Applying PhET Interactive Simulations Media With A Guided Investigation Approach to Improve Student's Critical Thinking Skills

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ARTICLE INFO	ABSTRACT
	The purpose of this research is implementation PhET Interactive Simulations Media with a Guided Inquiry Approach to Improve Students' Critical Thinking Skills" based on the description provided above. Physics Educational Technology (PhET) simulations is the virtual laboratory makes use of practical simulation principles to carry out engaging learning. By using an inquiry-based learning approach, students are trained to formulate problems, generate hypotheses, conduct experiments, gather data, analyze data, write and describe theories, and honestly follow rules so that the actions of the offenders mirror those of scientists. This study method is quasi-experimental, because it uses a guided inquiry learning strategy to assess how critical thinking abilities are improved when learning the pH of acid and base solutions. The study's conclusion is combining PhET Interactive Simulations media with a guided inquiry approach, the average learning outcomes are higher than when using a conventional learning.

Introduction

According to Law No. 20 of 2003 governing the National Education System, national education serves to develop skills and build the civilization and character of a respectable country in order to raise the standard of living in that country. The objective of national education is to help students become human beings with noble character, who believe in and are devoted to God Almighty, who are healthy, knowledgeable, capable, and able to think critically and creatively on their own. They also want to become democratic and responsible citizens. Reaching the country's educational objectives requires learning. states that learning is an effort to instruct students (Darman, 2020).

High levels of abstraction are required to comprehend both the qualitative and quantitative aspects of many concepts in chemistry lessons. Chemistry is seen by most students as being difficult to learn because of these abstract chemical events and complicated concepts. Students prefer to employ quick learning strategies like memorization to get beyond their challenges since they find it tough to apply concepts and

understand chemistry (Johnstone & Otis, 2006). It is challenging for students to accept abstract notions when they are presented directly in the form of scientific data; therefore, an analogous model that can concretize abstract concepts is required (Antara, 2022; Lestari & Muchlis, 2021). To truly understand chemistry, one must examine topics from three perspectives: symbolic, microscopic (particles), and macroscopic (observable qualities) (Ramadhani et al., 2020; Ristiyani & Bahriah, 2016).

The chemistry test results for Acids and Bases in the XI grade at Madrasah Aliyah Negeri 2 Bengkulu City for the 2022–2023 academic year indicate that the learning outcomes are still below the Minimum Completeness Criteria and are not satisfactory. The results of the acid and base material tests for a few of the XI grade at MA Negeri 2 Bengkulu City are listed below.

Table 1. The results of chemistry tests of the XI grade at MA Negeri 2 Bengkulu City

N	Class	Number of students	Minimum Completeness Criteria	Average	Number of completed students	Number of incompleted students
1.	X IPA 1	34	75	53,82	10	24
2.	X IPA 2	34	75	48,67	7	27
3.	X IPA 3	35	75	39,28	6	29
4.	X IPA 4	35	75	46,42	9	26

Because white board learning materials are thought to be the simplest and most useful to use, chemistry teachers at MA Negeri 2 Bengkulu City continue to utilize them extensively, according to the reality at the school where the author teaches. For a variety of reasons, such as difficulty, a shortage of time, or information that is too deep, teachers are hesitant to use the internet, computers, laptops, and other current technologies to creatively package their lessons. Instructors typically impart their chemical knowledge through written materials, and students are expected to just take in what they are taught without questioning whether the information is abstract or needs more explanation in the form of audio and visual tools.

Learning at MAN 2 Even now, Bengkulu City doesn't do many lab tests. This is brought on by inadequate infrastructure and facilities in addition to a lack of supplies and equipment in the lab. The acquisition of knowledge about acids and bases necessitates an explanation and experimental evidence in order to enhance students' critical thinking skills. Critical thinking is one of the key components of human maturation and one of the basic capital, or intellectual capital, that is very vital for every individual. Because thinking activities are actually tied to the pattern of self-organization that occurs in people themselves, every human has the potential to grow and develop into a critical thinker (Liliasari, 2001).

