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Learning Aids in Chemistry: Design and Development

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Abstract: Electrochemistry is found to be a difficult topic to learn due to its abstract concepts that involve the macroscopic, microscopic and symbolic representation levels. Research showed that animation and simulation using Information and Communication Technology (ICT) can help students to visualize and hence enhance students' understanding in learning abstract chemistry topics. As a result, Interactive Multimedia Module with Pedagogical Agent (IMMPA) named EC Lab was developed in order to assist students in the learning of the Electrochemistry topic. KemGerly Model (combination of Kemp Model, Gerlach and Ely Model) were combined as instructional design models for the design of IMMPA EC Lab. Pedagogical Agents (PAs) were added in IMMPA EC Lab to facilitate learning in computer-mediated learning environments. The information delivery and the flow of content follow the Needham phases in constructivism theory. It is hoped that the IMMPA EC Lab would be able to assist students in the learning of Electrochemistry in terms of concept understanding and motivation level.

Keywords: Constructivism theory, electrochemistry, interactive multimedia module, pedagogical agent

INTRODUCTION

Electrochemistry is a study of inter-conversion of chemical energy and electrical energy that occurs in electrolytic and voltaic cells. Previous studies (Bojczuk, 1982; Lin *et al*., 2002; Roziah, 2005; Lee and Kamisah, 2010) showed that the topic is difficult to learn because the concepts are abstract. Students often encounter misconceptions in the learning of this topic (Garnett and Treagust, 1992; Garnett and Hackling, 1993; Garnett *et al*., 1995; Sanger and Greenbowe, 1997a; Sanger and Greenbowe, 1997b; Lin *et al*., 2002; Lee, 2008; Lee and Arshad, 2009; Karsli and Çalik, 2012). Generally, some common misconceptions or problems faced by students in learning Electrochemistry are:

- Students are always confused between the flow of current in the conductors and in the electrolytes;
- They cannot identify the anode and cathode/positive and negative terminal in the cell
- They cannot describe and explain the process happening at the anode and cathode
- They mix up the oxidation and reduction process at the electrodes
- They are unclear about the concept of electrolyte (Lee, 2008; Lee and Arshad, 2009; Lee and Kamisah, 2012)

Studies (Gois and Giordan, 2009; Lerman and Morton, 2009; Doymus *et al*., 2010) have been carried out and results showed that animation and simulation using Information and Communication Technology (ICT) can help students to visualize and hence enhance students' understanding in learning abstract chemistry topics.

Although the use of multimedia modules is able to assist students in visualizing the abstract concepts, but the students lack sufficient metacognitive awareness and comprehension monitoring skills to make effective choices (Land, 2000; Hill and Hannafin, 2001). 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 (Johnson *et al*., 2000; Slater, 2000; Craig *et al*., 2002; Moundridou and Virvou, 2002; Chou *et al*., 2003; Predinger *et al*., 2009) by providing metacognitive guidance whichinvolves embedding support, or scaffolds for procedural, strategic, or metacognitive control (Land, 2000). Hence, an Interactive Multimedia Module with Pedagogical Agents (IMMPA) with different roles of PAs, named EC Lab was developed in order to assist students in the learning of Electrochemistry.

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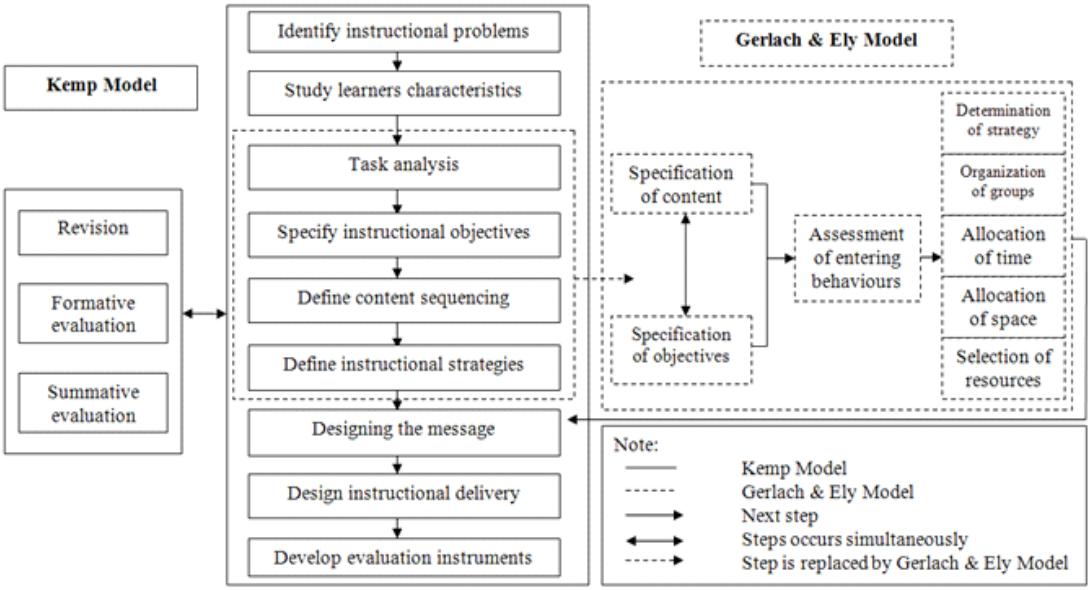

