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Research Article

Development of Interactive Multimedia Module with Pedagogical Agent (IMMPA) in the Learning of Electrochemistry: Needs Assessment

Lee Tien Tien and Kamisah Osman
Faculty of Education, National University of Malaysia, 43600 UKM Bangi, Selangor, Malaysia

Abstract: A needs assessment was carried out as preliminary step for the development of Interactive Multimedia Module with Pedagogical Agent (IMMPA) in the learning of Electrochemistry. Seven Chemistry teachers as well as 223 students from three secondary schools were involved in this needs assessment survey to investigate the felt needs and normative needs in the learning of Electrochemistry. Results showed that both teachers and students rated the Electrochemistry chapter as the second most difficult chapter from the eight chapters in the Malaysian Chemistry syllabus. Students demonstrated high confidence in answering the Electrochemistry test despite obtaining poor results in the achievement test. IMMPA named EC Lab was recommended in order to help the students visualize the abstract concepts in the learning of Electrochemistry via the application of animations and simulations.

Keywords: Chemistry learning, electrochemistry, Interactive Multimedia Module with Pedagogical Agent (IMMPA), needs assessment

INTRODUCTION

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

In Malaysia, the Science subject was introduced by the colonialist in the early 1970s (Lewin, 1975) in secondary schools. Formal science education was started in primary schools for year five students. Science as a subject was introduced on a trial basis in selected schools in 1993 and introduced in all schools in 1995 (Khalijah, 1999). Science for primary school curriculum consisted of five main themes:

- Living system
- Physical system
- World of matter
- The earth
- Technology

Teaching methods included directed investigation, discovery learning, group project, experimenting, simulation and role play to encourage discussions among students and application of rules in decision making. Integrated Science, Modern Physics, Modern Chemistry, Modern Biology and Modern Science were gradually introduced in secondary schools throughout the country.

Chemistry is taught at upper secondary level for science stream students. The themes for the Chemistry syllabus are:

- Introducing chemistry
- Matter around us
- Interaction between chemicals
- Production and management of manufactured chemicals

The Chemistry curriculum has been designed not only to provide opportunities for students to acquire scientific knowledge and skills develop thinking skills and thinking strategies and apply the knowledge and skills in everyday life, but also to inculcate in them noble values and the spirit of patriotism (Curriculum Development Centre, 2005).

Electrochemistry is the sixth chapter in the Malaysian Chemistry syllabus for secondary schools. Electrochemistry is a study of inter-conversion of chemical energy and electrical energy that occurs in electrolytic and voltaic cell. This chapter is one of the chapters under the theme interaction between chemicals. Students learn this chapter after they have basic knowledge and understanding regarding atoms, chemical formulae and equations, periodic table and chemical bonds in previous chapters.

Corresponding Author: Kamisah Osman, Faculty of Education, National University of Malaysia, 43600 UKM Bangi, Selangor, Malaysia