The growth of information technology has aided in the development of virtual laboratories, or software. A virtual laboratory is an educational tool that uses resources and tools from an application to simulate genuine practicums (Yunitasari et al., 2022). An interactive simulation of a science experiment within an application is called a virtual laboratory (Buchori & Pramasdyahsari, 2021; Sutrisno., 2011). When circumstances and conditions prevent doing experiments in the school chemistry laboratory, virtual laboratories are a useful tool for chemistry education. With the help of virtual practicums,

students can do their practica at any time, from home, without the need for tools or chemicals, and they can provide a more realistic appearance to something that would otherwise be abstract (Yunitasari et al., 2022). It is believed that the use of virtual laboratories will help in situations where practicums involve the use of hazardous substances that could compromise worker safety (Yang et al., 2023). Because learning management in virtual laboratories happens more quickly than in physical laboratories, learning in virtual laboratories is more efficient. The virtual laboratory makes use of practical simulation principles, such as Physics Educational Technology (PhET) simulations, to carry out engaging learning.

A team from the University of Colorado in the United States created the interactive simulation PhET Interactive Simulations, which can be accessed on the internet and is programmed in Flash and Java. PhET has created a range of interactive simulations that are highly helpful in incorporating computer technology into education (Perkins et al., 2006). The lack of adequate laboratory equipment led researchers to develop the PhET simulation medium, which emphasizes the connection between scientific principles and real-world phenomena, encourages interactive and constructivist methods, offers feedback, and serves as a workspace. The benefit of PhET simulation is its ability to do tests optimally that aren't possible with actual equipment (Putranta & Kuswanto, 2018). The reason this PhET simulation was selected is that it is built on a Java application called Easy Java Simulation (EJS), which is intended to make it easier for teachers to use computers to create chemical simulations relevant to their subject (Fithriani et al., 2016).

Researchers are interested in "Applying PhET Interactive Simulation Media with a Guided Inquiry Approach to Improve Students' Critical Thinking Skills" based on the description given above. Researcher wants to know whether the PhET Simulation used in chemistry learning can improve students' creative thinking abilities. By using an inquiry-based learning approach, students are trained to formulate problems, generate hypotheses, conduct experiments, collect data, analyze data, write and elaborate theories, and honestly follow the rules so that the perpetrator's actions reflect the actions of scientists.

The research questions for this study are as follows, based on the background that has been described: (1) How is the N-gain value of critical thinking skills for each indicator in classes that learn using PhET Interactive Simulations media with a guided inquiry approach and classes that learn conventionally?; (2) What is the percentage of critical thinking ability scores for each question item in classes that study using PhET Interactive Simulations media with a guided inquiry approach and classes that study conventionally?; and (3) Are the average learning outcomes using PhET Interactive Simulations media with a guided inquiry approach higher than the average learning outcomes conventionally?

Research Methods

This study method is quasi-experimental, because it uses a guided inquiry learning strategy to assess how critical thinking abilities are improved when learning the pH of acid and base solutions. Two classes are used in the study design—the experimental class and

the control class for comparison—under the Nonequivalent Control Group Design (Krishnan, 2023).

Table 2. Control Group Design

Class	Pretest	Treatment	Posttest
Experiment	O_1	X_a	O_2
Control	O_1	X_b	O_2

Noted:

X_a = Learning uses PhET simulation learning media

X_b = Conventional learning

O_1 = Pretest before treatment

O_2 = Posttest after treatment

For the academic year 2023–2024, all students in grade XI at MAN 2 Bengkulu City made up the research population. With 37 students in the XI grade A being used as the experimental class and 35 students in class XI B performing as the control class, a total of 72 students made up the research sample. The class forms the sample unit in the cluster random sampling technique.

Ten question essays representing the students critical thinking abilities were employed for data collection. All question indicators are described in the following table:

Table 3. Indicators for questions

N	Question
1	Students are able to distinguish between the characteristics of basic and acidic solutions by being presented with multiple solutions with distinct attributes.
2	Students can identify the most acidic solution given information on the concentration of an acid solution.
3	Students can identify the most basic solution given information on the concentration of a basic solution.
4	Students can determine the pH of an acid solution given information about its concentration.
5	Students can determine the pH of a basic solution given information about its concentration.
6	Students can determine the pH of a weak acid solution given information about its concentration.
7	Students can determine the pH of a weak basic solution given information about its concentration.
8	Students can determine the number of moles and dissolved particles in a solution by using concentration data for acid and base solutions.
9	Students can categorize acid solutions from the solution with the lowest pH to the solution with the highest pH by being given information on several types of strong acid solutions and their concentrations.
10	Students can categorize basic solutions from the solution with the lowest pH to the solution with the highest pH by being given information on several types of strong basic solutions and their concentrations.

