# Authentic Chemistry Problem Solving Competency for Open-ended Problems in Learning Electrolysis: Preliminary Study

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## Abstract

*This paper discusses a preliminary study, which was undertaken, to develop a model of authentic chemistry problem solving competency in learning chemistry. Students are inspired and motivated to learn new concepts and master problem solving skills to manage real life problems. Authentic practice in learning chemistry could assist in improving students' higher order thinking skills (HOTS), thence to solve open-ended problems. Open-ended problem is an ill-defined and non-routine problem, which presents in their real-life context that is interesting and relevant to the students. Student's prior scientific knowledge competency, experience, problem solving skills and authentic learning practice are identified to be the independent variables to develop a model of problem solving competency in learning chemistry. This preliminary study was conducted to determine the chemistry problem solving ability, skill and familiarity to solve open-ended problems in electrolysis among school students. Chemistry problem solving ability test and problem solving skills questionnaire were administered to 112 students having mean age of 16 years old. Results obtained from the preliminary study found that chemistry problem solving ability scale, generally, indicates low (20.5%) and average (53.6%) level of performance in achievers. Domains in the problem solving skills of "search, solve, create and share" adopted from the model of problem solving instruction (Pizzini, 1987; 1996) were also at the average and low level. Familiarity of students in solving the open-ended problem (non-routine and real life) was also found to be at average level (mean 2.64, S.D 0.84). Outcomes from this study shall be used to design a module for one selected topic in chemistry and then develop a 'Model of Authentic Chemistry Problem-solving Competency' for school students in general.*

**Keywords:** Problem Solving Competency, Authentic Learning Practice, Higher Order Thinking Skills

## Introduction

The 21$^{st}$ Century schools should provide a learning environment that enables students to explore the knowledge, then apply it with the appropriate skills to solve a real life problem outside the school (Suryawati *et.al*, 2010). Success in life depends on the ability of an individual to apply his/her thinking to solve problems (Kim & Tan, 2013). Conventional classrooms in Malaysian education system merely transfer knowledge and practice that is examination-oriented. In order to measure student's performance, most problems that are solved in school for the formal assessment are routine and well-defined which require only low order thinking level. However, real life problem are complicated and multi-faceted with many possible solutions.

The issue of real life problem solving skills also becomes important due to a high expectation from a child in global community and a requirement by modern life to be a competent problem solver. Moreover, to generate the future leader, education system needs to equip students with problem solving competency to solve real world problems. This problem solving competency is crucial to develop higher order thinking as many of the prospective jobs today demand advanced skills, learning readiness, critical and creative thinking to lead them to make decision and solve problems with reasonable justification (Holroyd, 1989; Lartson, 2013).

## Literature Review

Solving open-ended problems does not only involve the application of knowledge but requires the application of Higher Order Thinking Skills (HOTS) (Overton & Potter, 2005). In this paper, problem solving competency is a combination of scientific knowledge competencies and problem-solving skills that are required to solve open-ended problems in chemistry based on students' actual performance in their problem solving ability test. Open-ended problem is an ill-defined and non-routine problem, which is presenting in real-life context (Scottish QRA, 2010). If either one of the variables, whether the data, method or goal is not known, then the problem is regarded as an open-ended problem and is similar to problems encountered in real life (Johnstone, 1993).

According to Organization for Economic Cooperation and Development (OECD, 2012), problem solving competency is an individual's capacity to engage his cognitive processing to understand and resolve a problem situation where the method of solution is not immediately obvious. The research literature found that successful problem solving indicates that students have applied the knowledge, skill and ability to discover solution in Chemistry with certain justification (Boži & Tramullas, 2014). Finding of few studies (Ausubel *et al*, 1978; Reif, 1983, Camocho and Good, 1989; Gabel and Bunce, 1994; Niaz, 1995; Heyworth, 1999; Johari *et. al* 2013) have highlighted that an effective problem solving requires the problem solving abilities and skills including good understanding, meaningful learning knowledge, apply the appropriate problem-solving procedures, then able to identify the relevant linkages of information between the information of problem statements and the existing cognitive structure.

