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Enhancing Students' Understanding and Motivation During Covid-19 Pandemic via Development of Virtual Laboratory

Agung Panji Sasmito[1], Putri Sekarsari[2]

[1]*Institut Teknologi Nasional Malang, Indonesia, ORCID ID: 0000-0002-0368-8440*
[2]*Politeknik Negeri Malang, Indonesia, ORCID ID: 0000-0003-3033-2180*

ABSTRACT
One of the obstacles that occur in Chemistry learning is low student motivation due to monotonous media. Another thing that currently becomes an obstacle is the Covid-19 pandemic which limits face-to-face learning. However, Chemistry practicum learning in the laboratory is difficult to carry out at students' homes. The purpose of the study is to develop a virtual laboratory, the validity and effectiveness of which are measured, to increase students' understanding and motivation in Chemistry, the topic of exothermic and endothermic reactions. The 4D model is used in the development of learning media in the form of a virtual laboratory. The validity of virtual laboratory products is confirmed by media experts and material experts in their fields. Product effectiveness was measured using a posttest-only control group design with two groups of students involving 63 students. Data collection was carried out through questionnaires, tests, and interviews, with descriptive analysis for the results of validation of the learning media and pilot test and t-tests for testing the effectiveness of virtual laboratories. The results showed that the virtual laboratory is easy to use and has feedback at the end of the practicum simulation so that the virtual laboratory can be applied as a valid and effective learning media in increasing student understanding and motivation.

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Learning media, virtual laboratory, exothermic and endothermic reactions, effective learning, motivation.

Introduction

The development of technology and expertise in various fields of life demands the development of science and innovation in today's digital era (OECD, 2019; Hanna, 2018; Wiesböck & Hess, 2018). Today, chemistry is one of the most popular science which always develops (Borchardt *et al.*, 2018; *Future of the Chemical Sciences*.). The development is not only in the field of pure chemistry but also in the realm of chemistry education from school to university (Kinnunen et al., 2016; Kubiatko, 2015; Lay & Osman, 2018).

Chemistry learning not only requires improvement in critical and analytical thinking skills but also needs innovation (Irwanto et al., 2017; Sari et al., 2017; Suardana et al., 2018). The learning process is one of the focuses of developing learning technology, one of which is technology-based learning (Ghavifekr & Rosdy, 2015). Currently, ICT-based learning is one of the trends in society in addition to attention to classroom learning (Hernandez, 2017; Hernández & Chalela, 2017).

One of the obstacles that occur in chemistry classroom learning is that the student motivation is low (Olakanmi, 2016; Orvis et al., 2018). This is due to monotonous media, as a result, students become easily bored and less motivated to learn chemistry by textbook-based learning or other conventional methods (Rahmawati et al., 2019; Yusuf, 2017). Another thing that currently becomes a barrier in face-to-face learning is the Covid-19 pandemic (Mailizar et al. et al., 2020; Sharifov, 2020). As a result, students have to study material online, while chemistry learning which is often related to laboratory practice will greatly depend on the quality of the practicum learning (Heliawati & Rubini, 2020; Lestiyanawati & Widyantoro, 2020; Imaduddin & Hidayah, 2019).

Face-to-face limitations in the era of the Covid-19 pandemic have made it difficult for learning to be carried out face-to-face (Sari *et al.*, 2020; Yüzbaşıoğlu *et al.*, 2021). This includes laboratory practicum learning which is difficult to carry out at students' homes (Lansangan, 2020; Wahid et al., 2020). This can be overcome with virtual laboratories that allow practicum simulations in learning media. However, currently, there are still few virtual laboratories, especially for chemistry subject matter (Blackburn et al., 2019; Faulconer & Gruss, 2018).

The explanation above inspires the author to develop innovative learning media to be able to increase students' motivation and understanding of chemistry subjects. Therefore, this research aims to make learning media innovations in the form of virtual laboratories that can increase students' understanding and motivation to learn chemistry learning materials whose validity and effectiveness are measured.