Before receiving treatment, questions are asked at beginning of learning, and again at at the end of learning. In order to evaluate the growth in critical thinking abilities, data analysis was done on the pretest, posttest and N-Gain result using SPSS Statistics 26. Indicators of students, critical thinking ability used in this study are Analyze, Focus, Observe, Hypothesize, Assume, Reviewing, Conclude and Reflect (Greenstein, 2012)

Findings

Critical Thinking Skills Indicators

The average score on the pretest taken before learning and the average score on the posttest taken following learning are used to calculate the improvement in critical thinking skills. It is possible to analyze the average score for critical thinking abilities depending on each signal created for every question. Figure 1 displays the n-gain value of critical thinking skills for each indicator in the experimental class and control class.
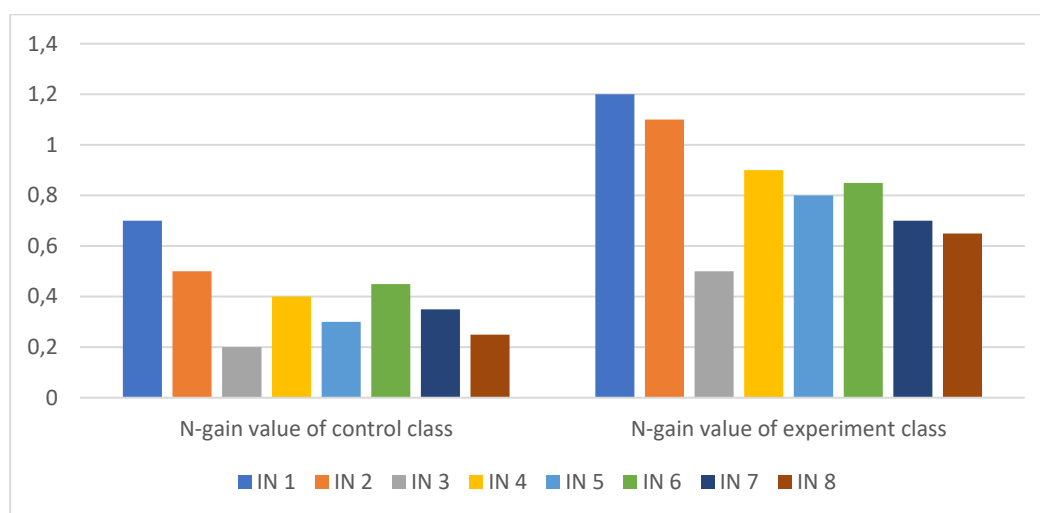

Figure 1. Students' critical thinking skills

Noted:
IN 1   : Analyze
IN 2   : Focus
IN 3   : Observe
IN 4   : Hypothesize
IN 5   : Assume
IN 6   : Reviewing
IN 7   : Conclude
IN 8   : Reflect

The N-gain value for the experimental class is greater than the N-gain value for the experimental class, as Figure 1 illustrates. The purpose of the normalized gain, or N-gain score, is to assess how successful the use of PhET Interactive Simulations media (Fadli et al., 2020). The N-Gain exam is administered by computing the difference between the scores from the pretest (a test administered using PhET Interactive Simulations before learning) and the posttest (a test administered using PhET Interactive Simulations following learning). The effectiveness of applying PhET Interactive Simulations can be determined by computing the difference between the pretest and posttest (Hanief & Himawanto, 2017).

The high n-gain of the experimental class suggests that guided inquiry learning can engage students in critical thinking exercises that make use of fundamental cognitive processes to evaluate arguments, produce insight into each meaning and interpretation, and create coherent, logical thought patterns while comprehending presumptions. underpins each position so that students can use it to create a conceptual theory of physics. when

people think critically, they evaluate the outcomes of their thought processes, calculate how good a decision is, or identify how effectively aproblem has been solved (Alsaleh, 2020).

