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SCIENTIFIC PROBLEM SOLVING COMPETENCY OF REAL LIFE TASK IN LEARNING ELECTROLYSIS

Suraiya Muhamad[1], Noor Dayana Abd Halim[2], Johari Surif[3], Jamalludin Harun[4] and Siti Salbiah Omar[5]

Transformation of global education is crucial in developing future leaders as competent problem solvers in life. The idea of changing the conventional classroom into an authentic learning environment is one of the potential factors in enhancing scientific problem solving competency through formal education. Authentic practice is also supported by instructional and learning module which consists of beneficial learning activities and tasks for students in applying Higher Order Thinking Skills (HOTS) to solve open-ended problems. Therefore, this study aimed to discuss the development of scientific problem solving competency in learning electrolysis among school students. The participants were assigned into groups to solve four real life tasks on electrolysis during the intervention in developing their scientific problem solving competency. The solution to the problems created for the respective real life tasks are categorized into four levels of competency. The outcome from this study indicates a significant positive development of scientific problem solving competency in enhancing the HOTS at school level.

Keywords: Scientific Problem Solving Competency, Real Life Task, Open-Ended Problem.

1. INTRODUCTION

In the current era, the purpose of authentic learning is to introduce learners to the basic elements of authentic learning practice. The result for the recent international assessment conducted to study the Trend in Mathematics and Science Study (TIMSS 2015) and Programme International for Student Assessment (PISA 2015) has reported a positive improvement in the performance of Malaysian students towards Science and Mathematics. Hence, Ministry of Education decided to emphasize more authentic learning practice in maintaining the continuous improvement in TIMSS 2017, focusing to more problem solving activities involving application of High Order Thinking Skills (HOTS) for the purpose of engaging student with in-depth knowledge construction and reflective learning (UNESCO, 2015).

Problem solving is an important area being considered in the national agenda for the purpose of upgrading the quality of education in Malaysia in order to achieve the international standard of TIMSS and PISA. In this study, scientific problem solving competency (SPSC) refers to the ability and capacity of an individual to

[1] Sekolah Menengah Sains Kuching Utara, Kuching, Sarawak, Malaysia, *E-mail: suraiyamuhamad@gmail.com*

[2] Universiti Teknologi Malaysia, *E-mail: noordayana@utm.my*

[3] Universiti Teknologi Malaysia, *E-mail: johari_surif@utm.my*

[4] Universiti Teknologi Malaysia, *E-mail: p-jamal@utm.my*

[5] Universiti Teknologi Malaysia, *E-mail: sitisalbiahomar@gmail.com*

solve open-ended problem using their scientific knowledge, problem solving skills, and scientific competencies. However, one of the greatest shortcomings of problem solving assessment is related to the process of measuring the level of problem solving competency during the learning process. Hence, an initiative must be taken to develop a rubric for the purpose of measuring the level of scientific problem solving competency (SPSC) through a framework known as Problem Solving Proficiency (Reeff *et al.*, 2006).

In the current study, several real life tasks (RLT) have been developed with the aim of guiding and leading the learners to develop scientific problem solving competency in the mean of confronting with potential problems in classroom as well as real world, especially in facing future career. RLT was also used as a learning tool for the reason of engaging the learners to a meaningful, fun-filled, and effective way of learning electrolysis in an authentic environment.

2. OBJECTIVES

The aim of this study is to investigate in what manner secondary school students choose to solve open-ended problems in real life tasks (RLT). Hence, the research questions are as follows:

(i) What is the level of scientific problem solving competency among school students in learning electrolysis?

(ii) How can students apply HOTS to develop scientific problem solving competency in solving real life task?

3. METHODOLOGY

The current case study chose to gather data using rubric method to determine the level of scientific problem solving competency. The sample of this study were purposely selected based on homogenous high academic achievement, which consists of 46 Chemistry students aged 16 years old who attend a secondary school in Sarawak. A set of four real life tasks were administered in six weeks intervention on the e-learning system known as "Chemistry Authentic Learning". In this study, real life tasks were adopted as an instrument to measure the level of scientific problem solving competency to solve open-ended problem for the purpose of learning electrolysis. In the case of this study, real life tasks (RLT) were designed based on the learning objective of Form 4 Chemistry syllabus listed as follows:

1. electrolyte and non-electrolyte,
2. electrolysis of molten compound,
3. electrolysis of aqueous solution, and
4. pollution caused by electrochemical industry.

