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The Development of an Augmented Reality-Based Virtual Reality Laboratory on Chemical Equilibrium Material to Increase Science Process Skills

Rafaela Renha Rena Novia; Jaslin Ikhsan

Chemistry Education, Yogyakarta State University, Indonesia

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Abstract

This study aims to develop an Augmented Reality-Based Virtual Reality Laboratory on Chemical Equilibrium Material to Increase Science Process Skills. The research method used is Research and Development (R&D) using the Four-D Model (4D Model). The subjects in this study were 11th-grade students at a high school in Yogyakarta. The results of this research and development are an Augmented Reality-based virtual laboratory presented in the form of an APK file that can represent 3D. The Augmented Reality-based virtual laboratory developed has also been deemed feasible by subject matter and media experts, teachers, and students in terms of its readability. The results of the trial showed that the augmented reality-based virtual laboratory can improve science process skills by 0.35, which is classified as moderate. This shows that the augmented reality-based virtual laboratory is effective in improving students' science process skills.

Keywords: *Virtual Laboratory; Augmented Reality; Science Process Skills*

Introduction

Learning today, especially in the 21st century, requires the extensive use of technology in the teaching and learning process. This technological advancement has resulted in society becoming very familiar with *smartphone* applications in their daily routines because they rely on computer programming. Chemistry is a branch of natural science that plays an important role in school learning. This branch of science studies various compositions, properties, structures, changes, energy, and natural phenomena (Ernawati & Ikhsan, 2023). These natural phenomena can be explained based on the concepts, theories, and laws of chemistry. In studying these concepts, theories, and laws, chemistry relates three levels of representation, namely macroscopic, microscopic, and symbolic (Tima & Sutrisno, 2020). Macroscopic representation is able to describe real observations of chemical phenomena occurring through the five senses, for example, in the events of color change, temperature, pH, and the formation of precipitates in chemical reactions (Zabala & Dayaganon, 2023). Submicroscopic representation is able to explain the observation process that occurs at the atomic or molecular particle level of phenomena occurring in macroscopic representation (Pane et al., 2023). In contrast, symbolic representation describes the use of symbols, reaction equations, images, diagrams, and chemical formulas (Tima & Sutrisno, 2020).

Practical work is one of the activities that supports these three levels of representation, but field studies reveal various limitations, such as a lack of equipment and materials, time constraints. Additionally, laboratory experiments alone cannot fully represent the submicroscopic level (Alhashem & Alfailakawi, 2023). As time progresses, abstract material can be explained with the help of technology (Broyer et al., 2020). Virtual simulation technology is virtual reality displayed in three dimensions on a computer. This simulation provides an immersive experience through various senses such as sight, touch, and hearing (Purwaningtyas et al., 2022). Many studies have stated that learning at various levels that apply simulation-based learning has successfully integrated theoretical knowledge with practice (Ernawati & Ikhsan, 2023). Some of the positive impacts experienced by students include improved student performance before conducting practical work in real laboratories, the opportunity for students to repeat desired experiments, an interactive learning environment, high flexibility and accessibility, improved achievement and learning motivation, and savings in time and costs (Köseler & Kalyon, 2020).(Amin & Ikhsan, 2021)(Gambari et al., 2018).

The topic of chemical equilibrium taught to grade XI MIPA students consists of factual, conceptual, procedural, and metacognitive knowledge. This material is a prerequisite for building most basic chemistry concepts, so it must be mastered well. The factual knowledge in this material, when analyzed based on the reaction pathway, divides equilibrium reactions into two types: reversible and irreversible reactions (Chang, 2004). Furthermore, the conceptual knowledge in this material is that reactions will occur in a state of equilibrium if there is no external influence, and the procedural knowledge in this chemical equilibrium material is that the process of making ammonia is carried out through the Haber-Bosch process (Haryono, 2019). However, in reality, the material on chemical equilibrium is still difficult for most students to understand. One of the main reasons is that this material involves dynamic concepts, such as reversible reactions, which are difficult to understand without the aid of visualization. Therefore, good visual depictions are needed during the learning process and during evaluation (Sofia, 2019). Interviews with chemistry teachers revealed that chemical equilibrium is one of the most challenging topics in practical work because time constraints during lessons prevent students from carrying out practical work at school. In addition, the main material covering the topic of chemical equilibrium includes many chemical concepts and requires clear visualization by students. Thus, they can relate the material studied to the results obtained when conducting practical work. Based on the questionnaire distributed to students, it was found that chemistry practical work conducted at school is usually once per semester.

Several visual representations incorporated into chemistry learning can improve learning outcomes, especially when students are taught to actively connect chemical representations such as moving particle animations, and encourage students to predict, observe, and make explanations based on the results of their visualizations (Lubis & Ikhsan, 2015). Learning materials will be easier to understand if they are implemented visually. Visualization can maximize the presentation of concepts that are sometimes considered difficult by students in the learning process. In addition, visualization makes the learning experience more meaningful. The limitations of students' concepts and skills are a source of difficulty in three-dimensional (3D) thinking (Falah et al., 2021). The application of augmented reality (AR) helps teachers and students in presenting three-dimensional visual representations, so that abstract mechanisms can be presented more realistically with 3D displays (Rusdi et al., 2023).

