Virtual Laboratory Development with Student’s Worksheet to Improve Critical Thinking on Electrochemistry for Vocational School Students

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Abstract. Vocational schools graduate students who are work-ready for the industries. In the era of Industrial Revolution 4.0, the critical thinking is needed. This research was aimed to develop the virtual laboratory with student’s worksheets to improve students’ critical thinking. The product, Virtual Laboratory with Student’s Worksheets (VLSW), was expected to increase students’ critical thinking after they had finished the lesson. Research and Development methods proposed by Borg and Gall were used in this research. The VLSW validation sheets were used as the instrument. The Delphi technique with eight experts was to validate virtual laboratory and student worksheets. The content validity by Aiken showed 0.94 for virtual laboratory while 0.90 for student worksheets. Therefore, virtual laboratory and student’s worksheets can then be used in electrochemistry learning. One hundred eighty tenth grade students from three vocational schools in Surakarta, Indonesia were used as samples. The average of the students’ responses to the content, presentation, language, and the chart was 92%, while student worksheets was 87%. The result of the paired sample t-test showed that VLSW significant to improve critical thinking for high and middle vocational schools, but not significant for low category vocational school. Development of learning media on other chemical concepts is needed to improve students' critical thinking skills.

Keyword: Development; Virtual laboratory; Critical thinking; Electrochemistry; Vocational school students.

1. Introduction
At the present time, the industry is faced with the Industrial Revolution 4.0. This has a major impact on vocational school education that prepared students to be ready to work in the industry. Furthermore, it is also summarized from the World Economic Forum (WEF), in 2020 where the fourth generation industrial revolution era begins there are ten soft skills that must be possessed to answer the challenges of the industrial world [1]. There are complex problem solving, critical thinking, creativity, people management, coordinating, emotional intelligence, judgment and decision making, service orientation, negotiation, and cognitive flexibility. Vocational schools prepared students in accordance with their respective field of expertise. Thus the infrastructure that supports these skills will be provided. Observing several vocational high schools in Surakarta, it shows that the chemical laboratory conditions are very apprehensive, even some without laboratories. Even though laboratory activity is needed in chemistry to be easily understood. The absence of laboratory could be overcome by developing a virtual laboratory. Virtual laboratory is a software for laboratory simulation which can be installed on computers or smart-phones. Afterward, students can do chemistry practicum in the classroom without any need for tools and chemicals. This
will certainly provide great benefits for teachers and students. In previous research conducted by Matthew showed that The Virtual Laboratory Practical Class (VLPC) Students who used the VLPC before the class reported an increase in their confidence in successfully completing the live practical experiment. They also showed a significant decrease in the mean completion time for the real laboratory session [2].

This study develops a media to learn chemistry using virtual chemical. In order teachers could monitor how students use virtual laboratories, it needs to be equipped with student’s worksheets. Virtual laboratories will address students for practicum and they will put it in student’s worksheets. The product in this research is Virtual Laboratory with Student’s Worksheet (VLSW). Beside to improve students’ learning achievements, this VLSW development aimed to improve students' critical thinking abilities because. The VLSW was developed based on 6 aspects of critical thinking skills.

Based on the survey that had been done in Surakarta, it showed that electrolysis concept was a difficult concept in chemistry subject. Therefore, it is needed a suitable learning media in electrolysis concept so that students can understand more. This VLSW development is expected to be used in vocational schools in Surakarta.

The rest of this paper is organized as follow: Section 2 presents review on existing related literatures. Section 3 describes the material used and proposed method. Section 4 presents the obtained results and following by discussion. Finally Section 5 concludes this work.

2. Related Works

Chemistry in vocational schools is not the same as high schools in general. Chemistry is a supporting course for the students’ field of expertise in the vocational school. As a supporting course, the teaching and learning process has to be made as attractive as possible. This because the students have the clear vocational intention and also requires some supporting study from the Chemistry [3]. These require the Chemistry to be drawn on differently to become the source of the knowledge and skills that various vocational occupations require. This research will discuss chemistry lessons in the department of mechanical engineering in vocational schools. One of the topics learned by the student is the electrochemistry. The concept taught should support the students’ expertise. Applications from electrochemical in mechanical engineering are metal coating and metal purification. In the preliminary research students conclude that electrochemistry was a difficult and abstract concept for students. Therefore, the presentation should be able to make electrochemistry easy and concrete.

Learning media is defined as anything can be used to facilitate the transfer of knowledge, channel the message or the content of the lesson, and stimulate students’ mind, attention, and skills to encourage the teaching-learning process. Various media can be used to enhance a more concrete learning experience. Teaching by using media, means the students do not learn just verbally, so we can expect to get the result of the most meaningful learning experience for students. The media is important to stimulate the learning process [4][5].