Research Question and Hypothesis

The research question of this paper is: "How is the effectiveness of virtual laboratory to increase students' understanding and motivation in studying chemistry, the subject of Exothermic and Endothermic Reactions?". The answers to this research question can be revealed by measuring the difference between the understanding of students who learn chemistry material using conventional teaching material and students who use a virtual laboratory. Therefore, the research hypothesis can be formulated as follows.

H_0: The use of a virtual laboratory is not effective for increasing students' understanding and motivation of chemistry material.

H_a: The use of a virtual laboratory is effective for increasing students' understanding and motivation of chemistry material.

The hypothesis is measured by calculating the significance of differences in the understanding of students who use conventional teaching materials with those of students who use virtual laboratories. If there is a significant difference and the students' mastery of understanding using virtual laboratory is higher than students' mastery of understanding using conventional teaching material, then the virtual laboratory is said to be effective.

Conceptual Framework

Virtual Laboratory

A virtual laboratory is a set of computer programs that can visualize complex phenomena that are generally carried out in real laboratories (Syahfitri *et al.*, 2020). The virtual laboratory offers a conducive learning environment that students can visit to learn at their own pace (Rohim, 2020). The advantage of a virtual laboratory is that students can learn objects that cannot be presented in class (Bima et al., 2021), including online classes during the Covid-19 pandemic.

A virtual laboratory can improve learning activities by integrating ICT (Syahfitri *et al.*, 2020). In addition, one of the advantages of a virtual laboratory is the possibility of learning in limited facilities and infrastructure (Bima *et al.*, 2021). Therefore, the virtual laboratory is useful for students to create and carry out simulated experiments by improving the perception and interpretation of the phenomena studied through the virtual laboratory (Salmerón-Manzano & Manzano-Agugliaro, 2018).

Studies about Virtual Laboratory in Science Education: Research in science education today tends to shift to the integration of ICT in learning. One of the focuses of this research is the effectiveness of using ICT-based devices in learning, including the use of virtual laboratories.

A study (Hamed & Aljanazrah, 2020) examined the effectiveness of virtual experiments in the physics laboratory. This research stems from the debate on the use of virtual laboratories that can replace performance in real laboratories. The results of the study show the effectiveness of using virtual experiments and supporting learning during Covid-19.

Another study (Faour et al., 2018) investigated the effect of using a virtual laboratory in studying electrical circuit materials. The research was carried out by comparing learning using a virtual laboratory with learning using simulation. The results showed that the group that studied with a virtual laboratory had better results.

Another study (Miyamoto et al., 2019) stems from the assumption that the laboratory class has a crucial role in science learning as well. A virtual laboratory is one of the findings that can improve learning activities and improve performance. The results showed the effectiveness of using a virtual laboratory in Biology learning.

The various research findings above imply the positive role of virtual laboratories in improving the quality of learning. Therefore, in terms of theoretical research, this paper can produce findings on the effectiveness of using virtual laboratories in chemistry learning.

Methods

The R&D model used in this study is the 4D model with steps including Define, Design, Develop, and Disseminate. (Sutarti & Irawan, 2017; Thiagarajan et al., 1995). The representation of these steps can be seen in Figure 1.