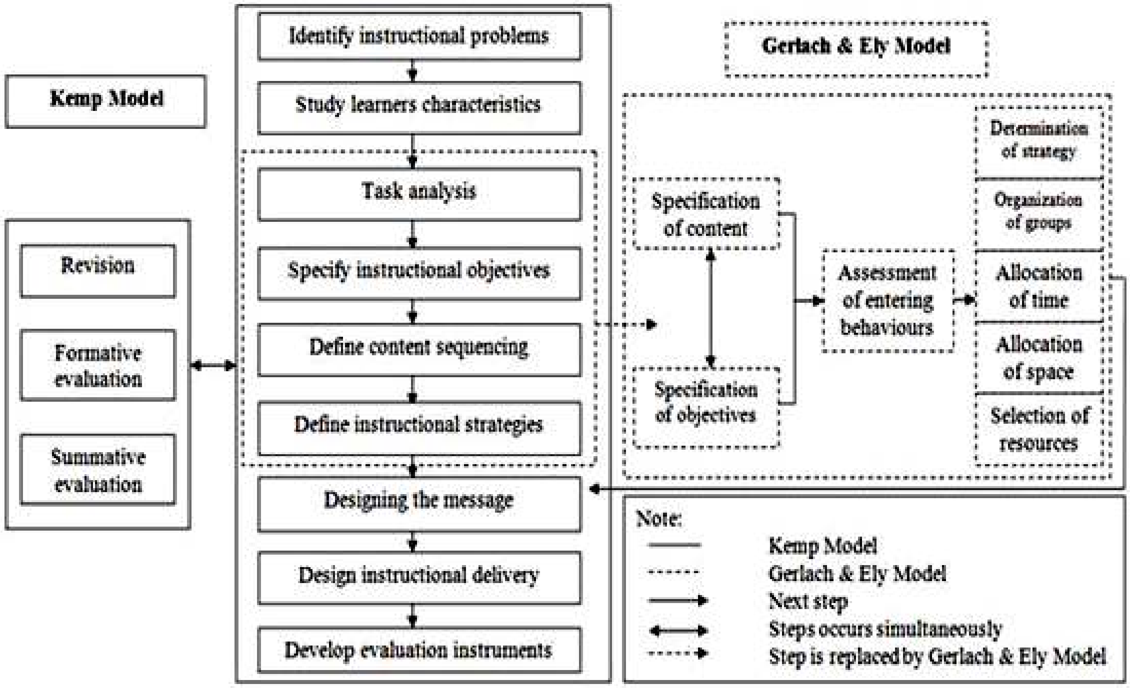

Fig. 1: KemGerly model

Difficulty in learning chemistry: Studies have been carried out to investigate the Chemistry syllabus in secondary schools, colleges and universities. Topics found to be difficult to study were Oxidation and Reduction, Chemical Equilibrium and Mole (Finley *et al*., 1982), Electrochemistry (Bojczuk, 1982; Lin *et al*., 2002; Roziah, 2005), Acid & Base (Schmid *et al*., 2009; Hajah, 2008). Gabel (1993) gave some possible explanations regarding difficulties in learning Chemistry:

- Chemistry teaching emphasizes the symbolic level and problem-solving at the expense of the phenomena and particle level
- Even though it is taught at three levels, insufficient connections are made between the three levels and the information remains compartmentalized in the long-term memory of students
- Even if Chemistry was taught at the three levels and the relationship among the levels was emphasized, the phenomena considered were not related to the students' everyday life

Students compartmentalized the knowledge as that learned in school versus that needed in everyday life. Hence, teaching of Chemistry should be done in three representational levels in an integrated way and should be related to students' daily experience

Needs assessment: In this study, an Interactive Multimedia Module with Pedagogical Agent (IMMPA) named EC Lab was developed by following the elements in KemGerly Model. KemGerly Model is an instructional model combined from Kemp *et al*. (1994) and Gerlach and Ely (1980). The reasons for using the combination of these two models are because they are classroom-oriented models (Gustafson and Branch, 1997) with their own strengths. The Kemp Model described elements, not 'step, stage, level or sequential item' in an instructional design (Kemp *et al*., 2004). All the processes of designing, developing, implementing and evaluating can be done concurrently and continuously. The Gerlach and Ely Model are 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 two models were combined as the instructional design model to develop the IMMPA EC Lab. The conceptual framework of the KemGerly Model used in the study is presented in Fig. 1. The first element in Kemp Model is identifying the instructional problems. Needs assessment is part of the important elements in identifying instructional problems in Kemp Model (Fig. 2).

A needs assessment was used to identify gaps in performance and then determine if the gap was worth addressing through an intervention (Morrison *et al*., 2007). Felt needs and normative needs (Burton and Merrill, 1991) were involved in this needs assessment. Felt needs expressed a gap between the current

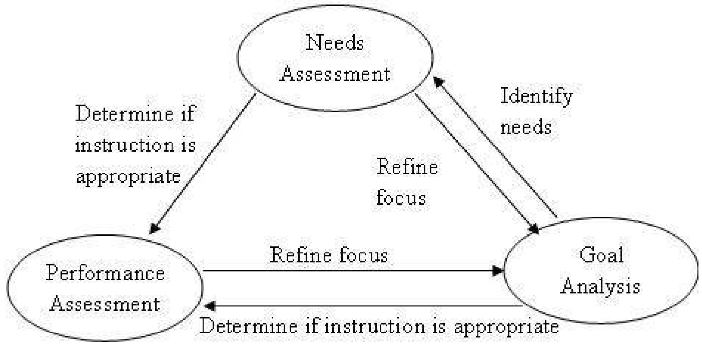

Fig. 2: Identifying instructional problems

performance or skill level and the desired performance or skill level. On the other hand, normative needs were identified by comparing the target audience against a standard.

Previous studies showed that some Chemistry topics were difficult to study and comparison was made in this study to show the scenario among Malaysian students. Hence, this needs assessment was conducted in order to find out students' problems in learning Chemistry as a preliminary step in the development of IMMPA named EC Lab.