Efforts to make teaching more concrete can be done using the media. Different types of learning media have their own usability value. Abstract concepts in electrochemistry can be demonstrated by the laboratory experiment, but based on surveys conducted in vocational schools in Surakarta most of the laboratory conditions are minimal for this activity. This makes the researchers want to develop a virtual laboratory (VL) as an alternative solution. This situation may be improved by the study of the laboratory work using VL. The VL directions for the laboratory work are visual and would be comprehensive to the student as a beginner. The visual explanations in the VL directions with simulations will help the student to understand the object and the procedures of the laboratory work intuitively. Moreover, students can study the laboratory work virtually at any place at any time. The VL directions of the laboratory work of physics will help the student to learn the laboratory work virtually before the experiment. And the virtual learning will help them in real laboratory work. Students can get the whole image of the laboratory work through the directions before the class. Several studies show a positive response of students to the use of virtual lab learning media [6,7].
Student’s worksheets (SW) is a sheet of paper on which task for students is presented. The tasks on a worksheet are constructed by teachers and refer to the basic competencies and the learning objectives. The SW is the resource to facilitate and direct them in the process of learning. The SW put more emphasis on the process of discovering concepts and, the most important of all they provide various stimuli through the exercises/activities given. Various research has concluded the worksheets was expected to aid the development of students’ social communication, emotional, moral, and aesthetic skills [8]. Students’ learning experiences are determined by students’ personal development planning. The SW is considered good if they have complied with the requirements in several aspects, i.e. the use of language (structure and vocabulary), the level of difficulty, and general appropriateness to students’ skills and needs.

World Economic Forum (WE), in 2020 where the era of Industrial Revolution 4.0 began, there are ten soft skills that must be owned to answer the challenges of the industrial world [1]. Critical thinking skills are one of the soft skills required to confront the Industrial Revolution 4.0. Besides preparing for the Industrial Revolution 4.0 the education also prepares students to be ready for the 21st century. National Education Association (NEA), explains the critical thinking and problem-solving can be used by students in the learning so that they can strive to provide sensible reasoning to understand the interconnections among systems and seek to resolve the problems [9]. Facione said that critical thinking is a purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or conceptual considerations upon which that judgment is based [10]. The vocational school prepares the students to be ready to enter the workforce. At work, the students will be faced with problems that must be resolved appropriately. At that time their critical thinking skills are needed.

This VL presentation is accompanied by a student worksheet, the product named VLSW (virtual laboratory with student’s worksheets). The SW guide the students in the exploration and problem-solving. Tasks from teachers included in the SW were designed to refer to basic competencies and learning objectives specified [8]. The SW can be viewed as the students’ instruction manual on the learning process. In this research SW contains the questions that the student should do. They will work on the worksheet by practicing using the VL. The existence of this worksheet is expected to improve students’ critical thinking skills. Therefore, in this study, researchers will develop a media VLSW that can improve students’ critical thinking skills.

3. Material and Method
This section presents the material used and the proposed method.

3.1. Data
The samples this research were 180 students’ from three Vocational Schools in Surakarta, Indonesia. Each school consists of 30 students’ control class and 30 students’ the experimental class. There were three Vocational high School (SMK), namely SMK A, SMK B, and SMK C. SMK A represents a vocational school as high category, SMK B represents a middle vocational school and SMK C represents a low vocational school. This categorization is based on the value data of UN/US 2016/2017. The instrument used in the form of questionnaire needs of students and teachers, VLSW validation sheet, VLSW response questionnaire and critical thinking test.

3.2. Method
Research and development methods from Borg and Gall were used in this research [11]. Nine steps of research are used: (1) research and information collecting; (2) planning; (3) develop preliminary form of product; (4) preliminary field testing; (5) main product revision; (6) main field testing; (7) operational product revision; (8) operational field testing and (9) final product revision. The study was conducted from January to March 2018. The questionnaire needs of students and teachers used to find out the problems and needs of teachers and students. Triangulation method was obtained to get the right data through observation, interviews and surveys. Data analysis for VLSW content validity uses
The Delphi technique with eight experts used to validate VLSW [12]. The Aiken formula was noted in equation (1). Questionnaire analysis of teacher, student needs and student responses to VLSW is calculated by determining the percentage. While the improvement of critical thinking skills was analyzed using paired samples test Statistical Package for the Social Sciences (SPSS) program.