Figure 1

4D Research and Development Flow

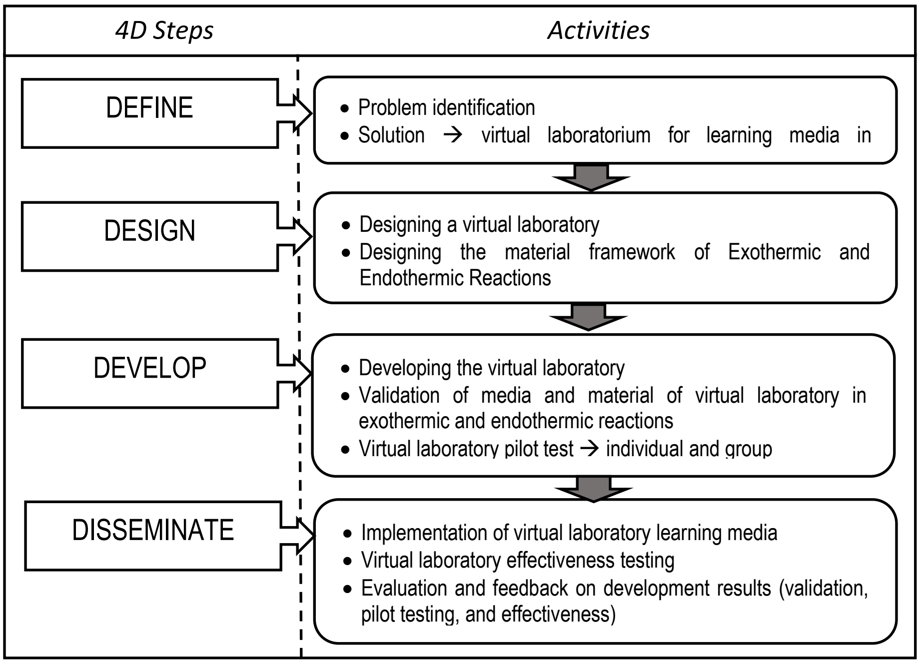


Figure 1 can be explained as follows. The Define stage is marked by defining the requirements of learning from concept analysis and formulating learning objectives (Thiagarajan *et al.*, 1974; Sutarti & Irawan, 2017; Willis, 1995). This stage is in the form of problem identification as described in the introduction and a solution is produced in the form of a virtual laboratory for learning media. The formulated learning objectives are to increase students' understanding and motivation in using learning media in the form of virtual laboratories. The Design stage is the preparation of a prototype for learning media products in addition to the preparation of a material framework and the selection of media in accordance with the learning objectives (Thiagarajan *et al.*, 1974; Sutarti & Irawan, 2017; Willis, 1995). This step is marked by designing the storyboard in addition to the design of the Exothermic and Endothermic Reaction material frameworks. The Develop stage is the development of learning media products, which includes device validation, simulation, and pilot testing (Thiagarajan *et al.*, 1974; Sutarti & Irawan, 2017; Willis, 1995). In the Develop stage, a virtual laboratory is developed using Adobe Flash in accordance with the learning media storyboard and material framework. After that, the virtual laboratory learning media was tested for validity by media experts and material experts. The Develop stage ends the virtual laboratory pilot test with individual and group tests. The Disseminate stage is characterized by the use of media on a wider scale and testing the effectiveness of the learning media being developed (Thiagarajan *et al.*, 1974; Sutarti & Irawan, 2017; Willis, 1995). Through the Disseminate stage, virtual laboratory learning media are implemented to students and their effectiveness is measured. At the end of the Disseminate stage, evaluation and feedback are carried out on the results of the development (validation, pilot testing, and effectiveness).

This research uses a mixed-method approach by combining a quantitative approach and a qualitative approach. The quantitative approach is used to calculate the validity and testing process, as well as the effectiveness of learning media in the form of a virtual laboratory obtained from different tests on students' mastery of understanding using conventional teaching materials and students' mastery of understanding using virtual laboratories. The qualitative approach is used to strengthen the findings of the effectiveness of the virtual laboratory by extracting the opinions of teachers and students using the virtual laboratory.

Each research approach has its own instrument to collect each data (Creswell, 2012; Morell & Carroll, 2010). The data collection techniques used in this article are questionnaires, tests, and interviews. The questionnaire was used in the development stage, namely in the validation and testing process to be able to determine the feasibility of the media, the validation of the learning material on the media, and students' interest in the media that had been developed. The instrument used in this study was a questionnaire sheet with 4 Likert scales, including (1) very poor or very inappropriate; (2) bad or inappropriate; (3) good or decent; and (4) very good or very feasible (Aini et al., 2018; Chyung et al., 2017; Simons et al., 2017). The questionnaire used refers to the aspects and criteria for assessing learning media including aspects of the application in software, learning design, and visual communication (Wahono, 2006). The framework of the questionnaire is shown in the Table 1.