The four real life tasks are collaboratively solved to create the respective solution. Participants upload the solution to the e-learning system after the solution

is achieved. Next, the answer script and product of the real life tasks posted by the participants were analysed using rubric adapted from Reeff *et al.* (2006). The product of solution for Real Life Task 4 was video clip. Moreover, proficiency in the four level of problem solving competency were adapted and validated into their respective level based on the domain in PISA Science Framework (2012). The constructs that were derived from the domains include identifying scientific issue (C1), explaining phenomenon scientifically (C2), using scientific evidence (C3), and creating the scientific solution (C4) for the given problem. The answer scripts of RLT were then analysed by coding the identified respective constructs, namely C1, C2, C3, and C4.

According to the integrated constructs, the level of problem solving proficiency was determined based on the rubric in order to establish scientific problem solving competency based on the problem solving proficiency as described in Table 1. Moreover, problem-solving proficiency was developed based on the presence of construct in the participants' answer script. In this case, participant will be awarded with C4 if they are able to create the solution by integrating all constructs in scientific competencies. Both instruments have been validated by three experts in order to meet the necessary criteria for the purpose of making them more practical and accurate to collect data.

TABLE 1: RUBRIC LEVEL OF PROBLEM-SOLVING PROFICIENCY (ADAPTED FROM REEFF *ET AL.*, 2006)

Level	*Problem-solving Proficiency*	*Scientific Problem solving competency*
1.	At elementary level, concrete, limited tasks can be mastered by created identifying scientific issue. At this level, participants are not allowed to use related scientific knowledge to solve problems, but the issues can be recognized from the problem.	No solution is created
2.	Participants are able to create the solution by identifying scientific experience issue. At this level, participants are able to find out the solution from the issues mentioned in the problem by applying an appropriate concept or principle in electrolysis.	Solution based on experience
3.	Participants are able to create the solution by scientifically explain the phenomenon and make justification based on the strategy, related concept, or principle.	Solution based on scientific knowledge and experience
4.	Participants are able to integrate all constructs by identifying scientific issue, explaining phenomenon scientifically, and using scientific evidence to systematically create a solution for the problem. They are able to draw an appropriate justification by applying the relevant principle and concept to solve the problem. Moreover, at this level, participants are able to justify how and why they managed to arrive at a certain solution. In this level of problem-solving competency, the highest cognitive level in HOTS is required.	Based on problem solving competency (scientific knowledge competency + experience + problem solving skills)

4. RESULT AND DISCUSSION

The results obtained were used to determine the level of scientific problem solving competency (SPSC) as well as the application of HOTS in solving real life tasks.

4.1 Level of Scientific Problem Solving Competency (SPSC)

The level of SPSC in real life task (RLT) was determined for the purpose of studying the development of SPSC in learning electrolysis. In this study, participants are required to collaboratively solve real life task in their respective eight groups. The ability of the participants to solve the problems was assessed using rubric that was adapted from Reeff *et al.* (2006). The assessment on real life tasks were conducted in group based on the four constructs (C1, C2, C3, and C4). The classification of level depends on the constructs present in participants' solutions in the real life tasks. As shown in Table 1, a detailed rubric of determination of level is presented. Meanwhile, Table 2 shows the achievement of participants in RLT based on the four constructs.

TABLE 2: LEVEL OF SCIENTIFIC PROBLEM SOLVING COMPETENCY (SPSC)

	Scientific Problem Solving Competency					
Real Life Task	*Scientific knowledge*	*N (group)*	*Level 1*	*Level 2*	*Level 3*	*Level 4*
1	Electrolyte and non-electrolyte	8	0(0%)	5(63%)	3(37%)	0(0%)
2	Electrolysis of molten compound		3(37%)	0(0%)	4(50%)	1(13%)
3	Electrolysis of aqueous solution		0(0%)	1(13%)	2(25%)	5(50%)
4	Pollution causes by electrochemical industry		0(0%)	0(0%)	5(63%)	3(37%)

In Table 2, the achievement level of problem solving competency in four real life tasks conducted on 46 participants that were assigned into eight groups are shown . In real life task 1, participants are required to carry out group discussion in order to find the solution for the problem related to the topic of electrolyte and non-electrolyte. As presented in Table 2, Group 1, 2, 3, 7, and 8 managed to achieve level 2 by identifying the scientific issue as well as creating the solution for the issue. Meanwhile, the level of scientific competencies for Group 4, 5, and 6 are slightly higher than the other five groups, whereby they managed to achieve level 3 as a result of their ability to scientifically explain the observed phenomena. Overall, none of the participants achieved level 1 and level 4 for real life task 1 of problem solving competency. As can be seen in Table 2, the highest level scored is level 2 with the total of 63% participants, while the second highest percentage is from level 3 with the amount of 37%. One of the samples of the solution from the participants scored level 3 for real life task 1 is shown below:

Solution from Group 4:

My suggestion is to [use the salt solution as the source of energy] [C1]. [The salt should be mixed with plain water to make it into salt solution and then put it into the canned food container. Then, remove the plastic insulation about 1 inch at the end of both copper wires. The ends of the copper wires should be connected with a graphite pencil and iron spoon then immerse it in salt solution] [C2]. Then connect the other end of the copper wires with the bulb. [Then, the bulb will light up] [C4].