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V = \frac{r - lo}{c - lo} \times n
\]

Where:
- \( V \) = validity
- \( S = r - lo \)
- \( r = \) number given by an appraiser
- \( lo = \) the lowest validity score
- \( c = \) highest validity rating
- \( n = \) the number of validators from Aiken

4. Result and Discussion

This section presents the obtained results and following by discussion.

4.1. Result

The result of preliminary research with teachers and students showed the concepts of electrochemistry were hard to understand. Learning difficulties found on the concepts of electrolysis reaction and determination of the cathode and anode in electroplating. Those concepts were hard to understand because it was too abstract for the students and the teachers were unable or have the hard time to organize the experiment because of limited resources (materials, tools, time constraints, and etc.). To overcome those difficulties, suitable learning media were needed.

Some research proved that VL was a set of interactive multimedia software based electronic laboratory, operated on computers or gadget, to simulate the laboratory activities as if the operators work on the real laboratory. The students will more interest to use virtual labs instead traditional teaching [13]. The VL can significantly improve the students’ learning experience. The VL help the teacher to overcome real laboratory resource barriers (materials, tools, etc.) [14]. The VLSW was done so the experiments performed with VL can be written in the results systematically.

The next step was to design the product (VL) that can facilitate experimentation to support the learning. The Adobe Animate CC Ver. 2017 was used to develop the Virtual Labs. Adobe Animate CC was developed by Adobe Systems (NASDAQ: ADBE). Minimum specification of Personal Computer (PC) with Intel Core Duo processor, Microsoft Windows 7 (64 bit), 2 GB RAM, 4 GB hard disk space, and 1024x900 display. Adobe Animate was the newest version of Adobe Flash Professional, with more complete features. It can make both interactive and non-interactive animations. The developed product was validated by eight experts consisted of the learning media expert, subject matter expert, language expert, computer expert, and also end users (teachers). The data from validations were analyzed using Aiken test [15]. The result of the analysis can be seen in Figure 1.

Figure 1 showed the Content Validity of Ratio (CVR) for the Virtual lab was 0.94, and for the worksheet was 0.90. Those values were bigger than 0.75, indicating the instrument was valid. The experts also gave some feedback, such as: (1) need the description sound or text for the on/off button of the voltaic cell and electrolysis cells’ schemes ;(2) More metal combinations for the determination of potential cells ;(3) Make a distinct colour for plating metal to distinguish from the plated metal, especially after the electroplating done;(4) Need for exercise questions;(5) In the student worksheet so that students can think critically, the work instructions are given to a minimum. The feedback was used for consideration to revising the VL. Some examples of the revision can be seen in Figure 2.
The preliminary trial was conducted on 15 students and three teachers from three different schools. Some corrections and revisions were obtained, such as: (1) Error on Voltaic cell scheme, the written potential was 0.44 volts, the correct one was 0.46 volts; (2) 1.16 V potential was obtained from the Voltaic cell with Chromium (Cr) cathode and Barium (Ba) anode, the correct one was 2.16 V. After revision, the trial was expanded with 30 students and three teachers from three different schools some corrections and revisions were obtained. There were: (1) The electrolysis experiment was written with Ba (OH)\(_3\) the correct one was Ba (OH)\(_2\), and the reaction was Zn \(\rightarrow\) Zn\(^{2+}\) + 2e, the correct one was Zn\(\rightarrow\)Zn\(^{2+}\) + 2e; (2) The electroplating was written with Cr\(_2\) (SO\(_4\))\(_3\) the correct one was Cr\(_2\) (SO\(_4\))\(_3\), and the ion was written as Cu\(^{2+}\) the correct one was Cr\(^{3+}\); (3) The plus mark (+) on the plated metal was confusing the students, better eliminated; (4) On the Question No. 7, written with (NaNO\(_3\)) the correct one was AgNO\(_3\). After revisions, the VL and student worksheet was tested on the field test. The questionnaire was distributed to obtain students’ responses to the developed VL and student worksheet. The results from questionnaires were shown in Figure 3.
In Figures 3 and 4, the average of the students’ responses to content, presentation, language, and the chart was 92%, while student worksheets were 87%. This means that the VLSW were considered good by the students. The improvement of students’ critical thinking skills was analyzed using the Statistical Package for the Social Sciences (SPSS) program. Students are given pretest and post-test about the critical thinking skills. The results of the t-test can be seen in Table 1.