METHODOLOGY

Design of study: This was a quantitative descriptive study to investigate students' instructional problem and their needs in learning Chemistry chapters in the syllabus. The study was carried out by using test and questionnaire in order to collect data from the respondents.

Respondents: Total students involved in the study were 223 Form Four and Form Five students from three secondary schools in Ledang district, Malaysia. Students from one of the schools answered two of the three surveys causing the total number of respondents for the three surveys exceeded 223 persons.

Chapter difficulty survey: Seven Chemistry teachers and 127 students from three secondary schools participated in the survey. After cleaning the data, the actual number of respondents involved was seven teachers and 118 students. Some students were eliminated from the data set because their questionnaires were incomplete. The Chemistry teachers consisted of two male teachers and five female teachers. They aged between 25 to 54 years old. On the other hand, students involved in the chapter difficulty survey were 50 males and 68 females aged between 16 and 17 years old.

Felt needs: Hundred and sixteen students answered the Feedback on Electrochemistry Questionnaire which focused on their felt needs in the learning of Electrochemistry. After cleaning the data, the actual number of respondents was 109. All the students were Form Four students aged 16 years old except one student aged 1 year older.

Normative needs: Twenty seven students from one of the classes answered an achievement test on Electrochemistry. All the students involved were female students aged 16 years old.

Instruments:

Chapter difficulty survey: Respondents were given the Chapter Difficulty Level Questionnaire with all the chapters listed in a table. Respondents were asked to rate all the chapters in the Chemistry syllabus using the Likert scale provided:

- Very easy
- Easy
- Moderate
- Difficult
- Very difficult

Student respondents must have learnt all the listed chapters while the teacher respondents must have experience in teaching all the listed chapters. The list of chapters in the chapter difficulty level questionnaire is presented in Table 1.

Table 1: List of chapters in chemistry syllabus

No.	Chapter
1	Introduction to chemistry
2	The structure of the atom
3	Chemical formulae and equations
4	Period table of elements
5	Chemical bonds
6	Electrochemistry
7	Acids and bases
8	Salts

Table 2: Distribution of items in feedback on electrochemistry questionnaire

Construts	Distribution of items	Total item
Feelings	1, 3, 14, 15, 19	5
Understanding	2, 7, 9, 17, 20	5
Confidence	4, 5, 11, 13, 16	5
Learning aids	6, 8, 10, 12, 18	5

Table 3: Distribution of items in 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
Identifying process at anode and cathode	e (i), e (ii), f	e (i), e (ii), f	Microscopic Symbolic
	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

Table 4: Mean score of chapter difficulty level by teachers and students

	Difficulty level			
	Teacher		Student	
Chapter	Mean	S.D.	Mean	S.D.
Introduction to chemistry	1.57	0.54	2.05	1.12
The structure of the atom	2.14	0.38	2.52	1.08
Chemical formulae and equations	3.83	0.75	3.20	0.98
Period table of elements	2.86	0.38	3.09	0.93
Chemical bonds	3.43	0.54	3.37	0.96
Electrochemistry	4.29	0.76	3.86	0.79
Acids and bases	3.86	0.90	3.83	0.83
Salts	4.57	0.54	4.08	0.74

Felt needs: Feedback on electrochemistry questionnaire which focused on the felt needs in the learning of electrochemistry was given in order to find out students' felt needs in learning electrochemistry. There were four constructs in the questionnaire to find out the students' felt needs on their feelings toward Electrochemistry, understanding of Electrochemistry concepts, confidence level in answering Electrochemistry questions and learning aids to assist them in the learning of Electrochemistry. Each construct had five items with a Likert scale provided:

- Strongly disagree
- Disagree
- Not sure
- Agree
- Strongly agree

The related constructs and distribution of items in the questionnaire is summarized in Table 2.

Normative needs: To find out the normative needs, students need to answer an achievement test on Electrochemistry. There were two questions in the test which tested on the students' understanding of electrolytic cell and voltaic cell in macroscopic, microscopic and symbolic levels. The students needed to answer the structured questions and give the reasons for their answers. The students' performance in the achievement test was then compared to the standard national examination score. The concepts tested in the achievement test and the representation levels are summarized in Table 3.

