous studies (Atkinson, 2002; Kizilkaya & Askar, 2008; Moreno et al., 2000) where students were found to achieve higher performances when learning with a tutorial supported by PAs. However, the IMMPA EC Lab was not able to increase students' motivation level compared with students learning Electrochemistry with traditional methods. Further investigation, such as interviewing the students from the treatment groups, should be carried out in order to assess the weakness of the IMMPA EC Lab in terms of motivating students in the learning of Electrochemistry. Research regarding PAs is still new among researchers in East-Asia. Studies associated with PAs should therefore be increased in order to involve various fields and should be applied at various stages of education so as to benefit students from diverse backgrounds.

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