![Figure 3. Students’ Responses of Virtual Laboratory](image1)

![Figure 4. Students’ Responses of Student’s Worksheet](image2)

**Table 1. The Result of Paired Sample T Test**

| The School | Mean | Std. Deviation | 95% Confidence Interval of the Difference | t | dF | Sig.(2-tailed) | Conclusions |
|------------|------|----------------|------------------------------------------|---|----|----------------|-------------|
|            |      |                | Lower | Upper |     |                |             |
| SMK A      | 20.667 | 13.309         | 25.636 | 15.697 | 8.505 | 29 | 0.000 | Significant |

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From Table 1, to see if there were differences in the use of VLSW in the three schools, it was necessary to observe the Sig. (2-tailed). At SMK A the value was 0.000; SMK B was 0.000 and SMK C was 0.098. Sig. (2-tailed): probability/p-value of the t paired test result = 0.000. Meaning there was a difference between before and after using VLSW. Because p value > 0.05 (95% confidence). There were significant differences between before and after electrochemical learning using VLSW. While in the SMK C sig. (2-tailed) > 0.05 there was no difference before and after electrochemical learning using VLSW.

4.2. Discussion
The development of a virtual laboratory with student’s worksheets or VLSW was done. The existence of student’s worksheets provides work procedures for using virtual laboratories. This is in line with research that students were overall satisfied with various aspects of the procedural guidance such as the simplicity and understand ability of the instructions, its conversion into physical actions, and experiment performance in virtual laboratory without the teacher’s help [16].

In the electrolysis cell scheme, equipped with a voice description that can be switched on or off depended on their need. By using this VL students could repeat whenever they want until they became aware of the material presented. After understanding the explanation, students applied it in a practicum using VL and pour the results of the practicum on the student worksheet. The guidance given was minimal so that the students able to analyze and conclude on their own. This will certainly improve students’ critical thinking skills. Using VL made the students doing experiments focus on experimental process. There was not on the equipment and tools as it is the case for physical labs, and follow the process more closely and at the same time enjoy themselves.

The SW prepared are used so that students can practice chemistry using VL. The instructions provided are made efficiently as possible. Detailed instructions will make students work according to instructions. However, if given a little guidance and questions, the ability to analyze, evaluate, explain and conclude will be formed. The sample of instructions in the SW are: (1) Open the electrochemical virtual laboratory application; (2) Select the Voltaic cell scheme menu. What is observed from the voltaic cell chart! (3) after you understand voltaic cells, please move to the potential standard electrode menu. Do an Experiment and write down your observations on the Student Worksheet. With such instruction, students will practice critical thinking. They will find a solution using a virtual laboratory.

The implementation of VLSW could improve the critical thinking skills of high and middle vocational school students. The increased critical thinking skills appear in the ability of interpretation, analysis and conclusion. This can be observed by the result of student’s worksheets. Students who use VLSW are able to write conclusions correctly and quickly. After studying metal coating using the VL, the student declared more understand the process. It was easier to understand the macroscopic, sub microscopic and symbolic presentations. The VL was able to integrate chemical representations. The students were able to link macroscopic, sub microscopic, and symbolic representation. The visualizations that existed in the VL provided an understanding effect on metal coating. According to previous researchers, virtual lab was more effective than classes without using visualization equipment [6]. The electrochemical abstract section can be answered using VL. They can work on SW with the practice of using VL, but the worksheets provided were less interesting. Worksheets provide fewer challenges for students. Most students confirmed that VL helps them to understand chemical electrochemistry deeply. Students also confirmed they prefer VL to the textbook method. Virtual laboratory software’s can be used as a supportive tool in real labs or as an alternative lab where there is not an available physical lab. or conditions of the physical lab are insufficient [7].

The SMK A represents a vocational school as high category, SMK B represents a middle vocational school and SMK C represents a low vocational school. This categorization is based on the value data of UN/US 2016/2017. This was occurred due to differences in students’ abilities from those three
schools above, the input of students from A and B had a higher ability than C. In addition to the different student input, this might be due to the different learning process, the condition of the infrastructure, and the school environment. From the discussion above, it can be concluded that VLSW can be used in vocational schools in Surakarta with high and middle school. However, for the low category, VLSW SMK can be used as an electrochemical learning media. Students were easier to understand electrochemistry by using VLSW. Further researches were needed on other vocational schools in Solo to prove whether that VLSW can only be used to improve critical thinking in high and medium category schools.

5. Conclusion

The Virtual laboratory and the student worksheet (VLSW) was developed. Aiken test’s result showed 0.94 for virtual laboratory and 0.90 for student worksheets. Therefore, virtual laboratory and students worksheets can then be used in electrochemistry learning. The average of the students' response to content, presentation, language, and the chart was 92%, while student worksheets were 87%. Students responded as they were easier to understand electrochemistry by using VLSW. Paired Sample Test showed the VLSW can improve the students’ critical thinking in SMK A and B. Development of learning media on other chemical concepts is needed to improve students' critical thinking skills.

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