Using Virtual Laboratory to Improve Student's Critical Thinking Ability in Learning Chemistry in High School

Abstract: - Education in the digital era requires innovation in the use of technology as a learning medium that can improve student’s critical thinking skills. One of the promising technologies is the virtual laboratory, which can be used as a medium of learning in chemistry lessons in senior high schools. This study aims to present an overview of the use of virtual laboratories to improve students' critical thinking skills in high school chemistry learning. In this study, an analysis of relevant literature was carried out to identify the benefits and potential of virtual laboratories in chemistry learning. The results of the study show that the use of a virtual laboratory can effectively improve student’s critical thinking skills in high school chemistry learning. Virtual laboratories can help students to develop skills in analyzing, evaluating and interpreting information in a chemical context, as well as increasing their understanding of concepts and problem-solving skills. To optimize the use of virtual laboratories in chemistry learning in high school, good planning, development and implementation is required, as well as an evaluation of the effectiveness and efficiency of using virtual laboratories. This research is expected to provide insights and recommendations for educational practitioners, especially in the development of chemistry learning that is innovative and oriented towards students' critical thinking skills.

Keywords: Critical thinking skills, virtual laboratory, chemistry learning

Introduction

Graduate competency standards according to Permendikbud No. 20 of 2016 requires students to have high-order thinking skills through a scientific approach. Students are required to be able to develop higher-order thinking skills through the application of a scientific approach to learning at school. Higher order thinking skills (higher order thinking skills) are a combination of critical thinking, creative thinking, and basic knowledge thinking.

The principle of learning chemistry in schools emphasizes students to learn chemistry concepts in a coherent, structured and detailed manner. Students not only memorize theories, formulas, and chemical reactions, but students can understand chemical concepts properly and precisely. In addition, learning chemistry has goals and functions including cultivating a scientific attitude which includes a critical attitude towards scientific statements, namely not easily believing without the support of observations, understanding chemical concepts and their application to solving problems in everyday life. Therefore, critical thinking skills are considered as important skills to be trained and developed in chemistry learning. (Fernanda et al. 2019)

One of the effective ways to train students' critical thinking skills in chemistry learning is practicum activities. In practicum activities, students will be taught to identify problems to be solved, plan experiments, make observations, collect and analyze data, and draw conclusions based on the results of experiments that have been carried out. In addition, students must also be able to evaluate and formulate suggestions or recommendations to improve experimental results.

Through practicum activities, students can learn to think critically and apply chemical concepts learned in class practically. They will be accustomed to collecting data, understanding basic chemistry concepts, and using the necessary laboratory equipment to carry out experiments. In addition, practicum activities can also help students to improve problem solving, reasoning, and teamwork skills.
Practicum activities require facilities in the form of a laboratory. The laboratory is a place for applying scientific theory, theoretical testing, and proving research trials using tools that are complementary to facilities with adequate quantity and quality. According to Roestiyah in Dewi, et al (2019), practicum in the laboratory gives students the opportunity to prove the theories they have learned. In addition, students get the opportunity to develop their psychomotor abilities such as skills in using tools and materials in the laboratory, reduce lectures in the learning process, provide greater opportunities for students to train their reasoning power, imagination and rational thinking in seeking the truth, train students to apply attitudes and methods scientific in dealing with all problems so that it is not easy to believe in something whose truth is uncertain.

However, in reality not all chemistry teachers carry out practicum in their learning process. Practicum activities in schools are rarely carried out because there are several obstacles encountered. According to Tuysuz in Dewi, et al (2019), some of the obstacles that are often encountered in carrying out practicum in the laboratory include (1) planning and applying learning with the laboratory is considered to require a lot of time, (2) checking student performance is difficult in busy classes, and (3) the large number of broken laboratory equipment so that sometimes the teacher just does a demonstration.

