Development of Virtual Laboratory for Chemical Kinetics

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Abstract. This study aims to develop a virtual laboratory for the chemical kinetics subject. This research is a Research & Development which refers Borg and Gall model which has been modified until the product validation stage. The instrument used in the study was a research data collection questionnaire, media and material expert validation questionnaire. The resulting product is a virtual laboratory developed using the Java programming language and student worksheets. The validation results in terms of material have a percentage of 97.22% and terms of media have a percentage of 94.31%. This research is expected to provide innovations in the use of virtual laboratories to create an interactive learning atmosphere for students.

Keywords: virtual laboratory, development, chemistry practicum

1 Introduction

Chemistry is a complex science, as much of the knowledge in this field relates to the molecular level, and students are expected to think on a molecular scale to explain phenomena on a macroscopic scale [1-3]. Therefore, learning practical chemistry in the laboratory cannot be separated from learning chemistry theory. Practical work in the laboratory (practicum) is a way for students to build an understanding of chemical concepts with practical experience with chemical tools and materials [4].

During the COVID-19 pandemic that is still engulfing the world, practical chemistry learning is a part of chemistry learning that is significantly affected. Skills that should be learned through practice in the laboratory are hampered because learning is done online. Practical learning of chemistry must adapt to online learning situations without reducing the meaning and skills to be achieved from the learning. One of the solutions for chemistry practicum in online learning is the use of a virtual laboratory.

A virtual laboratory is a new generation of computer-based chemistry learning [5]. Initially, a virtual laboratory was developed to solve problems encountered in conventional chemistry practice classes, namely practicums involving explosive and dangerous chemicals [6]. A virtual laboratory is a program that contains the same laboratory materials as a real laboratory [7]. Students can do practicum independently as if they were in a real laboratory[8]. The virtual laboratory is seen as a new approach in learning practical chemistry that is cheaper in terms of tools, materials and preparation time but still attracts students' interest. The virtual laboratory is seen as a new pedagogy for teaching in particular for enhancing students critical thinking and helping financially challenged institutions [9]

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Virtual laboratories also have the potential to increase student motivation in learning chemistry [10]. Chemistry learning with virtual practicum is learner-centered and inquiry-based that supports higher-order thinking skills and meaningfulness in chemistry learning [6]. Virtual laboratories have the potential to increase student motivation in learning chemistry. Chemistry learning with virtual practicum is learner-centered and inquiry-based that supports higher-order thinking skills and meaningfulness in chemistry learning.

Chemistry practicum learning with a virtual laboratory will be created using the Java programming language. The Java programming language was chosen because it is straightforward and platform-independent [11]. This study aims to develop a virtual reaction kinetics practicum to overcome the limitations of practical work in the laboratory due to online learning situations. This research is also expected to know the motivation of students in learning chemistry practicum through a virtual laboratory.

2 Research Method

This is a research and development (R&D) that aims to develop a product using modified Borg and Gall [12]. The development steps carried out in this study are presented in Figure 1.

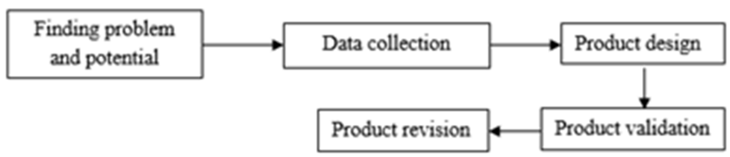

Fig 1. Research model modified from Borg and Gall

Finding problem and potential and data collection were conducted questionnaire. Need analysis was performed at this stage to find the information related to learning conditions in practical laboratory work for the chemical kinetics subject. The product design was conducted by the concepts and material substance in chemical kinetics for the development of a virtual laboratory in chemical kinetics. The title of chemistry practicum developed in this research is Factor that Affects the Reaction Rate.

The design of the virtual laboratory was developed Microsoft Office PowerPoint and was converted for interactive virtual laboratory using Java programming language. The product was validated by two lecturers in the Chemistry Education Study Program, Sanata Dharma University in terms of material and media. The quality of the virtual laboratory was assessed based on the validation of results in terms of material and media. The data analysis was performed by categorizing it into the validity rating category [13, 14].

$$P = \frac{f}{N} \times 100\%$$

P = percentage
f = score from validator
N = maximal score

The average percentage then is calculated, and the result was compared with the validity rating category.