RESULTS

Chapter difficulty survey: The chapter difficulty level questionnaire was analyzed to investigate the teachers' and students' perception regarding the difficulty level of each chapter in the Chemistry syllabus. Table 4 shows the results of the questionnaire. Overall, both teachers and students rated the Electrochemistry chapter as the second most difficult chapter in the syllabus. Both groups rated the topic as 'difficult' and 'very difficult' with a mean of 4.29 (teachers' view) and 3.86 (students' view).

Felt needs: Table 5 shows the results for Feedback on Electrochemistry Questionnaire. Overall, the students' felt needs in this chapter is moderate (M = 3.31, S.D. = 0.47). Although students have a low level of understanding (M = 2.94, Item Kf9) and little exposure to learning aids (M = 2.89, Item Bbp6), they still have high confidence (M = 4.17, Item Ky11) in learning the chapter and getting good results in the examinations.

Table 5: Mean score for feedback on electrochemistry questionnaire based on constructs

Construct	Item mean				
Feelings	3.41	3.11	3.19	3.42	3.37
Understanding	3.06	3.39	2.94	3.47	3.33
Confidence	3.21	3.02	4.17	3.21	3.37
Learning aids	2.89	3.89	3.59	2.92	3.27

Table 6: Achievement test and proficiency level

Standard mark range	Proficiency level	Total
80-100	High	0
41-79	Moderate	0
0-40	Low	27
	Total	27

Normative needs: The results of the students' achievement test on the Electrochemistry chapter were compared to the national examination score and it is as shown in Table 6. All 27 students in the study have poor understanding of the Electrochemistry chapter as their results were below 40.

DISCUSSION

Chapter difficulty survey: Research (Bojczuk, 1982; Lin *et al*., 2002; Roziah, 2005) has shown that Electrochemistry is an abstract and difficult topic. 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, b; Lee, 2008; Lee and Mohammad Yusof, 2009; Karsli and Çalik, 2012). Hence, a needs assessment was carried out to study the felt needs and normative needs among students in this topic.

From Table 4, we found that Salts, Electrochemistry and Acids and Bases were the top three most difficult chapters in the Chemistry syllabus in both the teachers' and students' opinions. The similarity among these three chapters is the abstractness and difficulty in terms of inter-connection of macroscopic, microscopic and symbolic representations of the concepts. In the chapter Salts, students need to study the types of salts, the preparation of salts, stoichiometry of reaction, qualitative analysis of salts which involve the anion and cation tests. In the chapter Electrochemistry and Acids and Bases, macroscopically, students need to study the concepts of electrolytes and non-electrolytes, electrolysis process, voltaic cells, acids and bases, pH, titration and neutralization. Microscopically, they need to understand the movement of ions, electrons and molecules during the electrolysis, titration and neutralization processes. Besides that, they need to transform the processes into chemical formulae and equations symbolically. Students faced difficulties in understanding the abstract chemical processes in Salts, Electrochemistry and Acids and Bases especially on microscopic and symbolic levels (Garnett and Treagust, 1992; Garnett and Hackling, 1993; Garnett *et al*., 1995; Sanger and Greenbowe, 1997a, b; Demircioğlu *et al*., 2005; Tan, 2007; Hajah, 2008; Lee, 2008; Norsiati, 2008; Lee and Mohammad Yusof, 2009; Mohamad Yusof and Salmiah, 2011).

Felt needs: The students' felt needs were identified through Feedback on Electrochemistry Questionnaire. Overall, majority (79.8%) of the students' felt needs were at moderate level. Students faced problems in writing half-equations in the cell during the electrolysis process (Item Kf9). Some of them also have problems remembering the Electrochemical Series well (Item Kf2). The teachers were still using the traditional method and no multimedia courseware (Item Bbp6) was used during the teaching and learning process of this chapter. Assistance in the form of extra classes (Item Bbp12) was at the minimum level. Despite all the weaknesses and shortages, students still have high confidence in the learning of this Electrochemistry chapter (Item Ky11) and they were confident that they will score better in the final examinations (Item Ky16).

Normative needs: The achievement test score showed that students have poor understanding of the Electrochemistry concepts. The achievement test was carried out after the final examinations and the students were informed about the test. They were reminded to do their revision on this topic. On the day the test was carried out, some of the students were involved in their school's programs and extracurricular activities resulting in the total number of students reduced to 27. The students did not seem to care about the test, did not put in their best effort when answering the questions and took the test for granted. They left the questions unanswered or gave irrelevant answers. One of the students wrote the following statement in her question booklet showing that she did not do any preparation for the test and she got 10% for the test.

