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CHEMISTRY PROBLEM-SOLVING COMPETENCY OF OPEN-ENDED PROBLEMS IN ELECTROLYSIS: AUTHENTIC LEARNING PRACTICE

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INTRODUCTION

Problem-solving in learning chemistry involves a thinking task as students need to constructa deep conceptual understanding, then apply the formulae and concepts to real-life situation. Fisher (2005) stated that life is a problem solving process and the ability of student to apply his thinking to solve problems will be the key to success in life. Deep understanding requires higher-order thinking skills for students to construct new knowledge or concepts in their cognitive map. Evidences from previous researchers have identified some difficulties in Chemistry problem-solving among school and university students (Cameron, 2008; Suryawati *et. al*, 2010; Johari *et. al*, 2012; Johari *et. al*, 2014).

By the year 2025, Malaysia aims to produce students who perform in the top third of international assessments such as Trend In Mathematics and Science Study (TIMSS) and

Programme International Students Assessment (PISA) (Malaysia Education Blueprint, 2012). However, to date, the performance of Malaysian students in PISA on problem solving test are below the global average score as compared to other countries due to low application of higher order thinking skills in solving the problems (OECD, 2012; Yunus *et al.*, 2006; Johari *et al.*, 2012, Johari *et al.*, 2014).

According to The Organisation for Economic Co-operation and Development of 74 countries (OECD) , it stated that the method on how individuals solve problems has changed in response to the current demands (OECD, 2013). Nowadays, most people tend to be more competent to solve problem with the assistance of information communication technology (ICT) since we are facing with a globalized world that is full of information access and rapidly changing technology. Thus, the approach used to solve the problems in the learning process must also suit with the current realities of life.

In order to compete with the rest in the world,the education system in Malaysia must develop citizens who are knowledgeable, able to thinkcritically, innovative and creatively, with leadership qualities and problem solving skills that enable them to communicate with the rest of theworld. In conjunction to this, problem-solving competency becomes a central objective within the educational programs of many countries such as China (Shanghai), Hong Kong, Singapore, Japan and Finland because the acquisition of increased levels of problem-solving competency provides a basis for future learning, effective participation in society and conducting personal activities (OECD, 2014).

PROBLEM SOLVING COMPETENCY

"Problem-solving competency"is defined as an individual's capacity to engage in cognitive processing to understand and

resolve problem situations where a method of solution is not immediately obvious (OECD, 2012). The competency includes the willingness to engage with such situations in order to achieve one's potential as a constructive and reflective citizen. Problem-solving Competency is considered as a predictor of chemistry achievement of student, therefore most of the students whose problem solving competency scores improved or students who scored high on the problem solving protocol would do well on the Chemistry Concept Inventory (Lartson, 2013).

Problem solving competency in Chemistry is a key area in which students should gain experience in school as problem solving can support subject learning and develop skills (Kim and Tan, 2013).However, most of the problems presented in school tend to be well-defined but real-life problems are usually open-ended and ill-defined such problems comprise the domain that is assessed in PISA (Lombardi, 2007; OECD, 2012).

The study of individuals'problem-solving strengths provides a window into their capabilities to employ basic thinking and other general cognitive approaches to confronting challenges in life.Johnstone (1993) has categorized problems into algorithms, conceptual and open-ended questions. Problems will be considered as open problems when any of these variables (data, method or goal) is absent and the characteristics of which resemble the problems encountered in real life.

Some key findings of the survey done in 2005 on problem-solving performance of PISA in Science, found that in most countries, more than ten percent of students were unable to solve basic problems, meanwhile half of the students on average in OECD countries were unable to solve problems that were more difficult than basic problems (OECD, 2012). In conjunction with the relatively poor performance, it is an essential to engage the students with open-ended problems in school in order to develop problem-solving competency among them. Successful competent problem solver can be developed when the students apply the knowledge, skill and ability to discover solutions in chemistry with certain justification for their answers (Boži and Tramullas, 2014).

PROBLEM SOLVING IN ELECTROCHEMISTRY

The common chemistry topics that are involved in problem solving research are about matter and its states, particulate nature of matter, mole concept, stoichiometry, chemical equilibrium and thermodynamics (Gabel and Bunce, 1994). Electrochemistry is difficult for many students but unfortunately research report on itare few i.e. Hillman *et.al* (1981), Garnent *et.al (*1990), Lee and Osman (2010) and Akram *et.al* (2014). Previous studies (Bojczuk, 1982; Lin *et al*., 2002; Lee and Osman, 2010) showed that this topic is difficult to learn because the concepts are abstract since electrochemistry is concerned with the study of electrolyte, electrolytic cell, electrolysis and voltaic cell, which students must understand to be successful problem solvers in the field.

