FOSTERING PROBLEM SOLVING IN CHEMISTRY: THE IMPORTANCE, DIFFICULTIES AND THE NEEDS OF SCIENTIFIC CREATIVITY

Siti Salbiah Omar, Noor Dayana Abdul Halim, Johari Surif, Jamalludin Harun

I. INTRODUCTION

Higher Order Thinking Skills (HOTS) is a thinking skill that occurs when an individual is facing a remarkable, uncertainty, question or dilemma (Goodson, Rohani, & King, 1998). HOTS enable students to better understand what they have learned (Heong et.al, 2011) and prepare themselves to undergo changes in the 21st century (Geersten, 2003 & Kenney, 2013). According to Zoller (2001) HOTS in the context of chemical education refers to the questioning, problem solving, decision making and critical thinking. HOTS especially problem solving primarily provide individual to meet the challenges in the world of work and everyday life to have enough skills to operate effectively in society and the workplace (Cooper, 2006; Ramos, Dolipas & Villamor, 2013).

II. PROBLEM SOLVING AND ITS IMPORTANCE

Hayer (1981) states that if you're having a problem if there are a gap between the present you with what you want to accomplish, and you do not know how to bridge the gap. According to Mayer (2003), the problem occurs when in any case, the goal to be achieved, but there is no routine method for achieving these goals. Each individual cannot escape from the problem, as it occurs in various aspects of life (Reid & Yang, 2002; Overton & Potter, 2007). Each of the problems must to be solved, especially problems that occur in learning, because the failure to solve the problem would be reduced motivation (Sarbiyik, et.al, 2004) and the students will less interested in pursuing education as a result of the lack of problem solving skills (Teichert & Stacy, 2002; Bodner, 2003).

Problem solving is also very effective in improving student achievement in education (Aka, Guven & Aydogdu, 2010; Gok, 2010) because when they managed to solve the problem, their motivation will increase and eventually they will be eager to learn (Hamza & Griffith, 2006). Problem solving also indirectly enhance the skills to argue, social skills and decision-making (Kim & Tan, 2013). This is because when solving problems, students learn how to exchange ideas and integrate the nature and level of knowledge and communication in an effort to find a solution. Mustafa (2008) states that problem-solving skills also allow individuals adapt to the environment, making the person more flexible and able to control what happens around him. In terms of education, particularly science education, providing students with problem-solving skills, will help them improve scientific thinking (Aka et.al, 2010). It is also very helpful in the development of science process skills in which are very important in solving daily problems (Aktamis & Ergin, 2008).

Other than that, problem solving is a method of student-centred, active learning and knowledge development (Aka et.al, 2010) and more recently it was used as the primary domain of large-scale assessment systems around the world such as PISA (Greiff et.al,

2013). Osman (2010) also noted that the key in determining the competency of a person at the moment are based on their level of problem solving. Because of that an effort to increase the level of problem solving in students need to be addressed in order to help countries create communities that are able to compete with the global world.

According to Johnstone (1993) there are three types of problems that is algorithm, conceptual and open-ended. Algorithm are problems involving low-level thinking skills and more to the form of exercise (Zoller & Pushkin, 2007) .While conceptual problem usually involve non routine chemical phenomenon among students and students should use the concepts that have learned to solve Johari Surif et al., 2014). The open ended problem requires the application of high level thinking skills, not just knowledge consumption. (Overton et.al, 2013).

Gotwals and Songer (2013) states teaching and learning that is able to produce students with a scientific attitude should be to foster something more than just rote learning and normal or, more accurately it should be applied with more open ended and high level questions (Zoller & Pushkin, 2007) . The ability to solve open ended problem has also been shown to increase the confidence of students to solve real life (Overton & Potter, 2007; Mourtos, 2010). This is because the real life problem is usually very open and lack of information (Douglas et al., 2012). Besides, the use of the open ended problem can enhance creative and analytical thinking (Scottish Qualification Authority (SQA), 2010). On the other hand, the use of open ended problem are also able to avoid the bias that may arise from the proposed solution is given and hence it can enhance the discussion of a topic (Johari Surif, et. al., 2014)