Studies on problem solving in chemistry have found out some issues. Most studies of problem solving in school focus on chemistry problem solving ability (Akram *et.al*, 2014). Conventional learning approach for chemistry in schools is to familiarize students in solving algorithms, routines that are usually not related to the real life (Surif *et.al*, 2014). Students in schools and universities are poor in solving "word" and "open ended" problems in chemistry ( OECD, 2012; Surif *et. al*, 2012). Moreover, "Electrolysis" in chemistry was considered as tough for many students but unfortunately research articles on it are few in number (Hillman *et.al* , 1981; Lee and Osman, 2010 and Akram *et.al*, 2014).

Review of research studies on problem solving in chemistry found that learning environment such as, authentic learning, is a core factor to develop competent problem solvers (Gabel and Bunce, 1994; Lartson, 2013). According to Lombardi and Oblinger (2007), authentic learning typically focuses on real-world, complex problems and their solutions, using some interesting approaches such to inspire and improve problem solving competency among students. Authentic learning practice gives students an opportunity to apply relevant knowledge and experience to solve real life problem, (Prins *et. al*, 2009). This approach provides a variety of educational and instructional techniques focused on connecting what students are taught in school to real-world issues, problems, and applications. It is a style of learning that encourages students to create a tangible, useful product to be shared with their world. Moreover, this approach is appropriate to emphasize the higher order thinking skills, depth of knowledge, and connectedness to the world beyond the classroom.

Educational research shows that authentic learning is an effective learning approach to preparing students for challengeable life career in the 21st century (Suryawati *et al.*, 2010; Lombardi & Oblinger, 2007). Meaningful learning is improved in four related domains of learning of cognitive (knowledge), affective (attitude), psychomotor (skills) and psychosocial (social skills) by situating the knowledge within the relevant context. Students are more motivated and more likely to be interested in what they are learning when it is relevant and applicable to their lives outside of school. Hence, it will be more effective to provide authentic practice in learning chemistry because some of the chemistry concepts are abstract and difficult to understand. Indeed, chemistry is an interesting subject that is related with real life applications and conditions but most students find that chemistry is a tough and abstract subject to learn. Therefore, shifting the classroom environment into authentic learning practice is an alternative to develop chemistry problem solving competency among students.

Model of problem solving instruction: Search , Solve, Create and Share ( SSCS ) by Pizzini (1987, 1996) was found compatible to enhance problem solving competency among students (Lartson, 2013). The SSCS model consists of four phases which begin with search, solve, create and share. One of the great advantage of this model is highlighting a "create" phase which is considered as one of the top cognitive level in the HOTS (Goodson & Rohani, 1998). On the other hand, this "four step cyclical" model allows for re-entry into the various states of the model during the problem-solving process. Additionally, the SSCS model provides students with an opportunity to share or communicate their solutions or results with others, something that is missing in other problem solving models of instruction.

## Objective

This paper focuses on one research objective that is: how to determine the level of chemistry problem-solving ability and skill in learning electrolysis among school students in Malaysia.

## Methodology

This ongoing study has adopted a quantitative method for the preliminary study. The preliminary study has been conducted to collect quantitative data. The results obtained will support the relevant independent variables for developing the model of authentic problem solving competency in learning electrolysis.

## Samples

Sampling technique that is used to select respondents for this study is purposive sampling or "judgment sampling" (Ary *et.al,* 1985). This study involves 112 form four (grade 10) chemistry students with mean age of 16 years, from full residential schools in Sarawak, Malaysia.

## Instruments

This study has gathered quantitative data. Chemistry Problem Solving Ability Test (CPSAT) sheet and Chemistry Problem Solving Skill (CPSS) questionnaire were administered to determine the respective level of chemistry problem solving ability, skill and familiarity of respondents in solving of open-ended problems. The alpha Cronbach reliability for the Chemistry Problem Solving Skill (CPSS) questionnaire is .84. Both of these instruments have been developed by the researchers for the purpose of this preliminary study.