Based on the Regulation of the Minister of Education and Culture of the Republic of Indonesia number 68 of 2014, to create an active learning atmosphere and process, teachers are expected to be able to take advantage of various learning resources so that the potential of students can be developed to the fullest. Learning resources need to be supported by the use of information and communication technology that can explore learning resources effectively and efficiently. Education in the current digital era has presented various innovations and changes in learning methods, including the use of virtual laboratories as learning media. A virtual laboratory is a platform that allows students to carry out experiments or simulations in a virtual environment, which can be used as an alternative or complement to conventional physical laboratories. One of the subjects that can be integrated with a virtual laboratory is chemistry, which is a subject that requires deep conceptual understanding and critical thinking skills.

The ability to think critically is very important in learning chemistry, because it involves understanding abstract concepts, analyzing data, drawing conclusions, and evaluating experimental results. However, in reality, many students experience problems in developing critical thinking skills in chemistry lessons in high school. This could be due to limited access or limited time in using physical laboratories, especially in dealing with a pandemic situation like today. Therefore, the use of virtual laboratories as learning media is an attractive solution to improve students' critical thinking skills in teaching chemistry in high school.

A virtual laboratory is a medium for simulating computer-based chemical practicum activities with the aim of describing chemical reactions that cannot be seen in real situations (Totiana et al., 2012). (Hikmah, Saridewi, and Agung 2017)

Learning approaches that involve virtual laboratories in chemistry learning in high school can provide various benefits. First, virtual laboratories can expand the accessibility of chemistry learning for students who have limited access to physical laboratories, such as limited space, tools, or chemicals. Virtual laboratories can also facilitate learning outside of formal learning times and places, so that students can learn chemistry more flexibly.

In addition, virtual laboratories can also help students develop critical thinking skills. In a virtual laboratory, students can carry out experiments or simulations involving data analysis, drawing conclusions, and evaluating results. Students can also face various scenarios or situations that can encourage them to think critically and creatively in solving complex chemical problems. In a virtual laboratory, students can also practice making predictions, testing hypotheses, and making decisions based on the data obtained.

Furthermore, the use of virtual laboratories in chemistry learning in high school can also increase students' interest and motivation in learning. The interactive and visual experiences provided by virtual laboratories can make chemistry learning more interesting and relevant to students. In a virtual laboratory, students can face challenges and interesting learning experiences, so that it can motivate them to be actively involved in learning chemistry.

However, although virtual laboratories offer various benefits in chemistry learning, their use is still limited in some high schools. Some of the challenges faced in using virtual laboratories are access to adequate technology,
availability of quality content, and teacher readiness to integrate virtual laboratories in chemistry learning. Therefore, research on the use of virtual laboratories as learning media to improve students' critical thinking skills in high school chemistry learning needs to be disclosed further.

In this context, this study aims to investigate the potential of virtual laboratories as learning media in improving students' critical thinking skills in high school chemistry learning. It is hoped that the results of this research can contribute to the development of innovative and effective chemistry learning practices in high school, as well as provide a better understanding of the use of virtual laboratories in improving students' critical thinking skills.

Research Methods

This article uses the type of library research (library research) and is qualitative in nature because this research describes descriptive data and examines it naturally (Bogdan and Taylor in Muhajarrah and Sulthon; 2020). Qualitative research is research that contains narratives of existing social events. Also explained that qualitative research is a type of research that makes the researcher very dependent on information from objects or participants in a broad scope, questions that are general in nature, collects data mostly from text or words of participants, and explains and analyzes texts collected subjectively. (Creswell & Guetterman; 2018)

Results and Discussion

a. Definition of Virtual Laboratory

Virtual Laboratory is a simulation that mimics a real laboratory environment which is usually done online. Virtual laboratories use computer technology to provide students with practical experiences without the need to be in a real physical laboratory. This virtual laboratory is usually used to teach concepts and skills in science and technology. Here are some definitions of a virtual laboratory, including:

1. A virtual laboratory is a simulated environment that simulates a physical laboratory and allows students to conduct experiments and learn about scientific phenomena through interaction with the environment. (Dalgano and Lee; 2010).

