The Use of Problem-Based Learning Supported by Virtual Laboratory to Improve the Ability of Chemical Representation on Metal Coating

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Abstract. This study analyses the students' improvement and students' understanding of chemical representation ability and metal coating concept. Samples were taken using random sampling consisted of 34 students of grade XI of vocational high school in Surakarta. This study used a descriptive qualitative method. The learning method was Problem-Based Learning supported by Virtual Laboratory as the learning media. The instruments used are 6 questions, 2 descriptions, and 4 multiple choice questions. Students' must write down the reasons for choosing the answer. The data were collected using observations, tests, and interviews regarding the subject matter of metal coating. Observations were used to know students' difficulties. Tests were used to know the students' understanding of chemical representation ability and metal coating concept. Then, interviews were used to confirm the students' reasons for answering the test. As a result, most students' confirmed that virtual laboratory helps them to understand chemical representation and metal coating deeply. Students' gave 84 % positive response to the virtual laboratory. Students' also confirmed that they prefer virtual laboratory to the textbook method. The use of a virtual laboratory enhances 60% students' representation on the subject of the metal coating. Problem-Based Learning supported by the virtual laboratory can improve student ability and understand the chemical representation concept and metal coating concept.

Keywords : chemical representation, metal coating, problem-based learning, virtual laboratory

INTRODUCTION

One of subject learned by the vocational student is metal coating. A metal coating is a process to prevent metal corrosion by electrolysis. Sometimes students have difficulties to understand the reaction. Johnstone said, there are three levels of thought: the macro and tangible, the sub-micro atomic and molecular, and the representational use of symbols and mathematics[1]. In order to understand metal coating, learners need to understand 3 levels of chemical representation (macroscopic, submicroscopic and symbolic). In macroscopic cathode is a metal/object. Submicroscopic the cathode is the site of the reduction reaction, while the symbolic/representation of the cathode is symbolized by C or another metal.

The concept of electrolysis is a chemical concept that requires an ability to integrate three representational levels. Teacher and student have some difficulties in combining the chemical representative. Professional learning module has been developed can be used to enhance the teaching and learning of chemistry in low resource Nigerian schools. In addition, new knowledge has been produced in relation to the use of multiple representations for effective chemistry teaching and learning in schools with limited resources [2]. Other research suggests that learning with multiple representations is suitable for lessons in classes where the students have low capability level to keep up with those who have a medium and high capability level [3].

Based on the survey that had been done by some teachers and students in Surakarta, it showed that electrolysis concept was a difficult concept in chemistry subject. Therefore, it is needed a suitable learning strategy in electrolysis concept so that students can understand more. Students encounter misconceptions in the learning of electrolysis, especially on submicroscopic and symbolic levels. Previous researchers state that students' response to the application of Volta-cell materials based on multiple chemical representations shows a positive response. Students agree to use the teaching material in chemistry learning and it can provide ease in integrating the three levels of representation [4]. Students have not been able to describe and explain the observed redox reactions (macroscopic) in terms of the atoms, molecules, and ions that are involved in the reactions [5]. Using interactive multimedia module shows a significant difference between control group and treatment group in the understanding of concepts in the learning of electrolysis [6].

Life is identical to the problem. One of the learning models that teach students the ability to solve problems besides improving their knowledge is Problem Based Learning (PBL). Therefore, PBL is very suitable to be applied to prepare our students for the challenges of the 21st century. This learning model trains and develops the ability to solve problem-oriented problems authentically from the student's actual life, to stimulate high-level thinking skills.

PBL was developed by McMaster University School of Medicine in Canada in 1960 by Howard Barrow and colleagues [7]. Now PBL has spread and used all over the world. Problem-based Learning provides an opportunity for students to be actively involved. This is in line with the results of several studies, Problem-based learning can invite students to be actively involved in learning so that students become learning centers. Learning with problem-based learning model is effective in improving students' ability as the learning center [8]. PBL is a learning strategy that is student-centered, in this methodology students research, explain, and cooperate in order to find meaningful solutions to real life problems [9]. The essence of problem-based learning is an authentic and meaningful problem to students that can be the basis of inquiry [10]. Arends proposes PBL in five steps: students' orientation to the problem, organizing learners to learn, guiding individual and group investigations, developing and presenting the work, and then analyzing and evaluating problem-solving process [11].