Improving Students' Critical Thinking Skills is Assessed from the Question Items

The evaluation results for each question item show how much the students' critical thinking abilities, which are measured by the questions, have improved. Every question item is evaluated using a set of scoring criteria that consists of four scales (Fithriani et al., 2016) : three points are awarded for correct answers and correct reasons; two points are awarded for correct answers and incorrect reasons; one point is awarded for correct answers and incorrect reasons; zero points are awarded for incorrect answers and incorrect reasons; and one point is awarded for incorrect answers and incorrect reasons. Figure 2 displays the percentage of the control class's average critical thinking skills score from each question item, while Figure 3 displays the results for the experimental class.
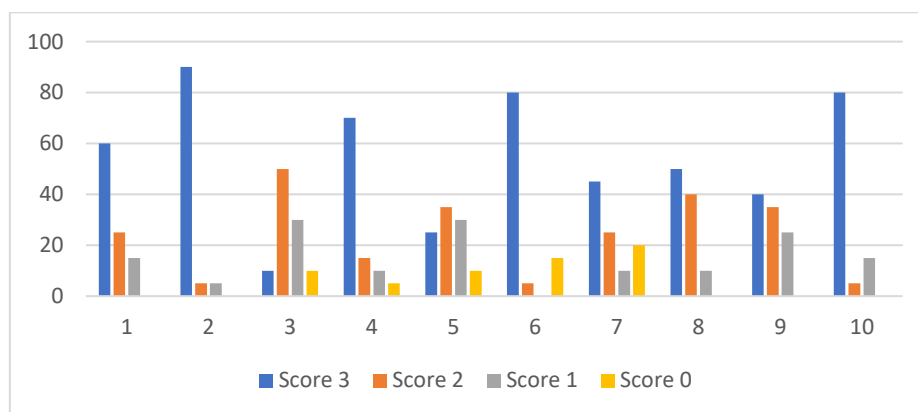

Figure 2. Percentage of the control class's average critical thinking skills score from each question item

For questions 2, 6, and 10, the control class had a percentage above 70% that provided the accurate response together with the appropriate justifications; question number 2 had the highest percentage, reaching 90%. Consequently, the critical thinking abilities of the students in the control group who used traditional laboratories did not increase.
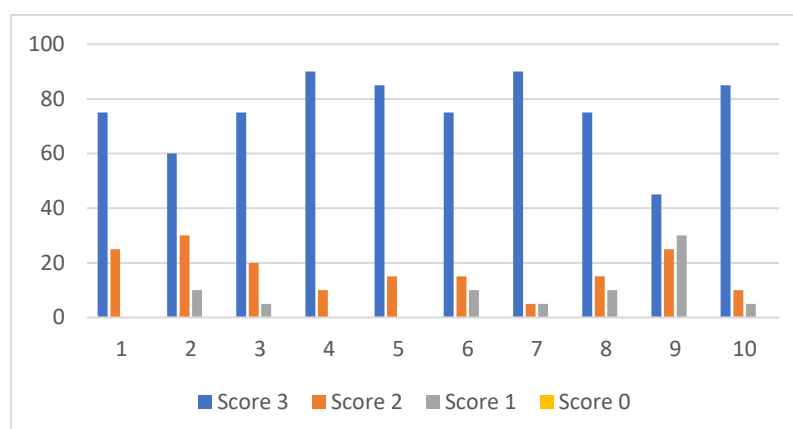

Figure 3. Percentage of the experiment class's average critical thinking skills score from each question item

Only questions 2 and 9 had low evaluation scores in the experimental class, while nearly every question had a percentage above 70%. In order to accurately answer questions and provide valid justifications, students in the experimental class are accustomed to participating in class discussions using the PhET simulation medium and the guided inquiry approach. Students who already know how to perform experiments using a guided inquiry approach that adheres to the steps in the scientific method have an impact on this. Students will become increasingly aware that they will conduct experiments on their own and that the teacher will simply serve as a facilitator as they commonly learn in the lab. Students can develop their critical thinking abilities if the curriculum is specifically created to do so through a progression of inquiry learning from concepts that are understood and observable to concepts that are abstract and difficult to understand supports this (Alsaleh, 2020).

The differences between the class which used PhET media with the guided inquiry model, and the class which used conventional learning

The control class's pretest results on critical thinking ability on the topic of acids and bases yielded a significance value of 0.154 and a post-test result of 0.110, while the experimental class's pretest data on the same topic produced a significance value of 0.143 and a post-test result of 0.151, according to the results of the normality test. Based on the results of the Kolmogorov-Smirnov normality test, which have a significance value of higher than 0.05, it can be said that the pre- and post-test data in both groups are regularly distributed.

The experimental class and control class's pretest and posttest scores on critical thinking ability items were compared as part of the data homogeneity test, which was conducted for both classes. The Levene Test for Equality of Variances yielded significance scores of 0.48 and 0.37. The variance of the two sample groups is deemed homogeneous as this significance value is more than 0.05.