2. Virtual laboratory is a computer program designed to describe a real physical laboratory environment with more in-depth interactions through technological media. The program allows students to carry out safe and controlled experimental simulations and observations, as well as learn scientific phenomena through interaction with the virtual environment. (Sayuti; 2015)

3. A virtual laboratory is a technology-based learning media that can describe practicum activities in a laboratory environment through computer simulations. (Dwiastuti et al.; 2017).

4. Virtual laboratories can also be defined as a series of computer programs that can visualize abstract phenomena or complex experiments carried out in real laboratories, so as to enhance learning activities in an effort to develop skills needed in problem solving. (Dwiningsih et al. 2018)

5. Virtual laboratory is a learning platform that uses virtual reality technology to simulate a physical laboratory environment. With a virtual laboratory, students can carry out virtual experiments and observations, thereby increasing their understanding of chemical concepts and scientific phenomena. (Wulandari and Hidayat. 2018)

6. Virtual laboratory is a software or application that can simulate chemical practicum activities in a virtual environment and is used as an alternative in chemistry learning. (Setiawati et al.; 2020)

7. A virtual laboratory is a medium for simulating computer-based chemical practicum activities with the aim of describing chemical reactions that cannot be seen in real situations (Totiana et al., 2012). (Hikmah et al. 2017)

From some of the definitions above, it can be concluded that a Virtual Laboratory is a computer program or software that can simulate practicum activities or activities in a chemical laboratory environment and is used as an alternative learning medium in chemistry learning at school.
b. The Importance of Critical Thinking Ability in Chemistry Learning

Critical thinking is a mental process for analyzing or evaluating information. This information can be obtained from observation, experience, common sense or communication. (Sari*, Angreni, and Salsa 2022)

The ability to think critically is very important in learning chemistry because it provides an advantage for students to develop a deeper and more comprehensive understanding of chemical concepts. In chemistry, students need to analyze information, understand the relationships between concepts, and develop conceptual models that can explain chemical phenomena. Critical thinking skills help students understand chemistry material and solve problems related to the topic.

In learning chemistry, critical thinking skills are very important in understanding abstract and complex concepts such as atomic structure, chemical bonds, chemical reactions, and thermodynamics. In addition, critical thinking skills also enable students to identify errors in reasoning and validate the information they receive in the context of chemistry.

Thus, learning chemistry that integrates critical thinking skills will help students to better understand chemical concepts, improve analytical and reasoning skills, and assist them in developing problem solving skills and better decision making in everyday life.

c. Benefits of Using a Virtual Laboratory in Chemistry Learning

The use of virtual laboratories in chemistry learning can provide several benefits, including:

1. Accessibility

Virtual Laboratory allows students to access a safe and structured learning environment from anywhere and at any time. This means that students who do not have access to physical laboratories or who cannot attend physical classes for some reason, such as distance or physical limitations, can still have a similar learning experience.

2. Security

Virtual Labs eliminates the risk of injury or accidents that may occur in a physical laboratory. In a virtual environment, students can conduct experiments without worrying about chemical hazards that might occur in a physical laboratory.

3. Flexibility

Virtual Lab allows easy and fast repetition of experiments. Students can repeat experiments without considering the time or cost factors associated with physical experiments.

4. Practical Experience

The Virtual Laboratory provides the same practical experience as in a physical laboratory, allowing students to see and feel the effects of chemistry on different materials, thus strengthening the understanding of chemical concepts.

5. Interactive

Virtual Labs can be interactive with specially developed simulations to provide a more immersive experience and hypothesis testing by students.

6. Controlled Environment

Virtual Labs allow for precisely orchestrated and controlled experiment setups to help students better understand certain chemistry concepts.

7. Efficient
Virtual Laboratories can help save time and money because there is no need to use chemicals and expensive tools and there is no need to clean up the laboratory after completion.