Table 1

Questionnaire Framework

No.	Aspect	Indicators
1.	Application in Software	a. efficiency b. reliability c. usability
2.	Learning Design	a. clarity of learning objectives b. the suitability of the material with the learning objectives c. material depth d. interactivity e. giving the motivation to learn f. completeness and quality of media g. easy to understand h. clarity of description and discussion in practical simulation
3.	Visual Communication	a. communicative b. audio component c. visual component d. mobile media e. interactive layouts f. creativity

The assessment criteria of questionnaires are obtained from the average value of these aspects, by: (1) if the average value is in the range of 1.00 to 1.75, the learning media is very invalid and prohibited to use; (2) if the average value is in the range of 1.76 to 2.51, then the learning media is invalid and needs major improvement; (3) if the average value is in the range of 2.52 to 3.27, then the learning media is valid and needs minor improvement; and (4) if the average value is in the range of 3.28 to 4.00, then the virtual laboratory is very valid and very feasible to be used as a learning media.

The test is used at the disseminate stage to measure the effectiveness of the virtual laboratory. The effectiveness of learning media in the form of a virtual laboratory was measured using a posttest-only control group on the results of the material comprehension test for 63 high school students which were divided into two groups, namely: (1) control group, with learning using video tutorial teaching materials that have been implemented conventionally during the Covid-19 pandemic; and (2) experimental group, using virtual laboratory learning media that has been developed. The control group will receive material related to Exothermic and Endothermic Reactions through demonstration learning videos that have been provided on YouTube and e-learning. The experimental group will be given a virtual laboratory file to be used as learning media independently on each student's computer. Learning takes one week of effective meetings. After the implementation of learning in each group, a material comprehension test was carried out in each group which contained measurements of students' mastery of the exothermic and endothermic reactions material. The data obtained will be analyzed using an independent sample t-test (5% significance) using IBM SPSS Statistics 25. If sig $\leq \alpha$ (5%) it is concluded that there is a significant influence between the use of virtual laboratories on student understanding. (Derrick et al., 2017; Gerald, 2018).

Interviews are used at the dissemination stage to measure student learning motivation based on students' perceptions of using virtual laboratory learning media. Interviews were carried out via WhatsApp chat and voice calls to several students who had used virtual laboratory learning media that had been developed. The questions used are: (1) How is the learning of chemistry subjects that have been given?; (2) What are the obstacles experienced?; and (3) Are you more motivated to learn by using a virtual laboratory?

Justification related to instruments validity involves an expert judgment process (Geisinger et al., 2012: 197; Yarnall & Ostrander, 2012: 286). The number of experts involved is two as suggested by the rules (LeCompte & Aguilera-Black Bear, 2012: 616).

Findings

This section presents the results and discussion of the 4D steps according to the flow in Figure 1.

Step 1: Define

The Define stage is carried out by identifying the problem as described in the introduction. It is known that students find it difficult to study chemistry subject matter. This is exacerbated by the low motivation of students in studying Chemistry, in addition to the learning process that was difficult to carry out during the Covid-19 pandemic. One of the reasons for this is the lack of innovative and easily accessible learning media for students, especially for practical learning. So far, the only learning media available are text-based teaching materials and eBooks, in addition to video tutorials uploaded by teachers to the YouTube site.

The solution offered to this problem is the development of learning media in the form of a virtual laboratory which is expected to measure its validity and effectiveness. The learning objectives formulated from this condition are to increase students' understanding and motivation in using learning media in the form of virtual laboratories.

Step 2: Design

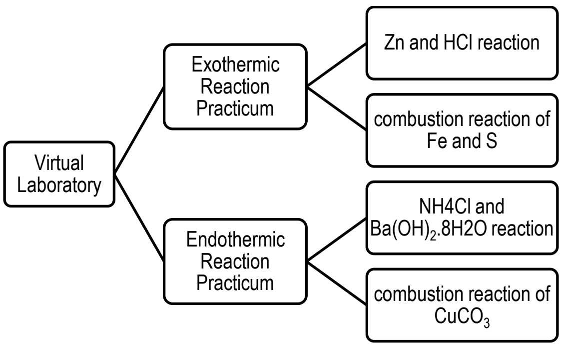
The learning media design in the form of a virtual laboratory has a design framework and material framework based on the expected final abilities along with indicators and competency mapping from the syllabus of Exothermic and Endothermic Reaction materials to be integrated into a virtual laboratory form.