## Result

This preliminary study was conducted to verify the research gap in learning chemistry among students of secondary school. The results obtained from this study will support the independent variables selected to develop the conceptual framework. The independent variables in this conceptual framework are scientific knowledge competencies, problem solving skills and authentic learning practice; meanwhile, the dependent variable is problem solving competency. The independent variables are selected as the research gap that was formulated from the literature review and verified by the results from the preliminary study.

**Table 1** Chemistry Problem Solving Ability Test (CPSAT) for Electrolysis

| Achievement Level | Score Mark | Frequency | Percentage |
|---|---|---|---|
| **Weak** | 0-33 | 23 | 20.5 |
| **Average** | 34-66 | 60 | 53.6 |
| **High** | 67-100 | 29 | 25.9 |
| **Total** | | N = 112 | 100 |

Chemistry problem solving ability test (CPSAT) was used as an instrument to measure the level of scientific knowledge and problem solving skills. The performance of the test was categorized into three levels (low, average and high) based on the scores, as indicated in Table 1. The results showed that 25.9% (29) respondents are high achievers, 53.6% (60) and 20.5 % (26) are average and low achievers respectively (N=112). Therefore, the overall level of problem solving skills and scientific knowledge among the school students is near average.

Chemistry problem solving skill (CPSS) questionnaire is the second instrument that was used to measure the respondent's problem solving skills and familiarity in solving open-ended problem. This questionnaire consists of four domains on problem solving phases (search, solve, create and share) which has been adapted from model of problem solving instruction by Pizzini (1987, 1996). Two out of four domains indicated the low level skill in comprehending the problem (mean 2.15, S.D 0.95) and creating the solution (mean 2.36, S.D 0.82). The two other domains have average level skill in planning solution (mean 2.75,S.D 0.68) and sharing the solution of the problem(mean 2.61, S.D 0.88).

**Table 2** Chemistry Problem Solving Skill and Familiarity in Solving Open-ended Problem

| Problem Solving Skill | N | Mean | SD | Level |
|---|---|---|---|---|
| Comprehending (Search) | 112 | 2.15 | .95 | Low |
| Planning Solution (Solve) | 112 | 2.75 | .68 | Average |
| Creating solution | 112 | 2.36 | .82 | Low |
| Sharing solution | 112 | 2.61 | .88 | Average |
| Familiarity in Solving Open-ended Problem | 112 | 2.64 | .84 | Average |

Note : Scale indicates the mean of level problem solving skill level

1.0 to 1.4 : Very low
1.5 to 2.4 : Low
2.5 to 3.4 : Average
3.5 to 4.4 : High
4.5 to 5.0: Very high

The questionnaire also gave a feedback about the familiarity of respondents in solving the open-ended problem (non-routine and real life). Results show that level of familiarity to solve this type of problems is at average point (mean 2.64, S.D 0.84). Hence, based on the research gap with this supportive data from the preliminary study, a conceptual framework for this research was developed as illustrated in Figure 1.