In the past few years, science educators have been trying to determine which science concepts students understand and which they do not. Annual performance reports for chemistry in Malaysia Education Certificate Examination have shown that a surprising number of high school students did not understand the meaning of electrolyte, anode, cathode and how to apply the concept of electrolysis in their real life (Ministry of Education, 2011-2013). Most students have difficulty to solve these problem in electrochemistry because they did not understand its' concepts and when these concepts were taught in the classroom, they were not been presented in a variety of contexts in which these concepts could be applied (Lartson,

2013). Often the instruction has been verbal and formal without hands-on and minds-on activity.

Studies have identified that students often encounter misconceptions in the learning of the aforesaid (Garnett and Treagust, 1992; Lin *et al*., 2002; Karsli and Çalik, 2012, Akram *et. al*, 2014). Students as novice learners do not always make connections to prior knowledge or everyday experiences in ways that are productive for learning (Land, 2000, Lee and Osman, 2012). The problems faced by students in solving problem in electrochemistry as identified by Lee and Osman (2012) were, most students cannot describe and explain the process happening at the anode and cathode, mix up the oxidation and reduction process at the electrodes, and are unclear about the concept of electrolyte.

Recent study done by Akram *et al*. (2014) found that secondary school students are having a poor background of knowledge, absence of teaching aids and misunderstanding of language caused conceptual difficulty in comprehension the problem in electrolysis. 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.

POTENTIAL OF AUTHENTIC LEARNING FOR CHEMISTRY PROBLEM-SOLVING COMPETENCY

Competent teacher plays an important role to design the constructive and meaningful learning process. This means that the teacher's job is not usually to move students from a state of ignorance to a state of knowledge, but more often to shift students'thinking from existing ways of understanding the world toward more novel and practical ones. Sufficient information, knowledge and experience of teacher can create constructive learning to improve the problem solving competency in Chemistry (Cameron, 2008). Chemistry lesson in the classroom is taught around real-world problems relevant to students'lives (Lartson, 2013). Thus, activities or lessons that involve real-world problem solving, should be incorporated into education in general and in chemistry education in particular.

Authentic instruction is an approach that contrasts with traditional teaching methods. In the traditional classroom, students take a passive role in the learning process (Herrington and Herrington, 2008; Herrington and Oliver, 2000; Lombardi and Oblinger, 2007). Traditional teaching and learning style focus on the delivery of knowledge and skills rather than creating an active, authentic, meaningful and innovative learning approach thatenhance students to apply the knowledge and skills to answer questions in the examination (Jaber and BouJaoude, 2012). However, students will be inspired and motivated to learn new concept and skill as the better preparation to succeed in college, careers, and adulthood if what they are learning mirrors real-life contexts, equips them with practical and useful skills, and addresses topics that are relevant and applicable to their lives outside of school (Pagliaro, 2012).

Authentic learning, on the other hand, takes a constructivism approach, in which learning is an active process. Teachers provide opportunities for students to construct their own knowledge through engaging in problem solving, critical thinking, and reflections in real-world contexts (Herrington, 2000). This knowledge construction is heavily influenced by the students' prior knowledge and experiences, as well as by the characteristics that shape the learning environment. Students no longer simply learn rote facts in abstract and artificial situations, but they experience and apply information in ways that are grounded in reality.

According to Ginnis (2002), people can generally recall 10% of they read, 20% of what they hear, 30% of what they see, 50% of what both see and hear, 70% of what they say and 90% of what they simultaneously say and do. Therefore, teacher is essential to create active, episodic and dramatic learning experiences that are really experienced by the students in order to maximize learning and improve problem solving competency. By engaging in real-life contexts, students should look for solutions to socially relevant questions through the exchange of knowledge and communicating for consensus which can further generate new knowledge into these issues (Kim and Tan, 2013).

Due to the connectivity of students prior knowledge, experience and real life, authentic learning has a potential to be practiced in order to overcome our greatest short coming in education to implement multi-sensory activities to enhance problem-solving competency in chemistry (Froyd , 2003; Suryawati *et al.,* 2010). Authentic learning approach can improve problem-solving skills among students with moderate and high cognitive skills (Suryawati *et al.,* 2010). In our interpretation of contexts, authentic chemistry practice is used for the design of meaningful learning environments to improve the problem solving skills among students (Lombardi and Oblinger, 2007; Prins *et al.,* 2008).