Exothermic and Endothermic Reactions are concerned with bond breaking, energy requirements, and the formation of chemical bonds releasing energy respectively (Chinaka, 2021). A reaction is said to be exothermic if it produces heat, while a reaction that absorbs heat from the surroundings is called an endothermic reaction (Poulsen, 2010). An exothermic reaction is indicated by a negative value of ΔH, while an endothermic reaction is indicated by a positive value of ΔH (Go *et al.*, 2020). Several examples of exothermic reactions are: (1) Zn and HCl reaction; and (2) combustion reaction of Fe and S, and the endothermic ones are: (1) NH4Cl and Ba(OH)2.8H2O reaction; and (2) combustion reaction of CuCO3.

Based on the instructional analysis of the syllabus, the virtual laboratory material framework is shown in Figure 2.

Figure 2

Virtual Laboratory Material Content Framework

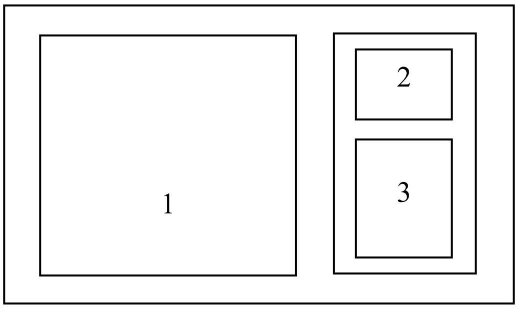


Based on Figure 2, it is known that in general the virtual laboratory learning media developed has 2 main menus, namely: (1) exothermic reaction practicum; and (2) endothermic reaction practicum. Each menu contains 2 reactions simulated in a virtual laboratory, namely: (1) for exothermic reaction practicum there are practicum simulations of (a) reactions of Zn and HCl; and (b) the combustion reaction of Fe and S; whereas (2) for the endothermic reaction practicum there are practicum simulations of (a) reaction of NH_4Cl and $Ba(OH)_2.8H_2O$; and (b) the combustion reaction of $CuCO_3$. At the end of each simulation, there are questions related to the practicum that has been simulated accompanied by feedback to the user.

The material framework will be developed into learning media in the form of a virtual laboratory. The design of a virtual laboratory framework in the form of a learning media storyboard is shown in Figure 3.

Figure 3

Virtual Laboratory Storyboard



The storyboard in Figure 3 can be explained as follows. The virtual laboratory has 3 basic parts. Part 1 is a virtual laboratory panel that displays practicum simulations. Part 2 is the status panel, including name and score. Part 3 is the navigation panel and tools of the virtual laboratory, which includes buttons to access the level of each practicum, save the progress of the practicum, a button to return to the beginning page, a setting button from the virtual laboratory, a help button, and a button to close the virtual laboratory.

Step 3: Develop

The virtual laboratory that has been created will be integrated into learning media using Adobe Flash CS5 with the target output for Action Script 2.0 and can be uploaded to the website or distributed via Google Drive to run on students' PC. The virtual laboratory screenshot is shown in Figure 4.

Figure 4

Virtual Laboratory Screenshot

Figure 4 shows that the learning media has a virtual laboratory appearance starting from taking tools and materials to practicum simulations on two exothermic reactions and two endothermic reactions. At the end of the practicum simulation, there is feedback on students' mastery of the material through questions related to exothermic and endothermic reactions according to the simulated practicum.

Validation is carried out to determine the validity of virtual laboratory products, including validation by media experts and material experts. The follow-up to the validation results is in the form of revision of learning media and materials if there are suggestions for improvements as improvements to the virtual laboratory.

The pilot test was carried out to determine the feasibility of a virtual laboratory learning media with several high school students as test objects. The pilot test design includes individual tests (one to one) and field tests in groups (Fraser et al., 2018). Revision of the virtual laboratory was carried out to improve learning media as feedback from the trial questionnaire. The results of filling out the validation questionnaire from each expert and pilot testing are shown in Table 2.