With PBL students become more experienced at accumulating, organizing, and storing information in a useable form for future use, as well as, confronting and resolving complex, realistic problems. Active participation in the small group requires good interpersonal skills, which include: listening, negotiating, compromising, educating peers, giving and receiving criticism, and motivating others. The teacher is a mentor who guides his students during their group work and helps them to find the knowledge needed to find the problem solution. Hence, PBL is suitable for teaching this topic.

In addition, in order to make chemistry lesson more interesting, the researcher also uses direct practice. There is also evidence that students find practical work relatively useful and enjoyable as compared with other science teaching and learning activities [12]. Their study suggests that practical work in science could be significantly improved if teachers recognize that explanatory ideas do not 'emerge' from observations, no matter how carefully these are guided and constrained [13]. However, some vocational school does not have a laboratory. In addition, the laboratory's condition in some vocational schools is not sufficient. A chemical practice needs a lot of time. This limits time makes chemistry lesson cannot be applied well. Providing a virtual chemistry laboratory is considered to be a very helpful tool for both chemistry teachers and students at secondary schools especially those who have limited opportunity of using chemistry labs and making experiments [14].

The use of multimedia modules is able to assist students in visualizing the abstract concepts, but students with lack, sufficient metacognitive awareness, and comprehension monitoring skill make effective choices [15]. Using a variety of visualization tools for teaching and learning science and chemistry is necessary because student better understands chemical phenomena and formulate appropriate mental models [16]. In physics laboratory, imaginary experiments environments should be formed by using computers to prevent harmful effects of experiments and to represent the related concept or event [17].

It is therefore believed to be important to include a virtual simulated laboratory which allows students to complete their own experimental measurements and also include assessment [18]. Furthermore, the researcher tries to answer the question whether the learning results of student, according to the experimental design of classes using a virtual laboratory, are better than results gained through teaching classical science classes without visualization tools. The research of the didactic experiment carries out on a relatively small, pilot sample of thas shown that acquiring knowledge is more effective when using the virtual laboratory instead of classical teaching [19].

Virtual laboratory (Virtual Lab) is a set of laboratory tools in the form of interactive computer-based software, computer-operated and can simulate activity in the laboratory as if the user were in the actual laboratory. Learners are more interested in the use of virtual lab than conventional learning [20]. Potential of the virtual laboratory is to provide significant improvements and more effective learning experiences. The use of a virtual lab can help teachers overcome the limitations of tools and practicum materials in real laboratories [14]. Many research studies state that Virtual lab can improve student capability [21]. Virtual lab software can be used as a supportive tool in the real laboratory or as an alternative laboratory where there is not an available physical laboratory or conditions of the physics laboratory are insufficient [22]. Moreover, the researcher is dared to look into the future to anticipate the evolution of this amazing technology that will bring laboratory experimentation to anyplace in the world.

Virtual lab can show the integration of the three chemical representations in metal coating concept. In macroscopic, the metal coating is showed with metal coating's schema. Then, it can be seen the cathode, anode, electrolyte solution, and power supply. In submicroscopic, it is described as electron flow and cation movement towards the cathode. This submicroscopic reaction is symbolized by chemical reaction. This reaction cannot be shown in the reality laboratory, the chemical representation is shown in the virtual lab. The Virtual Lab is made to overcome the problem of these three chemical representations' integration. If it is made well, it is hoped that the students' understanding of metal coating can improve. Hence, the researcher will show a metal coating process through a virtual lab.

Based on the theories above, the researcher uses Problem-Based Learning as the learning method and virtual lab as the learning media. By using Problem-Based Learning as the learning method, students' ability will improve and the virtual lab is used to present chemical representation in metal coating concept. The Virtual Lab is easy to use and prevents students from dangerous damage.