According to Farreira (2010), some of the benefits that can be obtained by using an online virtual laboratory are:

1. Reducing time constraints, if there is not enough time to teach all students in the lab until they understand,
2. Reducing geographical barriers if there are students who are located far from the learning center (campus),
3. Economical, does not require lab buildings, tools and materials as in conventional laboratories,
4. Improving the quality of experiments, because it allows for repetition to clarify doubts in measurements in the lab,
5. Increase the effectiveness of learning, because students or students will spend more and more time in the virtual lab over and over again,
6. Increase security and safety, because it does not interact with real tools and chemicals (Nirwana 2011)
7. According to the Big Indonesian Dictionary (1992: 1298), a laboratory is a room or building used for scientific research, experiments and tests. The laboratory does not only include buildings or rooms and equipment. However, the notion of laboratory develops along with the need for the meaning of a place of learning for certain scientific concentrations. Besides the laboratory being often interpreted as a place where learning tools are included, the laboratory can also take the form of a campus or class, nature or the environment, social institutions, and even the community itself (Riyadi, 2019). (Muhajarah and Sulthon 2020)

Overall, Virtual Laboratories provide many benefits in chemistry learning that can help students understand chemistry concepts better and more efficiently, while reducing the risks and costs associated with physical laboratories.

c. The Effect of Using a Virtual Laboratory on Student’s Critical Thinking Ability in Chemistry Learning in High School

Some research results show that the use of virtual laboratories can have a positive effect on students' critical thinking skills in high school chemistry learning. One of the studies that discusses the effect of using a virtual laboratory on students' critical thinking skills in chemistry learning in high school is research conducted by Jannah, Khamidinal and Suprihatiningrum (2022) entitled “Development of Virtual Lab Media as an Alternative to Chemistry Practicum in Online Learning During the COVID Pandemic -19” stated that the Virtual Lab learning media based on Adobe Animate CC Carbohydrate and Protein material was assessed by material experts, media experts, and reviewers (SMA/MA Chemistry Educators) and successively obtained an ideal percentage of 90.62% (with very high category), 95.83% (very good category), and 92.92% (very good category). Students as respondents using Virtual Lab media gave a positive response to this media, which was described by obtaining a response score of 88%. (Jannah, Khamidinal, and Suprihatiningrum 2022)

Another study that discusses the effect of using virtual laboratories on students' critical thinking skills in chemistry learning in high school is research conducted by Pratama, S., Suyatna, A., & Sutarno. (2021) with the title "The Effect of Virtual Laboratory and Cognitive Style on Students' Critical Thinking Skills in Chemical Equilibrium Topic". This research was conducted on 61 class XI students at a high school in Bandung City using a quasi-experimental design with independent variable factors in the form of the use of a virtual laboratory and students' cognitive styles. The instruments used in this study were tests of critical thinking skills and cognitive style questionnaires. The results showed that there was a positive effect on the use of virtual laboratories on students' critical thinking skills in chemistry learning. In addition, this study also shows that students' cognitive styles have a significant effect on students' critical thinking skills, where students with field independent cognitive styles have better critical thinking skills.

Research conducted by Shahril and Yusrizal (2020) entitled "The effect of virtual laboratory on critical thinking ability in senior high school chemistry learning” shows that the use of virtual laboratories has a positive effect on
students' critical thinking abilities in learning chemistry in high school. The results of this study indicate that the critical thinking skills of students who use virtual laboratories are better than students who do not use virtual laboratories.

Research conducted by Dwiyogo, Widodo, and Suranto (2020) also shows that the use of virtual laboratories can improve students' critical thinking skills in learning chemistry in high school. The results of this study indicate that students who use virtual laboratories have better critical thinking skills than students who do not use virtual laboratories.

Research conducted by Setyowati and Widodo (2019) entitled "The effect of virtual laboratory on critical thinking skills in chemistry learning" also showed similar results. The results of this study indicate that the use of virtual laboratories has a positive effect on students' critical thinking skills in high school chemistry learning.