Based on previous studies, most of the problems that are used in chemical education in particular are in algorithm (Bennett, 2008; Overton & Potter, 2007; Pappa & Tsaparlis, 2011, Reid & Yang, 2002). The learning are also more emphasis on the facts, vocabulary, definitions, and algorithms (Aksela, 2005). In Malaysia, application of open problems in the teaching and learning is still rare and less emphasized (Johari Surif et al., 2014) .This is not a good thing because the problem or question of low and medium level do not help develop problem-solving skills in real life (Mourtos, 2010). Even though the goals of chemistry curriculum are indirectly help students to develop problem-solving skills (Tsarparlis, 2005; Taasoobshirazi & Glyn, 2009), but if this continues, it will produce the students that can only solve the low level of problem.

To compete globally and career needs to come, of course students should be able to solve the high level problem (Overton & Potter, 2007). The fact is that students are still not able to solve an open ended and high level problem (Zohar & Dori, 2003) .Therefore, there is a need to improve problem-solving skills, especially those involving HOTS among students (Alhusaini & Maker, 2011; Altuncekic et.al., 2005; Zoller & Pushkin, 2007) .In order to improve problem-solving skills on higher level, we certainly need to know the difficulties faced by students and then find a way out to overcome these difficulties.

III. STUDENT DIFFICULTIES IN SOLVING OPEN ENDED PROBLEM

Mourtos (2010) found that students failed to use information from previous learning and not be able to apply these principles in a new context. There is also students do not want to allocate enough time for each problem. This thing leads failure to managing time effectively. The students also do not want to write or sketch ideas during the process of

solving the problem, and this is one of the reasons students fail to solve open ended problem.

Douglas et al. (2012) found that the difficulties face by students is failed to see the problem as a whole. They could not get into a problem or in other words, they only look at one task to the extreme and less focus on other tasks. Lack of confidence in own ability to solve open ended problem also become a constraint. When they failed in making the right choice of materials, they stopped there and did not see others aspect. There is also a students who use the concept of irrelevant and does not assess the suitability of the selected concept, they just write what they know related to the question.

Several other difficulties faced by the students are their failure to identify the problem in detail (Overton et.al, 2013). This is more geared to a less rigorous attitude and lack of knowledge about the problem. There are also students who use approach that does not help to solve the problem or in other words they did not use a scientific approach when solving problems. What's more concerns are those that solve open ended problem but using algorithmic approach (Overton et.al, 2013). This is not surprising because the students experience in solving the algorithm structured problem (Bennett, 2008; Overton et.al, 2013; Pappa & Tsaparlis, 2011). Reid & Yang (2002) states that students are not able to make a planning that can help identify a logical step for a solution. They also do not use the information solely and also do not try to find material from another source that make them unable to manage the available information to find solutions for the problems studied (Johari Surif et al., 2014).

It can be concluded that the students ' difficulties in solving open- ended problems can be divided into two parts , cognitive and affective aspects of the difficulties. The students who find difficulty in cognitive is failed to use the principles they have learned to use the settlement , unable to extract the information in the limited data , and failed to use the right concept and the approach is not suitable in solving open- ended problems . In affective aspects, students are not able to manage time well, often in despair because of the lack of knowledge and do not make a plan so that they can get the appropriate steps to solve the problem. It can be said that all these difficulties occurred because of lack of chances to solve open ended problem and the students did not know the appropriate method in solving open ended problem. Thus, an effort to help overcome these difficulties need to be done. Clearly, the difficulties of students to solve problems in an open ended and HOTS need to be corrected as soon as possible so that they can be shifted from low level solver to the higher (Overton et.al, 2013).

IV. THE NEEDS OF SCIENTIFIC CREATIVITY IN PROBLEM SOLVING

According to Hu & Adey (2002) in solving a problem, the students have to be creative with imagination of the ways of solutions, and build coalitions of knowledge or technique to get this solution and thus improve their problem solving skills (Pekmez et.al, 2009). Khairul (2011) stated that creativity is becoming a necessity because of the creativity helps individuals to analyze the various possibilities, creating a strong problem solving, constructive and effective. But the question is what is meant by creativity, how it is viewed from science viewpoint?