Table 1. Validity Rating Category

Percentage	Validity
81% - 100 %	Very Good

61% - 80%	Good
41% - 60%	Fair
21% - 40%	Poor
≤ 20%	Very Poor

3 Result and Discussion

The first stage of this research is a need analysis that includes the identification of potentials and problems as well as data collection. Identification of potentials and problems is carried out using descriptive analysis of the results of student responses questionnaires related to the implementation of online practicums as well as the reflection of the lecturers of chemical kinetics subject [15]. The need analysis was conducted by involving the students of the Chemistry Study Program of Sanata Dharma University. During the online course, the practicum in chemical kinetics was conducted using videos uploaded in the YouTube channel of the Chemistry Study Program of Sanata Dharma University.

The important aspects contained in the questionnaire are as follows:

a. Effective use of practicum videos
b. Weaknesses of using practicum videos
c. Difficulties experienced by students in online practicum

Based on the results of the questionnaire, as many as 55% of students answered that the implementation of practicum through video was quite effective. The reason given by the students was because the video was easy to access and could be played back if there was an unclear practicum procedure. In addition, students thought that practicum using video was the right solution during the Covid-19 pandemic. As many as 5% of students consider the use of practicum videos to be ineffective. This is related to the preparation of practicum reports. Students have difficulty in writing practicum reports only based on observations from videos. Careful observation is difficult. Students think that practicum should be practiced directly in the laboratory. The long video duration also makes students feel bored. On the other hand, some students think that the duration of the video in the reaction phenomenon section is too short.

Based on the results of the questionnaire, as many as 91.7% of students considered the unobservable reaction phenomenon to be one of the weaknesses of using practicum videos. Students feel that they do not get a clear picture of the phenomena that occur during the practicum, for example, changes in the reactions of the compounds being tested. The phenomenon of gas formation after the reaction takes place is difficult to observe. As many as 68.3% of students considered that another weakness of using practicum videos was not sharpening their practical skills. The results of the questionnaire showed that as many as 85% of students quite understood the entire implementation of the practicum through video, and only 15% of students understood the practicum. Students think some work procedures are difficult to understand.

Preliminary studies are also based on the results of reflections carried out by practicum lecturers. The results of the reflection stated that there were several obstacles in the use of practicum videos. The difficulties are also experienced when explaining the reaction phenomena that occur. Many important phenomena that arise when chemical reactions occur, cannot be conveyed properly to students. The use of practicum videos also reduces students' skills in carrying out practical's. Students cannot directly experience the use of laboratory equipment, preparation of practicum materials, implementation of work procedures, to observing reaction phenomena. This of course reduces the real meaning of practicum. Based on the identification of problems and the results of reflection, a virtual laboratory is needed that can overcome the problems experienced by students. As many as 86.7% of students have never used a virtual laboratory. This is a good opportunity to introduce virtual laboratories to students. According to 80% of students, this virtual laboratory can overcome the limitations of practicum implementation during online learning during the Covid-19 pandemic. This is supported by [16]

The first step in developing a product is to design a virtual laboratory display. The design of virtual laboratory display was developed Microsoft Office PowerPoint. The design then was converted for interactive virtual laboratory using Java programming language. The main components in the virtual laboratory are a) Title; b) Initial Information and Trial Objective; c) Theoretical background; d) Observation Data Form, and e) Start Practical Work. Several screenshots from the virtual laboratory design are depicted in Figure 2 – 9. Figure 2. is the main page of the virtual laboratory. The students can click the play button (main button in the middle) when they are ready. Figure 3 shows the initial information menu of virtual laboratory.

Fig 2. Main Page View of Virtual Laboratory

Fig 3. Initial Information Menu

Figure 4. depict the observation data form that can be downloaded by the students so they can write the observation data while conducting the practicum. The beginning of practicum is the aim of the practicum depicted in Figure 5. For the theoretical background of the practicum, it is shown in Figure 6 that the students can read the theory before starting the practicum, so they understand the fundamental theory for conducting the practicum.

