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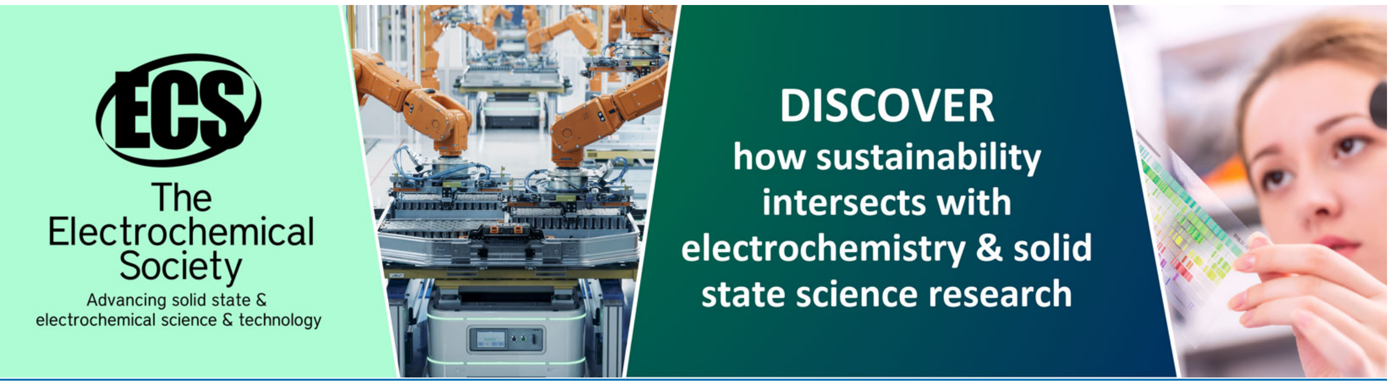

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Virtual chemistry laboratory (virtual chem-lab): potential experimental media in hybrid learning

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Abstract. A laboratory has a very important role in learning chemistry. It facilitates the experimental activity which supports the students' understanding. The development of information and communication technology has provided an innovation known as the virtual laboratory. This study aims to reveal the quality of virtual chemistry laboratory (virtual chem-lab) integrated into hybrid learning on chemical bonding. This research was a research and development study. The development procedure used in this study consisted of four stages: analyzing, product planning, product developing, and product assessing being adapted from the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) development model. The initial product of the virtual chem-lab was content validated by material and media experts. Product assessment was applied to 28 chemistry teachers, including content, learning quality, and technical quality aspects. The result of this assessment was descriptively analyzed to reveal the quality of the product. The findings of this study reveal that the quality of the virtual chem-lab integrated hybrid learning is in a good category. Thus, the virtual chem-lab is potentially used for further teaching-learning.

1. Introduction

The chemistry learning process is not only limited to studying theories or concepts, but is supported by experiment to prove or develop theories that are studied. Experimental activities are one of the important components in chemistry learning. These activities can generate motivation to learn, develop skills, and support understanding of the material [1]. Unfortunately, experimental activities in schools have not been carried out optimally. Studying chemistry requires a lot of time, because too much materials must be learned [2]. However, the allocation of time provided is very limited. In Indonesia the allocation of time for chemistry subjects in class X is three hours per week, while in class XI and XII there are four lessons per week. Moreover, learning activities are often disrupted by school activities outside learning and commemorating national holidays. This time limitation caused a lack of practical work in schools because the time available was used up to deliver the material.

Unlike other sciences that study macroscopic objects, chemistry tends to study microscopic objects. Most of the material in chemistry subjects is abstract. Objects in chemistry such as atoms, molecules, chemical bonds cannot be seen directly [2] so the imagination ability to understand these objects is essential. This causes students to have difficulty in understanding the chemical materials. Therefore, it is necessary to develop an alternative learning media that can present the visualization of micro-chemical objects to improve the learning outcomes of students. The chemistry materials of grade X are very important material because it is the basis for learning the materials in grade XI and XII. One of the most important materials is chemical bond [3].

The use of information and communication technology is necessary to improve the efficiency and effectiveness of learning. However, it has not optimal, especially to overcome the obstacles faced in learning. In line with increasingly advanced technological developments, an alternative media needs to be developed to overcome the obstacles faced in the implementation of learning and practicum. The virtual chemistry laboratory is an alternative that can be prospectively used to overcome obstacles in the implementation of learning and practicum. This study, therefore, aimed to develop and to know quality of virtual chemistry laboratory (virtual chem-lab) integrated into hybrid learning on chemical bonding.

2. Methods

This study was research and development study. The development procedure used in this study consists of four phases including: analyzing, product planning, product developing, and product assessing which was adapted from the ADDIE development model [4].