Torrance (1988), defines creativity as a process of formulating, reviewing, evaluating hypotheses in an effort to solve a problem is not known. But according to Lin et al. (2003) general creativity should be separated from the creativity from a scientific viewpoint. This is

supported by Liang (2002), which states that "a person who is creative in chemistry is not necessarily creative in the arts". This means that the creative person in life not necessarily creative in terms of science. Creativity in science education or accuracy of the so-called scientific creativity is a stand-alone field (Mukhopadhyay, 2013). Hu & Adey (2002) defines scientific creativity as intellectual abilities to produce certain products are original and have the personal or social, is designed with a specific purpose in mind using the information provided.

Hu & Adey (2002) also describe the first structure of scientific creativity is different from the creativity of others because it involves the creative science experiment, involving science-based problems. Second, scientific creativity is one involving intellectual abilities. Third, scientific creativity is based on scientific knowledge and science process skills. Fourth, creativity and analytical intelligence are two different factors that come from the mental. Based on the statement, it can be concluded that scientific creativity is a kind of creativity that measured scientifically, involves data and science-related issues.

Overton et.al, (2013) categorize the types of problem solvers based on the approach used to solve the problem. Categories of problem solvers are expert, non-expert and transitional. Expert problem solvers referring to students who use scientific approach in which the properties are to understand the problem, logic, making the estimates, and be able to manage the situation even though the data is reduced. The second is a non-expert problem solver, refers to a student who is not use a scientific approach. Problem solvers in this category cannot understand what the problem is, cannot adapt to the problem because of lack of data and lack of knowledge related to a given problem. They also not evaluate the selected solution. They also prefer to find a solution in form of algorithm. The third category is transitional problem solvers. Transitional problem solver refers to solver who uses both a scientific and non-scientific approach. Sometimes they use scientific approach, but on the other part they use non-scientific approach. They usually evaluate a solution, but at the same time using an algorithm approach. Problem solvers in this category are called transitional because they are in transition phase from non-expert to expert problem solvers.

Based on the above explanation and detail can be concluded to be good problem solvers, students must use a scientific approach (Cartrette & Bordner, 2010; Overton et.al, 2013). Here, the role of scientific creativity is needed. When the student creative scientifically, then the idea that issued is based on science and not just by logic or other views that may not correspond to a given problem situation and this will lead to more relevant solution (Overton et.al, 2013).

V. SUGGESTION OF FURTHER WORK

Apart from promoting the use of open- ended problem in the classroom, some of the learning strategies that are appropriate and can help to improve problem-solving skills and scientific creativity will be examined. Learning activities based on the selected learning strategies will be develop and the impact of this activity will then be evaluated on students' performance, the level of problem solving and the level of scientific creativity of students. Next, research will be study on how the learning activities promote the development of scientific creativity and problem solving. The process of construction of scientific creativity and problem solving occurs also will be examined. All of these findings will be used to develop a framework that can be used as a reference to help teachers and students improve problem-solving skills as well as scientific creativity.

Even though there is already a framework related to problem solving and framework that linking problem solving and creativity, but there is no such a model that specifically linking on open -ended problem solving and scientific creativity. Therefore, a flexible structure of the framework that can be used to improve the quality of problem solving and indirectly enhancing scientific creativity will be further explored. It will be such an effort to increase the level of problem solving among students in order to help countries create communities that are able to operate effectively in society and compete with the global world.

CONCLUSION

In order to help improve problem-solving skills, teachers have to develop problem solving culture in classroom. Students must be in a student-centered learning environment in which they are involved actively in the learning process, but should also be given counseling if they have difficulty in solving a problem. Teachers should always be willing to take risks to change strategy (Hamza & Griffith, 2006) and not just tied to a learning strategy in order to increase problem solving skills (Zoller et al., 2007). Through this study is expected to help provide a framework that can be used to improve problem solving skills as well as scientific creativity among students so that they can participate effectively in society and work environment (Cooper, 2006; Ramos, Dolipas & Villamor, 2013).