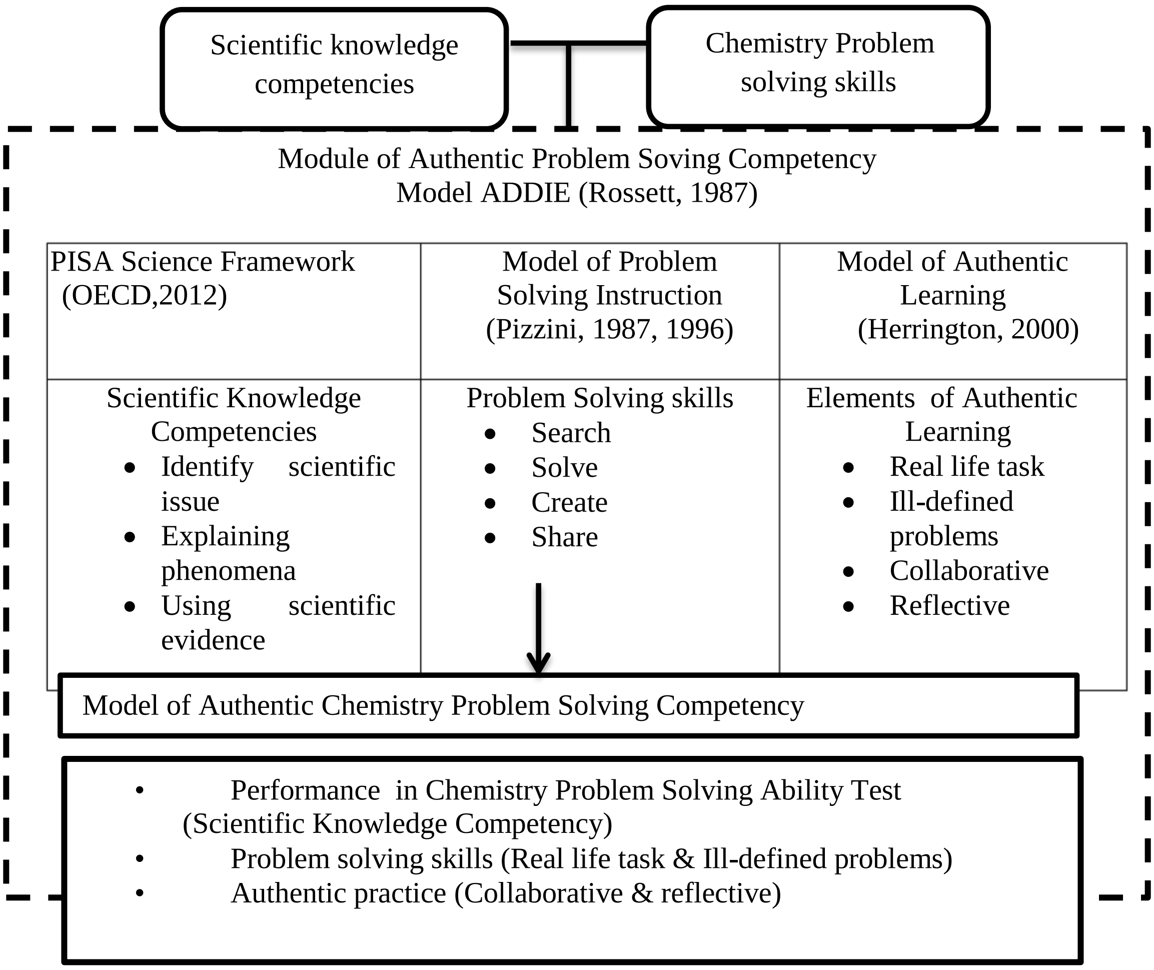


**Figure 1** Conceptual Framework for Model of Authentic Chemistry Problem Solving Competency

The independent variables in this conceptual framework are scientific knowledge competencies, problem solving skills and authentic learning practice, meanwhile the dependent variable is problem solving competency. The level of problem solving competency will be determined based on the performance in post chemistry problem solving ability test (CPSAT) and problem solving skills practiced in solving open-ended problem (real life and ill- defined). Elements in the authentic learning practice are integrated by providing the real life task to solve the ill-defined problems collaboratively and reflectively. These elements might enhance the higher order thinking skill in developing the problem solving competency among students. These independent variables are selected based on the research gap that was formulated from the literature review and verified by the results from the preliminary study.

## Discussion

In this study, chemistry problem solving competency is determined by the student's prior knowledge, experience and problem solving skills which, they are applying to solve the chemistry problem solving ability test (CPSAT) as illustrated in Figure 2. Performance of respondents in the chemistry problem solving ability test is a predictor for problem solving competency since it involves the cognitive process of respondent to solve the problem based on their knowledge, ability and application of problem solving skill due to familiarity to the problem.

Learning activities with the model SSCS (Pizzini, 1987, 1996) begins with the provision of problems or conditions related to the material to be studied. Then students look (search) information to identify situations or problems presented, after knowing the problems faced by the students to make a hypothesis and then plan how to solve (solve) the problem, with the information and plans that have been prepared; students make (create) solution for later presenting it for discussion together with friends and teachers and divide (share) knowledge of each other. The students will give the explanation and justification during presentation or discussion in sharing phase. This is an effective way to enhance the higher order thinking skills among students.