2.1. Development Procedure

The analysis phase includes needs assessment, and identifying problems. The needs analysis phase was carried out to gather information about the background of the development of a virtual chemical laboratory. Information gathering was carried out through several steps, the first was reviewing the curriculum to find out the ideal standard of learning implementation. The next step, collecting information about the facts of the implementation of learning in school and the problems that arise in learning activities. Needs analysis was also carried out by analyzing literature related to chemistry learning and virtual chemistry laboratories. The information obtained was then analyzed and used as the basis for the development of a virtual chemical laboratory.

The product planning phase was carried out with the determined and compiled material presented in a virtual laboratory, developed the design of virtual chem-lab and instruments of product assessment. The product development phase was carried out through compiled content from the media in the form of an interactive simulation of practicum on the material of chemical bonding, 3-dimensional models, and tasks that would be published in the media, and developed virtual chem-lab. The virtual chemistry laboratory was developed using several programs namely Panotour Pro 2.5, Blender, Game Maker, and HTML-5. The product virtual chem-lab was packaged in web form. Before assessed by chemistry teacher the virtual chem-lab was content validated by material expert and media expert. The validation was done to review the initial product and provide input for the product. The results of the validation were used to improve the quality of the virtual chem-lab.

The validated virtual chem-lab was assessed by chemistry teachers to find out the quality of product. The assessment was applied to 28 chemistry teachers from public senior high schools and an islamic high school. Assessment results and input from teachers were used as a reference to improve the product so that the initial product was produced. Furthermore, the product was also tested the readability to senior high school students. Readability test was applied to five students to find out whether the media produced could be used by students.

2.2. Data Collection Instrument

Product assessment instrument was in the form of assessment sheet using a 4 points modification of Likert scale (very good to poor). The assessment sheet was validated theoretically by expert. The criteria of quality refers to various quality of computer, internet, and multimedia-based media [5-8]. The aspects measured in the assessment sheet include the content, instructional quality, and technical quality which was described into 20 indicators.

2.3. Data Analysis
To reveal the quality of virtual chem-lab, descriptive-quantitative analysis was used in this study. The result of product assessment were analyzed by categorizing into ideal rating category [9] as shown in Table 1. Meanwhile the suggestion from chemistry teachers was considered to product revision.

Table 1. Ideal Rating Category

Score Range	Category
Xi +1.8 SBi < χ	Very Good
Xi + 0.6 SBi < $\chi \leq$ Xi + 1.8 SBi	Good
Xi – 0.6 SBi < $\chi \leq$ Xi + 0.6 SBi	Fair
Xi – 1.8 SBi < $\chi \leq$ Xi – 0.6 SBi	Poor
$\chi \leq$ Xi – 1.8 SBi	Very Poor

Note: Xi = (ideal max score + ideal min score); SBi = (ideal max score - ideal min score); χ = average of assessment score.

3. Result and Discussion
The virtual chemistry laboratory (virtual chem-lab) on chemical bond has been successfully developed through this research development. Virtual chemical laboratory products can be accessed online using laptops, tablets or smartphones. The virtual chem-lab can be used as a substitute or supplement for experimental activities in a real laboratory. The home page of the virtual chem-lab application can be seen in figure 1. The main menu of the virtual chemistry laboratory consists of a menu of basic competencies, experiment tool introduction, material MSDS, experiments, and tasks.

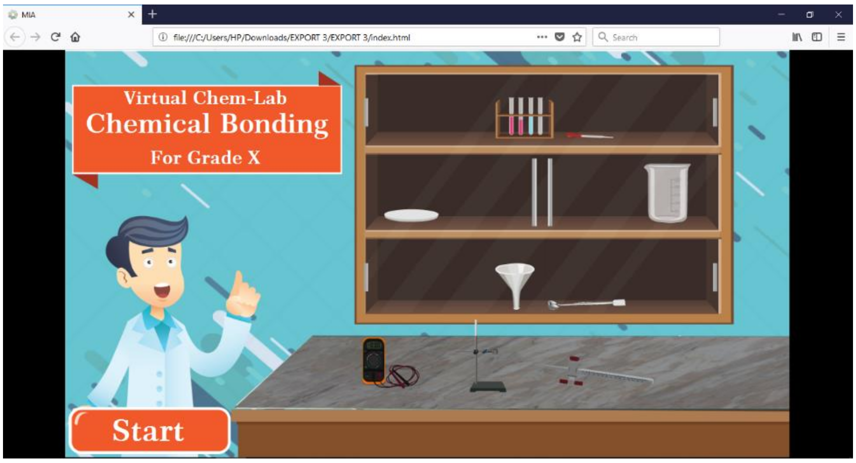

Figure 1. The Home Page Appearance

The basic competency menu contains basic competencies that must be achieved. The introduction menu of the tool contains a picture of laboratory equipment used in the practicum, complete with a description of the name and function of each tool. This menu aims to get students to know the tools used before doing the practicum. The material MSDS menu contains the ingredients used in the experiment supplemented with the MSDS, so the users know the ingredients used before doing the experiment. Thus users can understand the nature of the chemicals used and can be careful of the dangers that may arise from these materials.