RUJUKAN/REFERENCES

Aka E.I, Guven, E., Aydogdu, M. (2010). Effect of Problem Solving Method on Science Process Skills and Academic Achievement. *Journal of Turkish Science Education*, 7(4), 13-25.

Aksela, M. (2005). Supporting Meaningful Chemistry Learning and Higher Order Thinking through Computer-Assisted Inquiry: A Design Research Approach. Academic Dissertation, University of Helsinki.

Aktamis, H. & Ergin, O. (2008). The Effect of Scientific Process Skills Education on Students' Scientific Creativity, Science Attitudes and Academic Achievements.

Alhusaini, A.A, & Maker, C.J (2011). The Uses of Open-ended Problem Solving in Regular Academic Subjects to Develop Students' Creativity: An Analytical Review. *Turkish Journal of Giftedness and Education.* 1(1), 1-43.

Altuncekik, A., Yaman, S. & Koray, O. (2005). A Study on Levels of Self-efficacy Beliefs and Problem Solving Skills of Teacher Candidates. *Kastamonu Education Journal*. 13(1), 93-102.*Asia-Pacific Forum on Science Learning and Teaching*. 9(1), 1-21.

Bennett S.W. (2008). Problem Solving: Can Anybody Do It? *Chemistry Education Research and Practice*. 9, 60-64.

Bodner G.M, (2003), Problem Solving: The Difference Between What We Do and What We Tell Students To Do, *Chemistry Education*, 7 ,37-45.

Cartrette P.D. & Bodner, G.M. (2010). Non-mathematical Problem Solving in Organic Chemistry. *Journal of Research in Science Teaching*, 47(6), 643-660.

Douglas E.P., Ljungberg, K.L, McNeill, N.J., Malcolm, Z.T., & Therriault, D.J. Moving Beyond Formulas and Fixations: Solving Open- Ended Engineering Problems. *European Journal of Engineering Education*. 37(6), 627-651.

Funke, J. (2013). Human Problem Solving in 2012. *The Journal of Problem Solving*. 6(1), 2-19.

Geersten, H.R (2003). Rethinking Thinking about Higher-Level Thinking. *Teaching Sociology*. 31(1), 1-19.

Gok, T. (2010). The General Assessment of Problem Solving Processes and Metacognition in Physics Education. *Eurasian Journal of Physics and Chemistry Education*. 2(2), 100-122.

Gotwals A. W. & Songer N.B., (2013). Using Assessment to Gather Validity Evidence for a Learning Progression on Evidence-based Explanations with Core Ecological Content. *Journal of Research in Science Teaching*.40 (5). 597-626.

Greiff, S., Holt, D.V., & Funke, J. (2013). Perspectives on Problem Solving in Educational Assessment: Analytical, Interactive, and Collaborative Problem Solving. *The Journal of Problem Solving*. 5(2), 71-91.

Hamza, M.K, & Griffith, K.G, (2006).Fostering Problem Solving & Creative Thinking in the Classroom: Cultivating a Creative Mind. *National Forum of Applied Educational Research Journal-Electronic*, 19(3), 1-29.

Hayer, J.R. (1981). The Complete Problem Solver – Philadelpia, PA:The Franklin Institute Press.

Heong, Y.M, Othman, W., Md Yunos, J., Kiong, T.T., Hassan, R., & Mohamad, M.M (2011). The Level of Marzano Higher Thinking Skills among Technical Education Students. *International Journal of Social Science and Humanity*, 1(2), 121-125.

Hu W. & Adey, P. (2002). A Scientific Creativity Test for Secondary School Students. *International Journal of Science Education*. 24(4), 389-403.

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

Khairul, A.I. (2011). "Kreativiti, Kecerdasan & Kesihatan Mental". In: Sobian S. (Ed), *Islam, Kreativiti dan Inovasi*. Kuala Lumpur, Institut Kefahaman Islam Malaysia.

Kenney,J.(2013).Fostering Critical Thinking Skills: Strategies for Use with Intermediate Gifted Readers. *Illionis Reading Council Journal*, 41(2), 29-37.