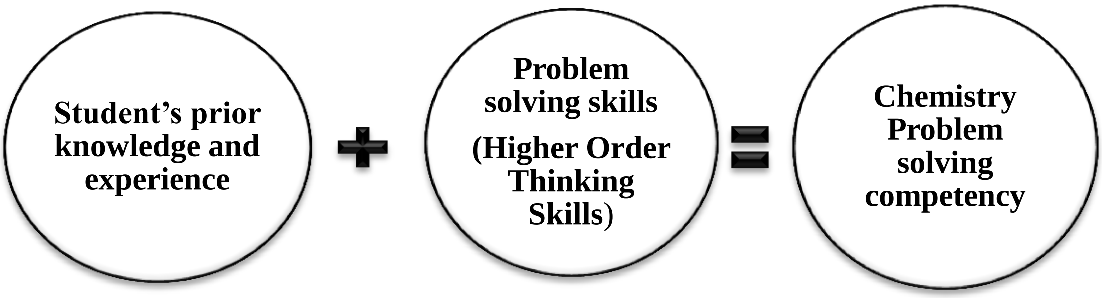


**Figure 2** Variables in Chemistry problem-solving competency Source: (Suraiya *et. al,* 2015)

This conceptual framework includes that authentic learning environment will help to promote interest based understanding by leading the students to relate their knowledge, experience and skill with real life context. This approach is essential for the educators to consider as prior knowledge of students and connectedness of such knowledge with real-world activities is quintessential in solving open-ended problems. Due to the connectivity or linkage of students' prior knowledge, experience and real life, authentic learning has a potential to be practiced in order to overcome Malaysians' shortcomings in education and to implement multisensory activities enhancing problem-solving competency in chemistry (Suryawati *et al.*, 2010; Lartson, 2013). In our interpretation of contexts, authentic chemistry practices are used for the design of meaningful learning environments and to improve the problem solving competency among students (Lombardi and Oblinger, 2007; Prins *et al.*, 2008,). 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 & Tan, 2013)

Teaching strategies can be implemented to foster the development of problem solving skills among learners. Teaching strategies that emphasize collaborative work, the use of cooperative groups, interactive solution format (Ngu *et. al.*, 2006). Contextual learning approach can improve problem solving skills among students with moderate and high cognitive skills (Suryawati *et al., 2010)*. Therefore, instructional models are essential in chemistry education but unfortunately most of chemistry problem solving instructional models have been developed for university students. However, school students also require the instructional model to overcome the lack of competency to solve open-ended problem.

To fill up these gaps, authentic learning practice will be integrated with problem solving instruction and scientific knowledge competencies to develop the authentic chemistry problem solving competency. In the response to the global challenge, practical framework for the design of authentic learning environment will be produced. Essentially, current literature suggests that applicable knowledge is best gained in learning environment that features, at least, a few elements of authentic learning.

## Conclusion

This authentic learning practice will assist to promote students with higher order thinking skills to solve open-ended problems of real life as well as for academic purpose. It is expected that authentic learning will help to improve Chemistry problem solving competency. This authentic learning practice (Herrington, 2000) will be incorporated with a model of problem-solving instruction (Pizzini *et. al*, 1987, 1996) and science framework in Programme for International Student Assessment (PISA) (OECD, 2012) to develop an effective and meaningful "Model of Authentic Chemistry Problem-solving Competency".

## References


Akram, M., Surif, J. Bin, and Ali, M. (2014). Conceptual Difficulties of Secondary School Students in Electrochemistry. *Asian Social Science, 10*(19), 276–281.

Ary, D., Jacob, L. C., & RAzavieh, A. (1990). *Introduction to research in education* (4thed.). Orlando, FL: Holt, Rinehart and Winston, Inc.

Bojczuk, M., (1982). Topic difficulties in O-and A-level chemistry. SSR, 64: 545-551.