The experiment menu contains four experiment, namely the determination of melting point of ionic and covalent compounds, the solubility of ionic and covalent compounds, the conductivity of ionic and covalent compounds, and the polarity of compounds. Each experiment was equipped with an experiment guide that includes objectives, tools, materials, and procedures. The display of practicum instructions can be seen in figure 2. In each practicum users could do an experiment simulation by clicking or moving the tool according to the instructions. While, the task menu contains two task packages that serve to measure students' understanding.

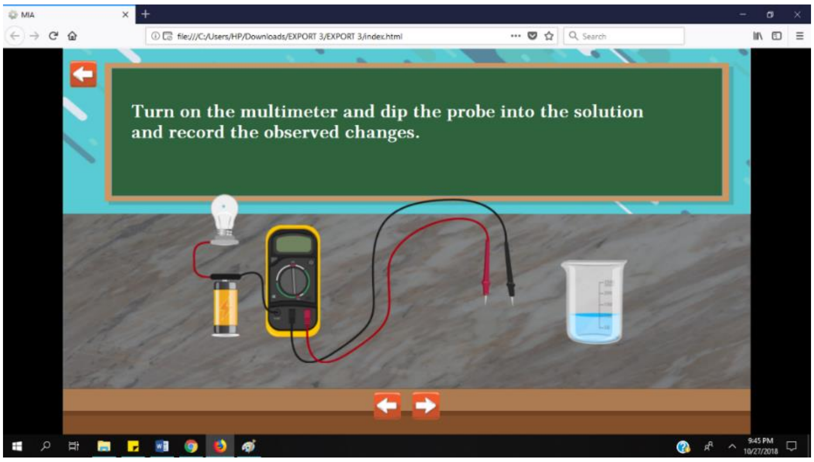

Figure 2. The Experiment Appearance

The initial product of the virtual chem-lab was validated by material experts and media experts. Based on the results of the validation, the virtual chemical laboratory products produced are suitable for use with revisions. Material experts and media experts also provide input to improve the product, as the followings. There were several writing errors that must be corrected. There were also errors in the results of the compound polarity experiment, wherein some compounds should not be deflected. The experts suggested to add more information or instructions and more navigation button so the users could easier to understand and operate. While comments and input from media experts were improving the process of loading from between pages, increase interactivity and add explanations to 3D models. The media expert suggested to fix the navigation buttons, because there is an error navigation button, more over the color composition was less able to adjust again between the background and the image objects.

In addition to being validated by experts, the product was also tested for readability to five students. The five students stated that they could operate a virtual-lab and understand enough the media content. Students were interested in using the media because it resembled a game. The students also provide input for added background music to make it more interesting and added more 3D models.

Product assessment was applied to 28 high school chemistry educators. Assessment covers three aspects, namely content, instruction quality and technical quality. These three aspects were described into 20 indicators. The assessment results for each aspect can be seen in table 2.

Table 2. The Result of Product Assessment.

Aspect	Total Score	Category
Content	16.68 (out of 20)	Good
Instructional Quality	30.16 (out of 36)	Good
Technical Quality	19.82 (out of 24)	Good

The material aspect consists of five indicators, the accuracy of content in a virtual chem-lab, content in a virtual chem-lab contains educational value, the content presented in virtual chem-lab is easily understood by students, the tasks given can be used to measure students' cognitive abilities, content in virtual virtual chem-lab is interrelated to clarify information delivery. In the aspect of content indicator material in the virtual chem-lab contains the value of education included in the very good category. While other indicators are in the good category. The average total aspect score is 16.68 from the maximum score of 20. The score is included in the good category with ideal percentage of

83.4%. Educators consider the content in the virtual chem-lab to be suitable to help form knowledge that resembles practicum in real laboratories. Contents in learning media should be easy to understand [7]. Based on teachers assessment, content in the virtual chem-lab is assumed to be easy to understand.