Authentic activities match the real-world tasks of chemistry in practice as nearly as possible(Lombardi and Oblinger, 2007). Learning chemistry rises to the level of authenticity when it requires students to work actively with abstract concepts, facts, and formulae into the realistic, highly social practices in the context of the culture. Authentic activities provide an opportunity for students to examine the task from a variety of theoretical and practical perspectives, using a variety of resources and requires students to distinguish relevant from irrelevant information in the process (Herrington and Herrington, 2008). Authentic activities enable students to make choices and reflect on their learning, both individually and as a team or community (Lombardi and Oblinger, 2007). If the authentic learning is carried out in groups, it becomes more meaningful for the students to construct their own understanding based on solving the problems in real life situation with collaborative and reflective learning approach.

This new approach in learning Chemistry will assist to promote students with higher order thinking skills to solve the open-ended problem. It is expected that authentic learning will help to promote a better interest and understanding among the students related with the knowledge, experience, skill and authentic practice. This authentic learning practice can be incorporated with a model of problem-solving instruction in order to develop an effective and meaningful learning of chemistry.

MODEL OF PROBLEM-SOLVING INSTRUCTION

Due to some identified difficulties in problem-solving among students including lack of problem solving skills, some researchers have developed model of problem-solving instruction (Pizzini, 1987, 1996; Osborn, 1963; Bransford and Steins, 1984). The impact of authentic practice or problem solving instruction depends on students'basic knowledge of problem solving processes. In other words, if a student does not have a clue on how to approach the solution of real-world problems even a strategy that has a potential of improving problem-solving skills, then he may not have a fair chance of successfully solving the problem. The selection of a problem

solving model of instruction is however one of the critical choices a teacher must consider to prepare and expose the students to solve open-ended problem in chemistry.

The problem-solving process is much more important than to obtain the ultimate answer or solution. Therefore to meet the expectation of this new era of education, it is essential to develop a model of chemistry problem-solving competency to improve higher order thinking skills among students to solve open-ended problem in chemistry. Unfortunately, the existing models of problem-solving are only focusing on the skills and metacognitive process in solving the problems without considering the problem solver's prior scientific knowledge, skill, ability and real-world relevance. Moreover, the current models of problem solving instruction are not specific in applying and relating high order thinking skills to solve open-ended problems for chemistry. Recently, global success of students in problem-solving are influenced by their collaborative problem-solving competency and this competency is applicable in their future workplace (OECD, 2013).

Chemistry in school has been traditionally taught around well-defined, routine and closed problems without any focus on the problem-solving skills. On the other hand, real-world scientific inquiry focuses on open-ended problems that are constructed in the international student assessment such as PISA (OECD, 2013). Open-ended problem can projected real-world problems, ill-defined, lacking some required information, and not necessarily having a known correct or the best solution. Even when we are looking deeply into the crucial development of problem-solving in education at present, there is a lack of specific knowledge base to teach problem-solving competency using authentic practices, such as contexts, to improve the higher order thinking skills.

In this research, the authors suggest to use the model of Problem solving Instruction by Pizzini (1987) to teach students the problem solving skill. This model consists of four stages; Search, Solve, Create and Share (SSCS) that seems appropriate to solve the open-ended problem. Recent researches had used Model of Problem solving Instruction (SSCS) in science, mathematics and engineering subjects successfully in secondary school and tertiary level (Lia and Bunga, 2014, Lartson, 2013; Johan, 2013; Irwan, 2011; Halizah and Ishak, 2008).

The outcomes of the recent studies indicate that SSCS Model can positively impact the particular variable under investigation i.e. HOTS. Most of the researches that have applied this model were conducted at higher level with problem-based learning approach. Therefore, it will be an opportunity to use this SSCS Model with other learning approach such as authentic learning in chemistry.

To date, there is not much research that is related in developing a model of problem solving competency specifically to solve open-ended chemistry problem for school students. This new model of problem solving competency will assist in enhancing students'performance, and solve problems of the subject matter but also to the real world problem successfully. Therefore, to meet the expectation of this new era of education, educators and researchers need to put their effort in coming out with an authentic, effective and meaningful of instructional approach for a competent future citizen to solve real world problems.

CONCLUSION

It is clear that problem-solving competency is regarded as one of the fundamental aims of chemistry education. The difficulties faced by secondary school students in chemistry problem-

solving has been addressed but so far there has not been an effective problem-solving instruction to guide the students toward more successful problem-solving experience. The author has outlined some reasons and proposed a different way of looking at this issue from the perspective of student's competency in solving open-ended problems with authentic learning practice with an appropriate model of problem-solving instruction (SSCS). The key concepts of the paper have been briefly introduced. Then the model of authentic chemistry problem solving competency will be developed to improve students'problem solving competency in Chemistry.

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