Identifying scientific issue (C1)	*Explaining phenomena scientifically (C2)*	*Using scientific evidence (C3)*	*Creating scientific solution (C4)*	*Level 3*
✓	✓	✓		

According to the result, participants still failed to fully apply HOTS to create the appropriate solution in solving real life task 1. Most of them failed to justify the solution using the scientific evidence in electrolysis. Meanwhile, in real life task 2, participants were required to carry out group discussion on real life application that involves electrolysis of molten compound. As shown in Table 2, only Group 7 managed to achieve the highest level of competency which is level 4 as a result of being able to identify the scientific issue, explain the phenomena scientifically, use scientific evidence, and create solution. A total of four groups, namely Group 1, 2, 3, and 8 only managed to achieve level 3 because they failed to provide the scientific evidence to justify the solution. Meanwhile, Group 4, 5, and 6 managed to score level 1 for this task as a result of only being able to state the scientific issue without any supporting evidence or solution to explain the phenomena scientifically. Level 3 achieved the highest percentage of problem solving competency which is 50%. Only one group managed to achieve level 4 of problem solving competency which the percentage of 13%. This task requires participants to engage themselves with cognitive domain of applying the relevant concept in electrolysis. This finding managed to reveal the obvious low application of HOTS.

Solution from Group 7:

[The bauxite is purified to yield a white powder which is aluminium oxide from which aluminium can be extracted][C1].[….first, the aluminium oxide must be melted so that electricity can pass through it. …it is dissolved in molten cryolite which is an aluminium compound with a lower melting point than aluminium oxide. The use of cryolite reduces some of the energy costs involved in extracting aluminium…][C2]. [The diagram is showing an aluminium oxide electrolysis tank. Oxygen will form at the positive electrodes. This oxygen will react with the carbon of the positive electrodes, forming carbon dioxide, and they gradually burn away][C3]. [As a result, the positive electrodes have to be replaced frequently. This adds to the cost of the process][C4].

Identifying scientific issue (C1)	*Explaining phenomena scientifically (C2)*	*Using scientific evidence (C3)*	*Creating scientific solution (C4)*	*Level 4*
✓	✓	✓	✓	

On the other hand, RLT 3 required the participants to carry out group discussion on solving the problem based on their existing knowledge in chemistry, specifically electrolysis of aqueous solution. As shown in Table 2, an obvious improvement can be detected from the previous RLTs. Five out of eight groups managed to reach level 4 (Group 2, 4, 5, 6, and 7). On top of that, Group 2 and 8 only able to achieve level 3 because they could not provide any scientific evidence to support their observations or solution. However, only Group 1 managed to score level 2 as a result of not being able to explain the phenomena scientifically and use scientific evidence. The results also revealed that participants can keep improving their SPSC by analyzing, evaluating, and creating appropriate solution. The problem solving process required participants to engage with HOTS that will enable them to solve real life task successfully, as illustrated in the answer sample below:

Solution from Group 3:

To solve this problem, Amirah can take a beaker of salt water from the sea because sea water is salty. [Seawater contains NaCl, sodium chloride][C1]. So, we should [do an electrolysis process by using carbon electrode as the anode and cathode. After doing the electrolysis process, the selectively charged anion for anode is chloride, Cl- as the concentration of the sea water is concentrated. While, at the cathode electrode, H+ will be selected to discharge][C3]. [Bubbles of yellowish gas can be observed that is the hydrogen gas][C2]. [That is how Amirah can obtain chlorine gas][C4].

Identifying scientific issue (C1)	*Explaining phenomena scientifically (C2)*	*Using scientific evidence (C3)*	*Creating scientific solution (C4)*	*Level 4*
✓	✓	✓		

In real life task 4, participants were assigned to work in groups to produce a video clip on the issue of pollution as a result of electrochemical industry. For this task, three out of eight groups, namely Group 1, 7, and 8 managed to achieve level 4. Meanwhile, the rest of the groups (2, 3, 4, 5, and 6) only managed to achieve level 3 of scientific competency due to their inability to use the scientific evidence to support their solution. The percentage of the participants who scored level 3 and level 4 are 63% and 37% respectively, which shows an increase in RLT 5. All of the groups managed to identify the scientific issues, explain the phenomena scientifically, and create solution based on their scientific knowledge despite the fact that only three groups managed to provide and use scientific evidence to justify the selected solution for the purpose of overcoming the pollution issue caused by electrochemical industry. Participants were allowed to collect information from the internet, reference book, or online forum with the expert.