METHODS

The research method used in this research was a descriptive qualitative. The variables were virtual lab and metal coating's ability. The sample of this research is 34 students of XITP 2 class in vocational school in Surakarta. The study was conducted in December 2017 - January 2018. The teaching method used was Problem-Based Learning supported by Virtual Lab as the media. The instrument used in this research were an observation, a test, and an interview. The Observation was done to know the students' knowledge, questions testing the ability of three representational levels (pretest and posttest), consisting of 6 questions measuring indicators of the relationship pattern of the three representational levels: 1) Macroscopic; 2) Macroscopic-Symbolic; and 3) Macroscopic-submicroscopic- symbolic[23]. After the test, the student was interviewed to confirm the student answer and to get the data about their reasons for the answer. The data were analyzed using the percentage students' correct answer and the students' reasons for choosing the answer.

RESULTS AND DISCUSSION

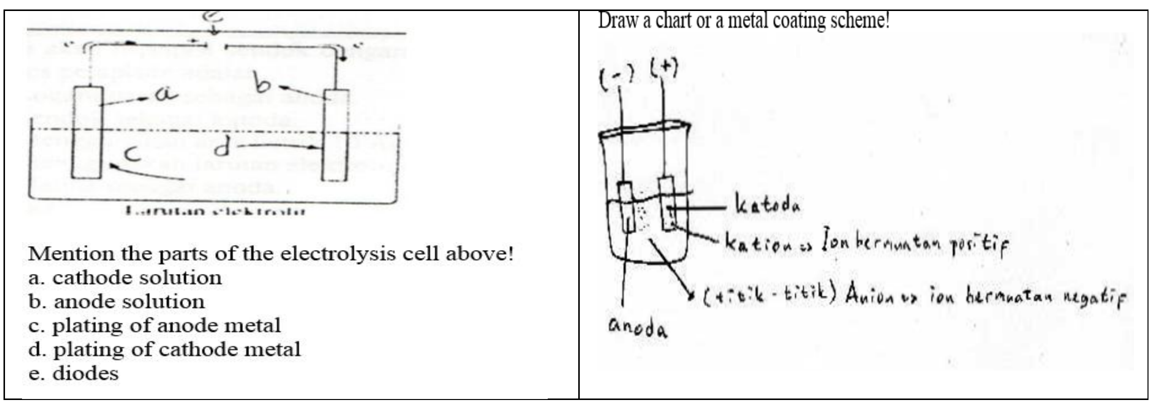
In the beginning, students were given a metal coating lesson by a textbook. Then, students were given a test about metal coating. The results showed the percentage of students' correct answer was around 21% - 41%. Factors that influence the result were as follows: (a) students' were not accustomed to working on multiple choice questions with additional reasons so that learners take longer; (b) students' could not be integrated three of representation; (c) students' tend to often solve problems only by using one rare way to check the results of their work. Further, students were given a metal coating material by PBL supported by the virtual lab and were asked to learn. Students then were given a post-test. The result showed the percentage of students' correct answer was around 84% - 97%. The percentage of students answer is presented in table 1.

Table 1. Percentage of Students' Correct Answer on Metal Coating

Question	Pre-test	Post-test
Macroscopic	30	84
Macroscopic	21	87
Macroscopic-symbolic	32	97
Macroscopic-symbolic	38	97
Macroscopic-submicroscopic- symbolic	41	97
Macroscopic- submicroscopic-symbolic	21	82

Overall of the result showed that the average of students' pre-test was 30 %. The smallest correct answers were in number 2 and number 6 and the highest correct answer was number 5. In number 2 and 6, the learners had difficulty in understanding the problems presented in various representations. A further understanding was achieved when a learner was consistent about what students deemed to be true. A representation of the problem of various forms of representation demanded a scientific perception of the passage. Students had difficulty in translating macroscopic, submicroscopic and symbolic representations. Hence, teachers should assist students in understanding chemical concepts at multiple levels of representation to enhance their conceptual understanding.

Question number 1 required a macroscopic. One of student' answer can be seen in Figure 1.



(a) Student's answer number 1 (b) Student's answer number 2

Fig1. The answer of the student in a macroscopic representation.