Fig. 1: Conceptual framework of KemGerly model

DESIGN AND DEVELOPMENT

Instructional design model: In this study, the researcher is interested to develop an IMMPA named EC Lab in the learning of Electrochemistry by combining two instructional design models: Kemp *et al*. (1994) and Gerlach and Ely (1980). The two models are combined as they are both classroom-oriented (Gustafson and Branch, 1997) with their own strengths. The model combined was named KemGerly Model and the conceptual framework of KemGerly Model is presented in Fig. 1.

Pedagogical agent: 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. Studies (Baylor and Kim, 2003; Baylor, 2005) showed that male agents were found to be more outgoing and agreeable, more intelligent and knowledgeable compared to female agents. Although female agents were perceived as less intelligent, but they were more aggressive in enhancing self-efficacy (Baylor and Kim, 2004; Baylor, 2005). Hence, the excerpt was designed in the form of a male professor of about sixty years old. Professor T (Fig. 2) gives accurate information and explains new concepts to the students. He speaks slowly in a formal way with minimal body gestures and facial expressions. On the other hand, Lisa (Fig. 2) is a fifteen-year old female youth who speaks with an energetic voice. She

Fig. 2: Professor T and Lisa

is a learning companion in the ECLab. She learns together with the students, gives 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 EC Lab.

Parts in IMMPA EC lab: The main menu for the EC Lab consists of tutorials, experiments, exercises, quizzes, memos and games. There are five sub units in the EC Lab:

- Electrolytes and Non-Electrolytes
- Electrolysis of Molten Compounds
- Electrolysis of Aqueous Solutions
- Voltaic Cells
- Types of Voltaic Cells

All the information delivery for the sub units are presented in the tutorial session. The experiment session

Table 1: Needham phases and sessions in IMMPA EC lab

Needham phases	Sessions in every sub unit	Main menu
Orientation	*Think about it!*	
		Tutorial
Elicitation of ideas	*Do you still remember?*	
Restructuring of ideas		
Clarification and exchange	*Give me your ideas...*	
Exposure to conflict situation	*Are you sure?*	
Construction of new ideas and evaluation	*Let's do it!! / Show time!*	Experiment
Aplication of ideas	*Practice makes perfect!*	Exercise
Review	*Before & after...*	
		Quiz
	Test yourself	
	Challenge yourself	
		Memo
		Game

consists of five experiments in Electrochemistry. After the information delivery process, the students will do some exercises to enhance their understanding on the concepts learnt in the *Practice makes perfect* session. A quiz will be given at the end of every sub unit consisting of multiple choice questions, structured questions and essays. Memos are created to give some hints and tips on learning of some of the Electrochemistry concepts. There are four activities in the game session to let the students relax their mind after the learning process.

Needham phases in constructivism theory: 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 EC Lab, the *Think about it* session is the orientation phase. The students will be shown some pictures that are familiar to them. Those pictures are related to the concepts that will be learnt in every sub unit. Then, in the *Do you still remember* session, the students will be reminded 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. Then, in the *Are you sure* session, the students need to give some ideas, 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. In these two sessions, the students will be exposed to the conflicting 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 will be done in the *Practice makes perfect* session. The students will apply the concepts learnt in new situations and examples. Lastly, *Before* and *after* sessions are 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 enable the students to evaluate themselves on the concepts learnt. The relationship between sessions in IMMPA EC Lab and Needham phases is as summarized in Table 1.

CONCLUSION

IMMPA EC Lab is developed by applying the combination of two instructional models to overcome the weakness of the individual model. Elements of multimedia are used in the information delivery process so that students can have a different experience of learning in the multimedia learning environment. PAs with different roles and gender are implemented in the EC Lab after considering the demands of students from different backgrounds.

Besides that, the learning process in the EC Lab implements the five Needham phases so that students can generate their ideas from their pre-existing knowledge through their daily experiences. The IMMPA EC Lab is developed after months of effort, so it is hoped that it can improve students' understanding and motivation in the learning of Electrochemistry.

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