The differences between the experimental class, which used PhET media with the guided inquiry model, and the control class, which used conventional learning, were then tested using a t test. The calculated pretest score for both classes, according to the author's findings, was -0.26. It can be concluded that there was no significant difference prior to learning using PhET simulation media because the significance is less than 0.05. The posttest t score, according to the author's findings, was 2.87. Given that the significance value is more than 0.05, it can be concluded that using PhET simulation media in conjunction with a guided inquiry strategy has improved the participants' critical thinking abilities. Subsequently, the author discovered that the N-Gain t-count was 6.32. Since this significance value is also greater than 0.05, it can be concluded that using PhET simulation media in conjunction with a guided inquiry approach increases students' critical thinking abilities. Put another way, using PhET simulation media in conjunction with a guided inquiry approach can help students become more adept at critical thinkers.

Discussion

When the guided inquiry method is being used in the control and experimental classes, students create preliminary theories about issues that are currently being faced, and

the teacher assists groups that are having trouble solving problems. In order to gather the information required to address problems utilizing traditional learning in the control class and PhET animation medium in the experimental class, the teacher asks the students to collaborate in conducting experiments. Test the validity of the hypothesis answer by having students in the experimental class complete their worksheets using PhET animations and the control class begin performing traditional practicums in the lab. Both classes then present their findings to the class for discussion.

Students conceptual comprehension improved as a result of the guided inquiry learning paradigm (Wahyuni et al., 2016). The guided inquiry learning model is an investigation-based learning approach in which students solve their own challenges (Nurmayani & Doyan, 2018). Students can be guided to recognize what they have learnt during the learning process by using the guided inquiry learning methodology. The foundation of the guided inquiry learning paradigm consists of the students' analytical and investigative skills (Kuhlthau et al., 2015).

Students with varied group members can collaborate to solve problems and share ideas using a guided inquiry approach. Students can also learn how to solve issues critically, honestly, collectively, and fairly and objectively. The guided inquiry approach aids teachers in presenting material to students while they work in groups (Cahyono, 2007). Students look over the problems on worksheets to be solved in these groups, and the teacher gives instructions on how to find answers. Students then select the best and most appropriate ideas to use in solving the given problems, using their selections to provide the solution.

The guided inquiry learning methodology uses the PhET interactive simulation virtual laboratory to teach students how to apply the scientific method, which entails articulating a problem, generating a hypothesis, gathering data, testing the hypothesis, and drawing conclusions (Gunawan et al., 2019). Students' science process abilities can be enhanced through the use of inquiry learning. Virtual laboratories offer valuable virtual experiences by showcasing key ideas, principles, and instructional procedures. In other words, virtual laboratories give students the chance to double-check their mistakes or get more insight into the scientific method (Chang, 2016).

Using PhET simulation learning makes students interested and motivated to complete student learning outcomes, increasing conceptual understanding in experimental classes using PhET simulations is higher than increasing conceptual understanding in control classes using conventional learning. Aside from that, the PhET simulation provides thorough explanations and leaves a pleasant, delightful experience. Students responded well to inquiry laboratory activities because they worked on and discussed the outcomes of the exercises themselves, which helped them understand the subject covered in a short amount of time.

Conclusion

The study's conclusion is that students' critical thinking abilities can be enhanced by using PhET interactive simulations media in conjunction with a guided inquiry method. The post test t count of 2.87 > 0.05 and the N-Gain of 6.32 > 0.05 provide evidence for this. This demonstrates that when combining PhET Interactive Simulations media with a guided

inquiry approach, the average learning outcomes are higher than when using a conventional method. Comparing the efficacy of this learning with other comparable virtual media is a recommendation for future research aimed at examining the utilization of PhET interactive simulations media. In addition, it was expected that research on developing lesson plans with PhET interactive simulations would be conducted.

References

Alsaleh, N. J. (2020). Teaching Critical Thinking Skills: Literature Review. In *TOJET: The Turkish Online Journal of Educational Technology* (Vol. 19, Issue 1).

Antara, I. P. P. A. (2022). Model Pembelajaran Problem Based Learning Untuk Meningkatkan Hasil Belajar Kimia Pada Pokok Bahasan Termokimia. *Journal of Education Action Research*, *6*(1), 15–21.

Buchori, A., & Pramasdyahsari, A. S. (2021). Implementation of virtual laboratory media to learning geometry in mathematics education program of Universitas PGRI Semarang. *International Journal of Research in Education (IJRE)*, *1*(1), 41–50.

Cahyono, A. N. (2007). Pengembangan Model Creative Problem Solving berbasis Teknologi dalam Pembelajaran Matematika di SMA. *Tersedia: Http://Www. Adinegara. Blogspot. Com*.

Chang, V. (2016). Review and discussion: E-learning for academia and industry. *International Journal of Information Management*, *36*(3), 476–485.