On the macroscopic level, the representation of the student's answers was drawn by the picture Figure 1. Based on the answers as in Figure 1(a), the student did not understand the macroscopic parts of the electrolysis cell. The student thought that the anode and cathode as a solution, the student did not see it as a solid material. In this section, the majority of students' answers were incorrect in sections c and d. Sections c and d are cation and anion that move to cathode and anode. This process is in submicroscopic representation. On section e, the student answered the diode because there was a positive pole and negative pole. The answer indicated that students did not understand precisely the scheme of electrolysis cells. In a macroscopic way, they did not understand the inside of the electrolysis cell.

In Figure 1(b), it appears that students already understood what was meant by cathode, anode, anion, and cation. But students did not understand how the movement of anions and cations on the electrolysis. During the interview, students understood if the cathode occurred reduction reaction and the anode occurred oxidation reaction, however, the student could not write the reaction. Students confused how to write it in symbols. From here it appeared that students who understood macroscopic representation could not state in symbol or submicroscopic. On the macroscopic problem, students who answered correctly were 25 %.

Question number 3 and 4 required macroscopic-symbolic. One of student's answer can be seen in Figure 2.

In an electrolysis reaction, when the anode is a nickel metal (Ni) and a cathode iron metal (Fe), while the electrolyte solution is a $NiSO_4$ solution. Then the reaction that occurs in the anode is …. a. $Fe + Ni^{2+} \rightarrow Fe^{2+} + Ni$ b. $Fe^{2+} + 2e \rightarrow Fe$ c. $Fe \rightarrow Fe^{2+} + 2e$ d. $Ni \rightarrow Ni^{2+} + 2e$ e. $Ni^{2+} + 2e \rightarrow Ni$ The Answer : a The Reason : because the results are comparable Katoda I anoda II katoda I anoda	The electrolysis reaction is the oxidation reaction at the anode and the reduction at the cathode. The sum of these two reactions is the total reaction of the electrolysis cell. The total reaction of electrolyzed cell of silver nitrate solution ($AgNO_3$) with zink (Zn) electrode is .... a. $4\,Ag^+_{(aq)} + 2\,H_2O_{(l)} \rightarrow 4Ag_{(s)} + 4\,H^+_{(aq)} + O_{2(g)}$ b. $2\,Ag^+_{(aq)} + Zn_{(s)} \rightarrow 2\,Ag_{(s)} + Zn^{2+}_{(aq)}$ c. $H_2O_{(l)} + 2\,Cl^-_{(aq)} \rightarrow 2\,OH^-_{(aq)} + H_{2(g)} + Cl_{2(g)}$ d. $4\,Ag^+_{(aq)} + 2\,Cl^-_{(aq)} \rightarrow 4Ag_{(s)} + Cl_{2(g)}$ e. $2\,H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)}$ The Answer : a The Reason : Katode : $Ag^+_{(aq)} + 1e \rightarrow Ag_{(s)}$) x 4 Anode : $2\,H_2O_{(l)} \rightarrow 4\,H^+_{(aq)} + O_{2(g)} + 4\,e$) x 1 $4\,Ag^+_{(aq)} + 2\,H_2O_{(l)} \rightarrow 4Ag_{(s)} + 4\,H^+_{(aq)} + O_{2(g)}$
(a) Student' answer number 3	(b) Student' answer number 4

Fig 2. The answer of the student in a macroscopic-symbolic representative.

Figure 2(a) discuss the students' abilities when given electrolysis reaction. Students then were asked to choose the right one. Students who answered correctly were 35%, while the other 65% were wrong. The representation of the students' answers was drawn by the picture Figure 2. Students chose the answer a, because they thought the reaction was comparable, besides the students wrote the voltaic cell notation. Students thought the voltaic cell and electrolysis cell reactions were the same. Students claimed the electrolysis cell reaction depended only on the type of electrode.