Boži, M., & Tramullas, M. T. E. (2014). Engineering practice : teaching ill-structured problem solving in an internship-like course, (April), 721–726.

Gabel, D. (1998). The complexity of Chemistry and implication for teaching. *International Handbook of Science Education* . Netherlands: Kluwer Publishers, 233–248.

Gayon, P (2008), The Problem Solving Ability of High School Chemistry Students and Its Implication in Redifining Chemistry Education (Abstract). CoSMEd 2007. Philphines.Book of Abstracts

Goodson, L., and Rohani, F. (1998). Higher Order Thinking Skills • Definition • Teaching Strategies • Assessment. *Thinking, 18,* 458

Heyworth, R.M. (1999). Procedural and conceptual knowledge of expert and novice students for the solving of a basic problem in chemistry. *International Journal of Science Education, 21*,195-211

Herrington, J., & Oliver, R. (2000). An instructional design framework for authenticlearning environments. *Educational Technology Research and Development,48*(3), 23-48.

Herrington, J. (2000). An Instructional Design Framework for Authentic Learning Environments, *48*(3).

Herrington, J., & Reeves, T. C. (2003). Patterns of engagement in authentic online learning environments. *Australian Journal of Educational Technology,19*(1), 59-71

Herrington, J. (2006). Authentic e-learning in higher education: Design principles for authentic learning environments and tasks, World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education, Chesapeake

Jonassen, D. H., (1997). "Instructional design models for well-structured and ill-structured problem-solving learning outcomes."Educational Technology Research and Development, 45, 65-90.

Johnstone, A. H. (1993). "Introduction". In: Wood, C. and Sleet, R. (Eds). Creative Problem Solving in Chemistry. London, The Royal Society of Chemistry.

Kim, M., & Tan, H. T. (n.d.). International Journal of Science A Collaborative Problem-solving Process Through Environmental Field Studies, (August 2014), 37–41.

Lee, T.T. & Kamisah, (2010). Construction of Interactive Multimedia Modules with Pedagogical Agents (IMMPA) in Learning Electrochemistry: Analysis of Needs. Paper Presented at Prosiding Kolokium Kebangsaan Pasca Siswazah Sains dan Matematik 2010, Universiti Pendidikan Sultan Idris, 22 December.

Lombardi, B. M. M., and Oblinger, D. G. (2007). Authentic Learning for the 21st Century : An Overview. *Learning*, *1*, 1–7.

Overton, T., and Potter, N. (2005). Open ended problem solving and the influence of cognitive factors on student success, 75–80.

The Organisation for Economic and Development (OECD) (2003), "Definition and Selection of Competencies: Theoretical and Conceptual Foundations (DeSeCo)", Summary of the final report *Key Competencies for a Successful Life and a Well-Functioning Society*, OECD Publishing.

The Organisation for Economic and Development (OECD) (2009), *PISA 2006 Technical Report*, OECD Publishing.

Pizzini, E. (1987). Project STEPS: Science Textbook Extensions through Problem Solving. Washington, DC: National Science Foundation.

Pizzini, E.L., Shepardson, D.P., & Abell, S.K. (1989). A rationale for and the development of a problem solving model of instruction in Science Education.*Science Education*, 73(5), 523-534.

Prins, G.T. (2010). Teaching and Learning of Modelling in Chemistry Education. Authentic Practices as Contexts for Learning. CD-ß Press. Netherlands.

Rule, A. C (2006) Editorial: The Components of Authentic Learning. *Journal of Authentic Learning,* 3(1), 1-10

Scottish Qualification Authority (2010). *Chemistry Open-ended Questions Support Materials*. Scotland: Learning and Teaching Scotland.

Surif, J., Hasniza, N., and Mahani. (2012). Conceptual and Procedural Knowledge in Problem Solving, *56*(Ictlhe), 416–425.

Surif, J., Ibrahim, N. H., and Dalim, S. F. (2014). Problem Solving: Algorithms and Conceptual and Open-ended Problems in Chemistry. *Procedia - Social and Behavioral Sciences*, *116*, 4955–496