4.2 Application of HOTS in Solving Real Life Task To Develop Scientific Problem Solving Competency

Problem solving is a part of thinking process which involves cognitive domain to create the expected solution. Most participants prefer to accomplish the RLTs in group because it allows them to create better solution with critical justification,

rather than working individually to solve the problem. Evidence from previous studies found that group work could enhance students' interpersonal communication skill as well as engage them to apply HOTS for the purpose of finding an accurate solution for the problem (Gardner, 1983). Adequately, this interpersonal skill is crucial to develop a successful solution, especially for future career undertaking.

Problem solving tasks have engaged the participants to real life tasks which also enabled them to apply their scientific knowledge based on electrolysis. In addition, RLT managed to engage students to authentic experiences and create new scientific knowledge to be applied in solving problem for further laboratory work or future career. Moreover, this finding has revealed the role of problem solving task in applying scientific knowledge and thinking to figure out the relevant justification to support the solution. This finding is in agreement with previous studies which states that students should be engaged to real life problem in order to optimize their reasoning skills towards the issue of the given problem (Johari *et al.*, 2014, Lartson, 2013, Gayon, 2008). Most students found that solving the problem collaboratively offers the opportunity to gather more ideas to accomplish the problem solving task. HOTS is applied as a strategy that is widely practiced by most students in solving RLTs successfully. Therefore, the competent participants managed to solve the problems based on their practice of applying HOTS due to the reason that RLT are non-routine, ill-defined, and real life contexts.

Most students seem to realize that they should not only rely on memorization, knowledge, and fact in the text-book because it is important for them to put in extra efforts to search for relevant information from alternative sources such as the internet. Hence, it has been proven that the transformation of learning strategy has occurred in the current education syllabus. The future implementation of new Secondary School Standard Curriculum which will take effect in January 2017 is one of the alternative approaches in managing the transformation wave issue. The emphasis on this newly revised curriculum is on authentic learning environment which is in alignment with 21st century education trend. It was evidence that the real life tasks have managed to meet a number of criteria of the 21st century learning that was injected into the new standard curriculum.

A deep understanding of electrolysis concept is essential in solving real life tasks based on experience and skills. This collaborative task helps to enhance students to share ideas and decide on the best solution based on the solid justification with the assistance of the relevant current issue. If the problem is solved individually, the participants had to come up and brainstorm their own idea to find the issue of the task given. Moreover, student is also required to think critically to come up with scientific evidence, thus resulting in a time-consuming process. Previous study has reported if the problem is solved collaboratively, the misconception of chemistry concept can be avoided (Chandran *et. al*, 1987).

Participants who are competent in solving real life task can apply problem solving skills due to their skills of comprehending the problems better as well as solving the problem using a particular concept or principle. Meanwhile, low competent participants would have fewer skills in solving real life task due to their lack of scientific knowledge and poor conceptual understanding about electrolysis. This finding revealed that only minimum number of students tends to apply HOTS in solving the problem in learning chemistry. Furthermore, solving open-ended problems require in-depth understanding, application of HOTS, and collaboratively work as an intellectual team (Overton and Potter, 2008) . The experience in solving open-ended problem is a part of real life problems which could involve any possible solution based on scientific justification (Boži and Tramullas, 2014).

More learning tools can potentially be provided with the rubric to assess the students' performance as well as to engage students in applying HOTS by utilizing knowledge, skills, ability, and experience in confronting real life problems. In addition, it might also be useful as an early preparation in international assessment. Therefore, the assessment of learners' progress is expected to solve real life task with a deeper conceptual understanding and mastering in scientific competencies.

5. CONCLUSION

Scientific problem solving competency (SPSC) is crucial in generating competent future leaders to solve real world problems. The quality or quantity of SPSC tend to increase as the students get familiar with the pattern of open-ended problem, which enables them to apply HOTS with appropriate problem solving strategy and related scientific knowledge and competencies. Hence, both instruments of real life tasks and rubric level of scientific problem solving competency are useful as learning tools for the purpose of enhancing the process of thinking (HOTS) and problem solving ability among school students, especially in the learning process of chemistry.

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