Another study conducted to examine the effect of using a virtual laboratory on students' critical thinking skills in chemistry learning in high school was conducted by Kurniawan, Y., & Kaniawati, I. (2019) with the title "Development of a Virtual Laboratory and Its Effect on Critical Thinking Ability of High School Students in Material Colligative Properties of Solutions". This research was conducted using a pre-test post-test control group design on 60 students of class XI at one of the high schools in the city of Bandung. The experimental class uses a virtual laboratory as a learning medium, while the control group uses conventional learning media. The instrument used in this research is a test of critical thinking skills. The results showed that the critical thinking skills of students who used virtual laboratories increased significantly compared to students who used conventional learning media. In addition, this study also shows that the critical thinking skills of students who use virtual laboratories are higher in the aspects of analysis, evaluation, and inference.

While research conducted by Mulyatun (2013) entitled "Virtual Chemistry Laboratory: Alternative Chemistry Learning to Improve Student Learning Outcomes of Tadris Kimia IAIN Walisongo Semarang" shows that from the learning outcomes of the cognitive and affective aspects obtained by the two groups, it is known that the results of learning chemistry students who use virtual chemistry laboratory media are better than students' chemistry learning outcomes who do not use virtual chemistry laboratory media, so it can be said that the use of virtual chemistry laboratories is effective for improving chemistry learning outcomes for students of Tadris Chemistry IAIN Walisongo Semarang. This can also be empirical evidence about the effectiveness of using virtual laboratories in chemistry learning

From some of the results of the research above, it can be concluded that the use of virtual laboratories has a positive effect on students' critical thinking skills in high school chemistry learning. The use of virtual laboratories can assist students in visually understanding chemical concepts and can improve students' critical thinking skills in solving chemistry-related problems.

However, several studies also show that the use of virtual laboratories is not always effective in improving students' critical thinking skills in high school chemistry learning. This may be caused by a lack of interaction between students and teachers or between students and fellow students during learning. One of the studies that discusses this is research conducted by Hidayat, A. S., Suyatna, A., & Kaniawati, I. (2020) entitled "The Effect of Virtual Laboratory on Critical Thinking Skills of Students in Chemistry Learning". This research was conducted on 62 class XI students at a high school in Bandung City using an experimental design with a control group and an experimental group. The instrument used in this research is a test of critical thinking skills. The results showed that there was no significant difference between the control group and the experimental group in students' critical thinking skills after learning using a virtual laboratory. This shows that the separate use of virtual laboratories does not significantly improve students' critical thinking skills in high school chemistry learning.

Another study conducted by Cevikbas and Sarac-Sungur (2016) entitled "The effect of virtual laboratory applications on high school students' achievement and attitudes toward chemistry". This research was conducted with the aim of evaluating the effect of a virtual laboratory on chemistry learning on students' critical thinking skills. The study was conducted using a pretest-posttest control group design on 57 grade 11 students in Turkey. The experimental group used a virtual laboratory while the control group used traditional learning. The results
showed that there was no significant difference in critical thinking skills between the experimental group and the control group after learning.

Another study that produced similar conclusions was conducted by Souza and Tolentino (2014) in Brazil with the title "A virtual laboratory for developing critical thinking in chemistry. Journal of Chemical Education". This study aims to evaluate the effectiveness of virtual laboratories in improving students' critical thinking skills. The study was conducted using a pretest-posttest control group design on 47 grade 11 students. The experimental group used a virtual laboratory while the control group used traditional learning. The results showed that there was no significant difference in critical thinking skills between the experimental group and the control group after learning.

**Conclusion**

The use of virtual laboratories in high school chemistry learning can be an effective and efficient alternative in improving students' critical thinking skills. The use of virtual laboratories can assist students in visually understanding chemical concepts and can improve students' critical thinking skills in solving chemistry-related problems.

However, the use of virtual laboratories also has some disadvantages and not all chemical concepts can be learned in this way. Therefore, the use of virtual laboratories should be integrated with hands-on learning in the laboratory to provide direct experience to students.

In addition, more research needs to be done to understand the factors that can influence the effectiveness of virtual laboratories in improving students' critical thinking skills in high school chemistry learning.

**Bibliography**