Kim, M. & Tan H.T (2013).A Collaborative Problem-Solving Process through Environmental Field Studies. *International Journal of Science Education*. 35(3), 357-387.

Liang, J.C (2002). Exploring Scientific Creativity of Eleventh Grade Students in Taiwan. Unpublished PHD thesis, The University of Texas.

Lin, C., Hu, W. & Adey, P. (2003). The Influence of CASE on Scientific Creativity. *Research in Science Education.* 33(2), 143-162.

Mayer, R.E. (2003). *Learning and Instruction*. Upper Sadle River, NJ: Prentice Hall.

Mourtos, N.J (2010) Challenges Students Face in Solving Open-Ended Problems, *International Journal for Engineering Education.*

Mukhopadhyay, R. (2013). Measurement of Creativity in Physics – A Brief Review on Related Tools. *Journal of Humanities and Social Science*. 6(5), 45-50.

Mustafa, D. (2008). The Application of Problem Solving Method on Science Teacher Trainees on the Solution of the Environmental Problems. *Journal of Environmental & Science Education*, 3(1), 9-18.

Osman, M. (2010). Controlling Uncertainty: A Review of Human Behavior in Complex Dynamic Environments. *Psychological Bulletin*, 136(1), 65-86.

Overton, T. & Potter, N. (2007). Solving Open-ended Problems, and the Influence of Cognitive Factors on Student Success. *Chemistry Education Research and Practice*. 9, 65-69.

Overton, T., & Potter, N. (2011), Investigating Students' Success in Solving and Attitudes towards Context-Rich Open-ended Problems in Chemistry. *Chemistry Education Research and Practice*. 12, 294-302.

Overton, T., Potter, N., & Leng, C. (2013). A Study of Approaches to Solving Open-ended Problems in Chemistry. *Chemistry Education Reseacrh and Practice*, 14, 468-475.

Pappa E.T. & Tsarparlis, G., (2011). Evaluation of Questions in General Chemistry Textbooks According to the form of the Questions and the Question-Answer Relationship (QUA): the Case of intra and intermolecular chemical bonding. *Chemistry Education Research and Practice*. 12, 262-270.

Ramos, J. L. S., Dolipas, B. B., & Villamor, B. B. (2013). Higher Order Thinking Skills and Academic Performance in Physics of College Students : A Regression Analysis. *International Journal of Innovative Interdisciplinary Research*, (4), 48–60.

Reid, N. & Yang, M.J, (2002) The Solving of Problems in Chemistry: the More Open-ended Problems. *Research in Science & Technological Education*, 20(1), 83-98.

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

Taasoobshirazi G. & Glyn S.M. (2009). College Students Solving Chemistry Problems: a Theoritical Model of Experience. *Journal of Research in Science Teaching*.46 (10), 1070-1089.

Teichert M.A & Stacy, A.M., (2002). Promoting Understanding of Chemical Bonding and Spontaneity through Students Explanation and Integration of Ideas. *Journal of Research in Science Teaching*. 39, 464-496.

Torrance E.P. (1988). "The Nature of Creativity as Manifest in its Testing". In: R.J Stenberg (Ed), *The Nature of Creativity: Contemporary Psychological Perspectives* (43-75).New York: Cambridge University Press.

Tsaparlis G., (2005). Non-algorithmic Quantitative Problem Solving in University Physical Chemistry: a Correlation Study of the Role of Selective Cognitive Factors. *Research in Science & Technological Education*, 23, 125-148.

Zohar, A., & Dori, Y. J. (2003). Higher Order Thinking Skills and Low-Achieving Students: Are They Mutually Exclusive? *Journal of the Learning Sciences, 12*, 145–181.

Zoller, U. & Pushkin, D. (2007).Matching Higher-Order Cognitive Skills (HOCS) Promotion Goals with Problem-based Laboratory Practice in a Freshman Organic Chemistry Course. *Educational Research*. 8(2), 153-171.

Zoller, U. (2001). Alternative Assessment as (Critical) Means of Facilitating HOCS-Promoting Teaching and Learning in Chemistry Education. *Chemistry Education: Research and Practice in Europe*.2 (1), 9-17