Based on the answers as in Figure 2(b), the student could write the reaction at the cathode correctly. However, the reaction in the anode was wrong. Students did not understand if the anode react was oxidation. Students could not understand well how the reaction occurred in electrolysis.The student confirmed, they understood the electrolysis chart but it was difficult for them to write down his reaction equation. The students had difficulty in writing the symbol of electrolysis reaction. Hence, from these two questions, the students' ability to integrate submicroscopic and symbolic was still low.

Question number 5 and 6 required macroscopic-submicroscopic-symbolic. One of student's answer can be seen in Figure 3.

One way to overcome the iron metal rendering by coating it with copper metal. The correct statement for the process is ... a. copper metal (Cu) as the cathode. b. The cathode used is copper metal (Cu). c. the reaction that occurs is a spontaneous redox reaction. d. electrolyte solution used AgCl solution. e. copper metal (Cu) as an anode. The Answer : c Reason : because what happens is a spontaneous redox reaction	Andi will coat the spoon with silver metal, the following which can inhibit the coating process is .... a. Silver metal as anode. b. Spoon as cathode. c. It uses 10 Ampere electric current. d. Using electrolyte solution AgNO3. e. Platinum as anode. The Answer : b Reason : because the spoon should be an anode in order to coat well
(a) Student's answer number 5	(b) Student's answer number 6

Fig 3. The answer of the student in Macroscopic-submicroscopic-symbolic representation.

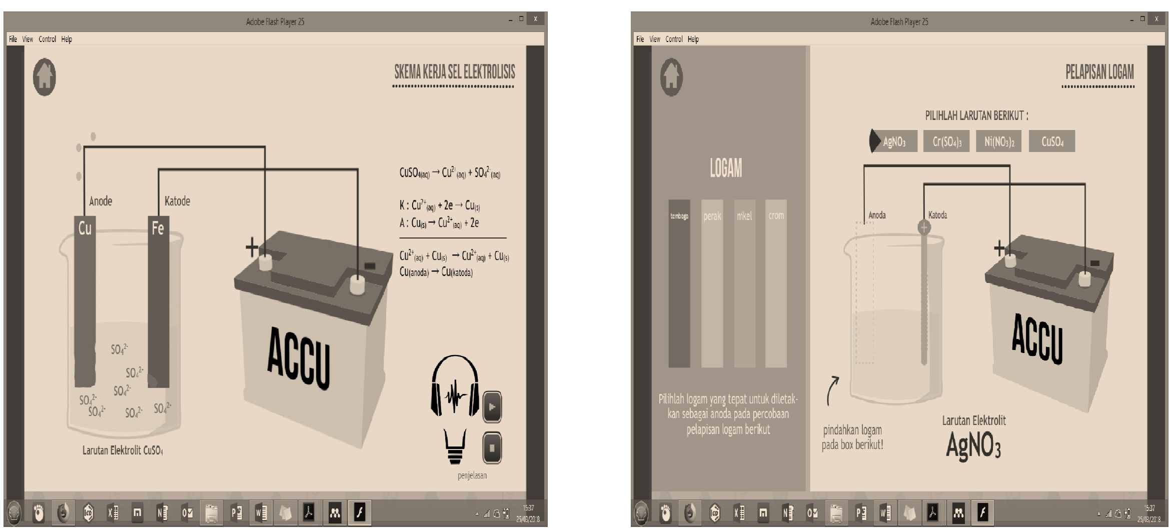
On questions 5 and 6 as shown in Figure 3(a) and 3(b), the researcher wanted to know the students' ability to analyze three chemical representations of macroscopic, submicroscopic and symbolic. 31% of students answered correctly. Question number 5 asked the exact statement on metal coating with copper. The student responded to the reaction as a spontaneous redox reaction. The student claimed the reaction was spontaneous because the reaction just happened. The student was asked to describe electrolysis cell chart, it turned out student described the voltaic cell chart. From this, it can be seen that the student did not understand the macroscopic difference of voltaic cells and electrolysis cells. This made it difficult for the student to write down the reaction. The student could not analyze the question. The macroscopic level of metal coating was not well understood by the student, this would cause the submicroscopic and symbolic levels were mistaken. Consequently, there was lacking integration between these three levels of representations.