Darman, R. A. (2020). *Belajar dan pembelajaran*. Guepedia.

Fadli, M. R., Sudrajat, A., Zulkarnain, A., Setiawan, R., & Amboro, K. (2020). The effectiveness of E-Module learning history inquiry model to grow student historical thinking skills material event proclamation of Independence. *Decision Making*, *6*(7).

Fithriani, S. L., Halim, A., & Khaldun, I. (2016). Penggunaan media simulasi PhET dengan pendekatan inkuiri terbimbing untuk meningkatkan keterampilan berpikir kritis siswa pada pokok bahasan kalor di SMA Negeri 12 Banda Aceh. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, *4*(2), 45–52.

Greenstein, L. M. (2012). *Assessing 21st century skills: A guide to evaluating mastery and authentic learning*. Corwin Press.

Gunawan, G., Harjono, A., Hermansyah, H., & Herayanti, L. (2019). Guided inquiry model through virtual laboratory to enhance students'science process skills on heat concept. *Jurnal Cakrawala Pendidikan*, *38*(2), 259–268.

Hanief, Y. N., & Himawanto, W. (2017). *Statistik pendidikan*. Deepublish.

Johnstone, A. H., & Otis, K. H. (2006). Concept mapping in problem based learning: a cautionary tale. *Chemistry Education Research and Practice*, *7*(2), 84–95.

Krishnan, P. (2023). A review of the non-equivalent control group post-test-only design. *Nurse Researcher*, *31*(1).

Kuhlthau, C. C., Maniotes, L. K., & Caspari, A. K. (2015). *Guided inquiry: Learning in the 21st century*. Bloomsbury Publishing USA.

Lestari, D. D., & Muchlis, M. (2021). E-LKPD berorientasi contextual teaching and learning untuk melatihkan keterampilan berpikir kritis siswa pada materi termokimia. *Jurnal Pendidikan Kimia Indonesia*, *5*(1), 25–33.

Liliasari, M. (2001). Model Pembelajaran IPA untuk Meningkatkan Keterampilan Berpikir Tingkat Tinggi Calon Guru sebagai Kecenderungan Baru pada Era Globalisasi. *Jurnal Pengajaran MIPA*, *2*(1), 54–66.

Nurmayani, L., & Doyan, A. (2018). Pengaruh model pembelajaran inkuiri terbimbing terhadap hasil belajar fisika peserta didik. *Jurnal Penelitian Pendidikan IPA*, *4*(2).

Perkins, K., Adams, W., Dubson, M., Finkelstein, N., Reid, S., Wieman, C., & LeMaster, R. (2006). PhET: Interactive simulations for teaching and learning physics. *The Physics Teacher*, *44*(1), 18–23.

Putranta, H., & Kuswanto, H. (2018). Improving students' critical thinking ability using problem based learning (PBL) learning model based on PhET simulation. *SAR Journal*, *1*(3), 77–87.

Ramadhani, L. F., Nurjannah, I. M., Yulistiani, R., & Saputro, E. A. (2020). teknologi aktivasi fisika pada pembuatan karbon aktif dari limbah tempurung kelapa. *Jurnal Teknik Kimia*, *26*(2), 42–53.

Ristiyani, E., & Bahriah, E. S. (2016). Analisis kesulitan belajar kimia siswa di SMAN X Kota Tangerang Selatan. *Jurnal Penelitian Dan Pembelajaran IPA*, *2*(1), 18–29.

Sutrisno. (2011). *Pengantar Pembelajaran Inovatif*.

Wahyuni, R., Hikmawati, H., & Taufik, M. (2016). Pengaruh model pembelajaran inkuiri terbimbing dengan metode eksperimen terhadap hasil belajar fisika siswa kelas XI IPA SMAN 2 Mataram tahun pelajaran 2016/2017. *Jurnal Pendidikan Fisika Dan Teknologi*, *2*(4), 164–169.

Yang, L., Feng, Z., & Meng, J. (2023). An intelligent experimental container suite: using a chemical experiment with virtual-real fusion as an example. *Virtual Reality and Intelligent Hardware*, *5*(4), 317–337. https://doi.org/10.1016/j.vrih.2022.07.008

Yunitasari, Y., Danim, S., & Kristiawan, M. (2022). Pengaruh Penerapan Discovery Learning Berbantuan Virtual Laboratory terhadap Minat dan Hasil Belajar Siswa pada Masa Pandemi. *JURNAL PENDIDIKAN MIPA*, *12*(4), 1117–1124.