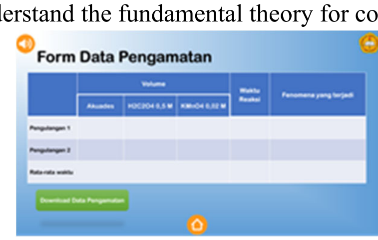

Fig 4. Observation Data Form

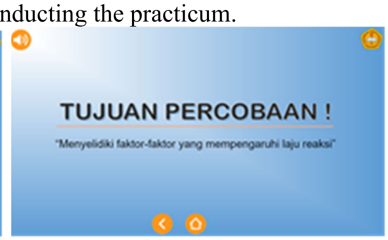

Fig 5. The aim of the practicum

Fig 6. Theoretical Background

Before starting the virtual laboratory, it is showed the practicum video made by Chemistry Education Study Program, Sanata Dharma University. This video can give the students a better understanding of the practicum about the overall procedures of Factor that Affect the Reaction Rate which is depicted in Figure 7. The chemicals and glassware for practicum are shown in Figure 8.

Fig 7. Practicum Video

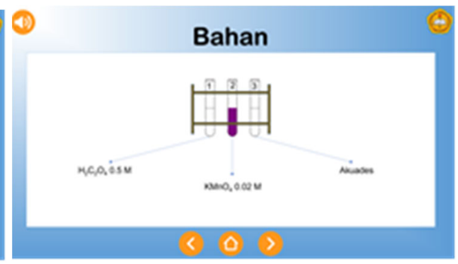

Fig 8. Chemicals for practicum

The practicum procedure is shown in Figure 9. There is an instruction procedure that leads the user for conducting a practicum. The user can use drag and drop to practice and follow the instruction procedure. The phenomenon of reaction will show while the user conducting the practicum. The observation data of practicum can be written in the observation data form that can be downloaded in the initial information menu. By interacting and actively conducting practicum using virtual laboratory, it is expected the students understanding and scientific skill increase than using usual practicum video. After conducting the practicum, ten questions can be answered as a posttest evaluation for students. The comprehensive virtual laboratory is developed for also evaluating students' understanding after conducting the practicum.

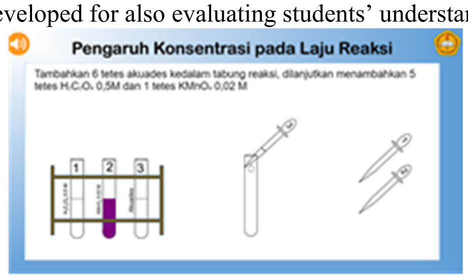

Fig 9. Practicum procedure

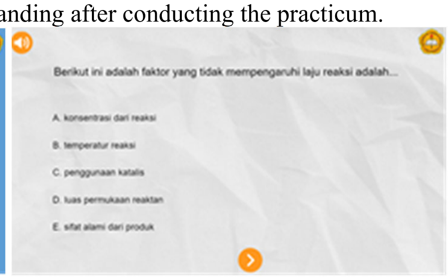

Fig 10. Quiz after practicum

The product that has been developed was validated by two material validators and two media validators. The validators are lecturers at the Chemistry Education Study Program, Sanata Dharma University. The validation result in terms of material is presented in Table 2. The validation aspects include 1) relevance of the material to the syllabus; 2) material quality; 3) systematics of material presentation, and 4) aspects of language and writing. The average percentage for validation in term of material have an average percentage of 97.22% which is very good. The validators stated that the material inside the virtual laboratory is already following the syllabus.

Table 2. Validation Results in Term of Material

No	Aspects
1	Relevance of the material to the syllabus

2	Material Quality
3	Systematics of Material Presentation
4	Aspects of Language and Writing
	Average percentage = 97.22%

The validation results in terms of media are presented in Table 3. The aspects of validation are 1) function and advantages; 2) visual media aspects; 3) audio media aspects; 4) language aspects; 5) writing aspects; 6) programming aspects. The results of validation in term of media got an average percentage of 94.31% which indicates that the product is very good and feasible.

Table 3. Media Validation Results

No	Aspects
1	Functions and Advantages
2	Visual Media Aspect
3	Audio Media Aspect
4	Language Aspect
5	Writing aspect
6	Programming Aspect
	Average percentage = 94.31%

The suggestions from the validator are used to improve the product. A few comments from validators are 1) the improvement of the drag and drop menu; 2) the addition of the home button; 3) making a slower transition for the chemical phenomenon of changing colour. The suggestion from validators will be considered for the revision of the virtual laboratory.

4 Conclusion

The development of a virtual laboratory in chemical kinetics for the topic Factor that Affects the Reaction Rate has been successfully developed. The product has been validated by validators in terms of material with an average percentage of 97.22% with very good criteria. The validation result in terms of media gets an average percentage of 94.31% with very good criteria. This virtual chemistry laboratory has the potential for further use of chemistry learning.

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