The question number 6 asked which statement was inhibiting metal plating. The student chose the answer spoon as a cathode. When the teacher asked the student why the student chose the answer, a student said that the coated metal was as an anode. The student stated an anode reaction was a reduction. If the spoon was in the cathode then the spoon would react oxidation. However, if the spoon in the anode then the silver ions would accumulate in spoons and spoons would be coated. Generally, the students' understanding of the anode and cathode was reversed. Students did not understand the reaction at the anode or the cathode.

To improve the understanding of electrolysis, it is necessary to do a full integration of electrolysis representation. In general, educators explain the macroscopic and symbolic dimensions, while submicroscopic is less attention. One of the ways that can be done is to describe or visualize the process that occurs at the submicroscopic level [24]. The movement of electrons in the electrodes could not be imagined by the students. The metal coating process is a positive ion reduction process in the cathode that causes the coated cathode. However, this cannot be understood by students well.

In the next step, learning by PBL was applied. In the small group, students learned again about electrochemical especially metal coating. Student developed and presented the work, and then analyzed and evaluated the problem-solving process. Then, students learned metal coating by using the virtual lab. The use of Virtual Lab made submicroscopic representation visible. With virtual equipment, it can be seen or made transparent to reveal the inner structure [25]. Virtual Lab made the students understand the representations. So far students could imagine chemical representations well.

Based on table 1, it can be seen that the average students' correct answer increased 60%. From the interview result, the students had difficulty in understanding the three levels of chemical representations, macroscopic, submicroscopic and symbolic. The Virtual lab can be used as a learning tool for schools that do not have an adequate laboratory. The Virtual Lab's illustrations can be seen in Figure 4.



(a) (b)

Fig 4. The virtual laboratory (a) scheme electrolysis (b) electroplating

Figure 4(a) describes the electrolysis reaction occurring. It is macroscopically represented by an electrolysis cell scheme. The writing of chemical reactions is presented in symbols, while the submicroscopic picture is represented by the movement of copper ions toward the cathode. At the end of electrolysis of iron, metal coated with copper. All three chemical representations can be shown at once, this will make students understand the reaction of electrolysis better. In Figure 4(b) the students could perform a metal coating experiment. In this experiment, students should select the electrolyte and anode used to coat the iron. The virtual lab would provide information whether the experiment was done right or wrong. By using a virtual lab, students would not hesitate to do a practice work because no material was wasted and did not pose a risk to the student. This is one of the advantages of the virtual lab.

After using the virtual lab, students are given a response questionnaire sheet to the virtual lab. Results of student responses can be seen in table 2.

Table 2. Students' Response of Virtual Lab

Component	**%**	**Evidence**
Content	86	good
Presentation	83	good
Language	82	good
Chart	88	good
Average Number of Student Response	84	good

From the table 2, the average of the students' assessment of content, presentation, language, and the chart was 84%. This means that the virtual lab was considered good by the students.After studying metal coating using virtual lab the student declared more understand the process. It was easier to understand the macroscopic, submicroscopic and symbolic presentations. Electrochemical learning especially metal coatings became more fun using a virtual lab. Most students confirmed that virtual lab helps them to understand chemical representation and metal coating deeply. Students also confirmed that they prefer virtual lab to the textbook method.

The virtual lab was able to integrate chemical representations. The students were able to link macroscopic, submicroscopic and symbolic representation. The visualizations that existed in the virtual lab provided an understanding effect on metal coating. This was in line with previous researchers that virtual lab was more effective than classes without using visualization equipment [26].

CONCLUSION

Problem-Based Learning supported by Virtual Lab can improve students' ability in chemical representation and metal coating. The data showed that the average of students' correct answer increased 60 % after using Problem-Based Learning supported by Virtual Lab. Students gave positive response after using Virtual Lab. The use of Problem-Based Learning supported by Virtual Lab enhances students' representation on the subject of the metal coating. Further study in using Problem-Based Learning supported by Virtual Lab is needed to improve chemical representations' understanding in another chemistry concepts such as mole concept, atom structure, and chemical bonding.

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