Table 2

Virtual Laboratory Validation Results

No.	Aspect	Mean Score			
		Media Expert	Material Expert	Individual Pilot test	Group Pilot test
1.	Application in Software	3.44	3.20	3.72	3,74
2.	Learning Design	3.50	3.75	3.65	3,71
3.	Visual Communication	3.58	3.64	3.55	3,64
	Average	3,51	3.53	3.64	3.69

Table 2 illustrates the mean of media experts and material experts in the range of 3.28 to 4.00, which indicates that the resulting virtual laboratory is very feasible or very good. These results are in line with the results of the individual pilot test which resulted in a mean of 3.64 and the results of the group pilot test which resulted in a mean of 3.69. From these results, it can be concluded that the virtual laboratory learning media can be said to be very feasible and very good. Although overall this virtual laboratory is declared very valid and does not need to be revised, improvements still need to be made to produce a better virtual laboratory. Some of the revisions made included general revisions that were made based on the findings obtained during the development of learning media products. General revisions include: (1) adding a warning message when users who are using the virtual laboratory on learning media will close the application; and (2) providing clear and straightforward instructions at each level.

Step 4: Disseminate

The Disseminate stage is marked by the implementation of a virtual laboratory into classroom learning, even though learning is being carried out online amid the Covid-19 pandemic. This stage begins with uploading a virtual laboratory to Google Drive and distributing it to students. Data collection was carried out by conducting a student understanding test using a virtual laboratory. The data collected will be used for testing the effectiveness of the virtual laboratory and compared with groups using conventional teaching materials, such as practicum teaching through video tutorials. Sixty-three students were involved in this stage, with 32 students in the control group (with conventional video tutorial teaching materials) and 31 students in the experimental group (with a virtual laboratory). The test used is a test of student understanding after using the virtual laboratory, and then the test results of each group will be tested using an independent sample t-test. A summary of the results of the t-test using IBM SPSS Statistics 25 is shown in Table 3.

Table 3

Summary of t-test Results

No.	Group	Number of Samples	Mean	Standard Deviation	t-test for Equality of Means		
					t	df	sig
1.	control group (conventional)	32	74.31	6.36	-6.14	61	.00
2.	experimental group (virtual lab)	31	82.90	4.59			

Table 3 shows the sig value on the t-test of .00 (t value of -6.14). This shows that there is a significant difference between students' mastery of understanding using conventional teaching materials and students' mastery of understanding using virtual laboratories, with the average understanding score of students using virtual laboratories (74.31) higher than the average value of students' understanding. which uses conventional teaching materials (82.90). That is, the use of virtual laboratories has a significant effect on student understanding.

Interviews were conducted with several students who had used learning media in the form of virtual laboratories. The majority of students said that virtual laboratories were more fun to use than video tutorials so that the practicum learning materials were easier for students to accept.

The result of the interview with AR as a student is known that

> The virtual lab makes learning fun and I feel comfortable.

The results of the interview above show that students find learning with a virtual laboratory was more fun. The same thing was conveyed by another student, CYL

> It's very interesting, the material is easier to learn and I am excited about studying the material.

The results of interviews with other students showed that students felt that learning material were easier to understand by using a virtual laboratory, such as the results of an interview with NA

> In my opinion, learning using a virtual laboratory is more effective and efficient, very interesting so that the material is easier to understand.

The results of the interviews above show that it is easier for students to learn the materials using a virtual laboratory so that learning is more fun for students. This is as the results of interviews with other student, DAP

> I recommend that learning better use the virtual laboratory because this method can make it easier and the material can be remembered more. I prefer to use this method instead of video.

The findings of this interview support the results of the t-test which states that the results of understanding from learning with virtual laboratories are better than using conventional methods. Another support was delivered by AUN as the teacher

> Most students admitted that they enjoyed receiving the material more. In addition, they are usually less excited about online learning. After this, they asked for a virtual laboratory in other materials. I think they are more excited.