"I had set my mind that I would never read the book (would not even touch it) because I want freedom for a while after the final exams. Electrochemistry is actually a moderate subject, neither hard nor easy. I think I would have done better if I had really studied it."

Another students stated that 'the questions were too hard to understand'. She love Chemistry but she was not confident to answer the test. Students found the questions were difficult because they need to explain the reasons of their answers. All the questions were related to Electrochemistry concepts in macroscopic, microscopic and symbolic levels. Normally, students had no problems in answering macroscopic questions because the observations can be sensed by our sensory motors. Students always encountered problems and misconceptions in understanding microscopic and symbolic questions (Garnett and Treagust, 1992; Garnett and Hackling, 1993; Garnett *et al*., 1995; Sanger and Greenbowe, 1997a, b; Lin *et al*., 2002; Lee, 2008; Lee and Mohammad Yusof, 2009; Karsli and Çalik, 2012).

Generally, some common misconceptions or problems faced by students in learning Electrochemistry were:

- Students were 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 mixed up the oxidation and reduction process at the electrodes
- They were unclear about the concept of electrolyte (Lee and Mohammad Yusof, 2009; Lee, 2008)

CONCLUSION AND IMPLICATION

The needs assessment study portrayed the needs and problems faced by students in one of the states in Malaysia in the learning of the Electrochemistry chapter. Overall, both teachers and students rated Electrochemistry as the second most difficult chapter in the Chemistry syllabus. Results from Feedback on Electrochemistry questionnaire showed that majority of the students had moderate felt needs toward the Electrochemistry chapter. The achievement test showed that the students' understanding of Electrochemistry was very poor. However, further studies should be conducted involving a number of classes in other schools to gain a more comprehensive picture of the issue.

Chemistry is a visual science (Wu and Shah, 2004). Hence, students' major problem in learning abstract Chemistry topics is the ability to visualize the concepts, which is to form a mental image or picture in the mind (Lerman, 2001). In educational practice, visualization is applicable to one of the following situations:

- The experiment is too long or too short
- The dimensions of the examined object are too small or too large
- The environment of the experiment is not accessible
- The parameters of the experiment or its effects are not directly available to the observer's senses
- There is a need for multiple revisions of the experiment
- The experiment is difficult to arrange or revise effectively
- The experiment is dangerous
- The experiment is too expensive; etc., (Burewicz and 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 in which the changes of the process are at the microscopic level.

In order to overcome the problems, an IMMPA named EC Lab was planned to develop to help the students in the learning of Electrochemistry. Many researches (Widhiyanti, 2011; Gois and Giordan, 2009; Lerman and Morton, 2009; Doymus *et al*., 2010; Lou *et al*., 2012) have been carried out and results have shown that animation, video and simulation using Information and Communication Technology (ICT) can help students to visualize and hence enhance students' understanding in learning abstract Chemistry topics. Animations in the IMMPA EC Lab will show the movement of ions and electrons during the electrolysis process. This will help the students visualize the oxidation and reduction processes occurring at both electrodes. Hence, they can understand the processes microscopically and the knowledge can help them transform the processes into half-equations symbolically. On the other hand, video shows the procedures to carry out the experiments give a clear picture on how to run an experiment. Simulations enable the students to manipulate on the types of electrolyte and electrodes used in voltaic cells. Students can observe the changes on the voltmeter when they use different combinations of metals as the electrodes. The pedagogical agents in the IMMPA EC Lab will guide the students in the learning process by giving helpful information and instructions. They will provide examples that are related to students' daily experience (Gabel, 1993; Demircioğlu *et al*., 2005) and recall their existing knowledge (Demircioğlu *et al*., 2005) when discussing the Electrochemistry concepts. Besides that, pedagogical agents will give some hints when students try to solve problems. Encouragement and moral support will be given when students do exercises and answer the quizzes.

The study was carried out in three secondary schools in one of the districts in the country. So, further studies can be done in other districts and states in Malaysia or even other countries in Asia Pacific involving more schools and respondents. Previous studies (Lin *et al*., 2002; Chen *et al*., 2007) showed that students in Taiwan and China also encountered problems and misconceptions in learning Electrochemistry. If the study conducted in other countries in Asia Pacific, with similar cultures and background of students, it is believed that this type of needs assessment in Chemistry will obtain similar results. We also suggest that this needs assessment could be done on the chapter Salts since both teachers and students in this study rated it as the most difficult chapter in the Chemistry syllabus. Results from other countries can be compared and this will contribute to the Chemistry education in the region.

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