The quality aspects of learning were consist of nine indicators: compatibility of virtual chem-lab with the needs of current students, the virtual chem-lab can be used to support students in achieving learning objectives, the virtual chem-lab supports learning using hybrid learning communication modes, the virtual chem-lab motivates and attracts students, the virtual chem-lab helps the learning process of students, visual design of virtual chem-lab in accordance with users (teachers or high school students), the virtual chem-lab can stimulate students in practicing, the virtual chem-lab facilitates students to acquire new skills, simulation of experimental activities provides interactive learning opportunities.

All indicators on the quality aspects of learning are in the good category. The average total aspect score is 30.16 from a maximum score of 36. The score was included in good category. Virtual chem-lab were developed according to the needs of students and support the achievement of learning goals. Educators assumed the use of virtual chem-lab will motivate learners to help their learning process. The virtual chem-lab that could be accessed online will make it easier for users to repeat experiment outside of learning so that learning could be done more flexibly.

The third aspect was technical quality. The technical quality aspect consists of six indicators: the virtual chemistry laboratory program has relevance to the technology that is developing at this time, users can easily navigate practicum activities in virtual chem-lab, the combination of forms of visualization can be used to convey information, suitability between objects with the context in the practicum activities, suitability of the 3D model with the context in learning, the illustration shown in the virtual chem-lab is clear

In the quality aspect of the technical indicators the virtual chem-lab program has relevance to the technology that was developing at present in the very good category. While other indicators were in good category. The mean technical aspect score was 19.82 from a maximum score of 24. The score was also included in the good category. Along with the rapid development of technology, virtual chem-lab programs were very relevant to the technology that is developing today. Educators state that students tend to be enthusiastic about using technology-based learning media. Educators could use the product quite easily and the display inside was also quite clear. Objects and 3D models in virtual chem-lab were also in accordance with the context of learning and chemical practicum. Chemistry educators highly appreciate the existence of virtual chem-lab because their use was easy and educators do not need to prepare material tools when they want to practice.

In addition to providing assessments, educators also provide comments and input to improve virtual chem-lab products. Comments and input provided by educators were to added a summary of the material so that it could be used as a source of students' independent learning, color changes need to be displayed when there were two substances that were mixed which indicate a chemical reaction, the pointer button should change to another sign when highlighting clickable objects, added practice questions, we recommend adding videos to make it more interesting, temperature settings using English, should be changed to Indonesian, the display should be made more contrast between the background and objects in the media, there are still errors in writing and practical steps. Comments and input provided by material experts, media experts, educators, and students are taken into consideration in improving the virtual chemical laboratory products.

In general the total score obtained was 66.66 from a maximum of 80. The score was in the good category with an ideal percentage of 83.3%. The virtual chem-lab is potential to be used as experimental media. The virtual chem-lab is an alternative that can be used to overcome obstacles in the implementation of learning and practicum. The results of the Tüysüz [10] study show that virtual laboratories have a positive effect on the achievement and attitudes of students. The virtual chem-lab provides experimental simulations that can be accessed online so students can freely repeat simulations anytime and anywhere. It can enrich their knowledge. 3D models added in a virtual laboratory can visualize microscopic chemical objects, enriching students' knowledge and enthusiasm.

In addition, virtual chemistry laboratories encourage and motivate students to gain deeper and wider knowledge [11] which encourages discussion in the online phase.

The virtual chem-lab is potential for further use. Research conducted by Hawkins and Phelps [12] shows that the use of virtual and traditional laboratories provides relatively similar learning outcomes in electrochemical learning, so that virtual laboratories can be used instead of laboratories. Similar results were also expressed by Tatli and Ayas [13] which stated that virtual chem-lab–applications were as effective as the real labotorium seen from learning outcomes and the ability of students to recognize laboratory tools. According to the results of Arista and Kuswanto [14] virtual chem-lab can even improve students' learning independence and conceptual understanding.

The virtual chem-lab was designed to can be implemented using hybrid learning that combines online and face-to-face learning. Learning that combines face to face and online also influences learning outcomes. In accordance with the results of research by Means, Toyama, Murphy, and Baki [15], hybrid learning has a significant effect on learning outcomes. According to Dale [16], direct and imitation experience of learning will be more effective because more messages can be absorbed. However, several problems made students could not do the experimental activity. The virtual chem-lab can give experimental experience even tough students do not do experimental work directly in the hands-on lab.

4. Conclusion

The virtual chem-lab on chemical bond material has been successfully developed as an experimental media. Based on the assessment of chemistry teachers it was found that the quality of the virtual chem-lab integrating hybrid learning was is in a good category. Thus, the virtual chem-lab is potential for further use.

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Acknowledgments

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