Based on the interview explanation above, it is known that the feedback from the majority of students is more enthusiastic and more interested in learning with the use of learning media in the form of virtual laboratories. This is also supported by the results of interviews with chemistry teachers. Therefore, the developed virtual laboratory can increase student motivation.

Discussion

The 4D method was used in this paper to develop a virtual laboratory in chemistry material of Exothermic and Endothermic Reactions. This method is referenced from various research results and adapted into a virtual laboratory with Exothermic and Endothermic Reactions material derived from high school chemistry textbooks. The Define and Design stages are marked by the design of a virtual laboratory developed from Exothermic and Endothermic Reactions material. These stages are marked by the formation of a virtual laboratory material content framework and learning media storyboards.

The 4D method is an effective method in developing learning media as the result of various previous studies. In this paper, the developed learning media is in the form of a virtual laboratory that has been successfully developed as shown in the Develop and Disseminate stage.

The Develop stage which leads to virtual laboratory validation is an important stage. This validation stage is carried out by involving both media and chemistry material experts. This stage is intended to find out the weaknesses and shortcomings of the virtual laboratory as a learning media that can be used during the Covid-19 pandemic. The validation phase ends with individual and group pilot tests to measure the satisfaction of potential users of the developed virtual laboratory.

The Disseminate stage is marked by the distribution of learning media in the form of a virtual laboratory via Google Drive to students and leads to the measurement of the effectiveness of the virtual laboratory. The level of effectiveness can be seen from the results of the different tests between students' mastery of understanding using conventional teaching materials and students' mastery of understanding using virtual laboratories. The results show that there is a significant difference between students' mastery of understanding using conventional teaching materials and students' mastery of understanding using virtual laboratories. In addition, the average understanding score of students using virtual laboratories is higher than the average value of students' understanding. This shows that chemistry learning using virtual laboratories can improve students' mastery regarding Exothermic and Endothermic Reactions when compared to learning using conventional teaching materials. This is in accordance with some of the results of previous studies which state that the use of learning media in the form of virtual laboratories can improve students' understanding (Faour et al., 2018; Gunawan et al., 2018).

The results of the effectiveness test were strengthened by the findings of interviews with several students and teachers who showed that the developed virtual laboratory can increase student motivation. This is supported by the results of previous research which states that learning through virtual laboratories and assisted by ICT will be able to increase student motivation (Ambusaidi et al., 2018; Sarıoğlu & Girgin, 2020).

This study has not considered other affective or cognitive aspects such as practical laboratory skills and emotional activity which according to previous studies also support learning in the laboratory (Leite & Dourado, 2013; Hinampas *et al.*, 2018; Musawi *et al.*, 2017; Hewson, 2018; Nasution, 2018). In addition, in terms of ICT, this research has not integrated the latest technologies such as artificial intelligence and augmented reality which can increase student motivation and understanding through virtual laboratories (Chassignol et al., 2018; Diwanji et al., 2018; Khan et al., 2019; Petrov & Atanasova, 2020; Sirakaya & Cakmak, 2018). Therefore, the next development of learning media in the form of a virtual laboratory can pay attention to these aspects.

Conclusion

The virtual laboratory that has been developed empirically is proven to be used as a valid and effective learning medium in increasing students' understanding and motivation regarding the material of Exothermic and Endothermic Reactions. The existence of feedback at the end of the practicum simulation is useful in reflecting on students' understanding directly. In addition, virtual laboratories can be easily installed on PC devices that have Adobe Flash Player or a web browser, so that they can be used as learning media that can be accessed by anyone, anywhere.

In this study, the effectiveness of the virtual laboratory is focused on increasing mastery related to chemistry materials owned by students as well as a study of students' learning motivation in using a virtual laboratory. This study does not consider the affective and cognitive aspects that support learning in the laboratory, as described in the Discussion section above. In addition, the resulting virtual laboratory has not integrated artificial intelligence and augmented reality that can support the learning process. Therefore, further research can be carried out on a broader subject and pay attention to other aspects such as affective and cognitive aspects and the latest technology.

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