The novelty of this research is a 3-dimensional virtual laboratory product with AR. AR elements and virtual laboratories are two combinations of software that use the Unity programming language and are capable of visually representing laboratory equipment and chemicals (Salvetti & Bertagni, 2019). Markers presented in the virtual laboratory help students access AR elements (Azma et al., 2022). Science process skills are very important to instill in the learning of today's students, due to the rapid development of science and technology, which causes teachers not to teach all concepts and facts to students but rather (Molefe et al., 2016). That is why the development of this Augmented Reality-based virtual laboratory is very important to developed. This is why this research needs to be conducted, not only to provide a new experience for teachers and students but also to determine the extent to which Augmented Reality-based virtual laboratories are utilized in chemistry learning, particularly on the topic of chemical equilibrium.

Method

This type of research is research and development using the 4D Model developed by Thiagarajan. The Define stage was carried out in several stages, namely, needs analysis, analysis of students' chemistry learning abilities, task analysis, concept analysis, and learning objective analysis. The results obtained at this stage were used as a reference when designing the virtual laboratory to be developed. Next, in the Design stage, with the aim of directing the product development process, several stages were carried out, namely instrument preparation, media determination, format determination, and initial product preparation. The result obtained was the design of a virtual laboratory based on Augmented Reality that is currently being developed. The Develop stage involved assessment of the final product by validators, feasibility testing, and readability testing. Validation was carried out by two experts in learning materials and media. At the same stage, development trials were also conducted, including practicality tests by five chemistry teachers and readability tests by 72 students. The results obtained at this stage were an assessment of the developed Augmented Reality-based virtual laboratory, as well as suggestions and input for improvements to the virtual laboratory. The final stage, dissemination, involved testing the effectiveness of the product and disseminating the final product.

The data collection techniques used were non-tests in the form of questionnaires, interviews, literature studies, and tests in the form of pretest and posttest questions. The data collection tools used included questionnaires to analyze student needs, product feasibility validation sheets (subject matter experts and media experts), questionnaires on practicality by chemistry teachers and readability by students, and questions on the topic of chemical equilibrium. The grid for the science process skills questions developed can be seen in Table 1 below.

Table 1. Science Process Skills Item Matrix

Science Process Skills Aspect	Question Indicators	I N	Cognitive
Observe	Students can predict a state in an equilibrium reaction and the effect of temperature on the reaction.	19 and 20	C3
	Students can analyze the effect of volume on a reaction in a practical experiment, namely by presenting nitrogen dioxide gas in two different tubes and observing the phenomenon that occurs when pressure is added and reduced pressure on the color change of the gas	23	C4
	Students can determine the equilibrium constant formula (K) from a reaction equation.	7	C3
Classify	Students can determine *reversible* reactions between molecules through the questions presented	1	C3
	Students can classify the characteristics of chemical reactions chemical equilibrium	2	C3
	Students can classify the characteristics of chemical equilibrium reactions.	3	C2

	Students can give examples of homogeneous and heterogeneous equilibrium reaction equations	4 and 5	C2
	Students can determine examples of factors that influence the shift in the direction of equilibrium presented by chemical reaction equations	22	C3
	Students can identify the effect of catalysts on reactions.	28	C2
Science Process Skills Aspect	Question Indicators	Item Number	Cognitive Dimensin
	Equilibrium		
Interpreting data	Students can determine a calculation the dissociation equilibrium of a reaction presented from the known molar reaction	10	C3
	Analyzing quantitative calculations where the equilibrium constant (Kp) is known and the following is asked: partial pressure of the substance	11	C3
	Students can predict the shift in the direction of equilibrium, the value of K, and the color of the solution in the tube reaction tube formed when the temperature is increased in the equilibrium reaction process.	12	C3
	Students can determine the equilibrium constant (Kp) value of a reaction presented from known, namely the moles of the reaction	13	C3
	Students can determine the equilibrium constant value of equilibrium (Kp) for a given reaction from the known value of moles of reaction	14	C3
	Students can determine the equilibrium constant (Kp) value of a reaction presented from the known reaction moles	30	C3
	Students can determine the calculation of the equilibrium constant of equilibrium (Kc) for a given reaction from the known value of Kp	15	C3
	Students can analyze the effect of volume on a reaction in a practical experiment in which nitrogen dioxide gas is presented in two different tubes and the phenomenon that occurs when pressure is added and reduced on the color change of the gas.	23	C4
Communicate	Students can predict a state in equilibrium reactions and the effect of temperature on reactions	19 and 20	C3
	Students can analyze the effect of volume on a reaction in a practical experiment, namely by presenting nitrogen dioxide gas in two different tubes and the phenomenon that occurs when pressure is added and reduced on the color change of the gas	23	C4
Conclusion	Students can determine the equilibrium constant formula (K) from a reaction equation	6, 7, 8, and 9	C3
	Students can express the relationship of equilibrium reactions in the industrial world	24	C5
	Students can learn about the effect of catalysts on equilibrium reactions.	28	C2
	Students can learn the effect of catalysts on equilibrium reactions	29	C3
Predict	Students can determine the relationship between the equilibrium constant (Kc) of a given reaction and the factors that influence the shift equilibrium	16	C3
	Students can predict a state in an equilibrium reaction and the effect of temperature on the reaction	17	C2
		18	
Aspect Science Process Skills	Question Indicators	Item Number	Cognitive Dimensin
Controlling Variables	Students can predict a state in an equilibrium reaction and the effect of temperature on the reaction	19 and 20	C3
Planning Experiments	Students can analyze equilibrium reactions in the industrial world to obtain optimal experimental results	25	C4
Formulating Hypotheses	Students can predict a state of equilibrium reaction and the effect of temperature on the reaction.	21	C3

Measure	Students can predict a state in equilibrium reactions and the effect of temperature on reactions.	19 and 30	C3
	Students can analyze the effect of volume on a reaction in a practical experiment, namely by presenting nitrogen dioxide gas in two different tubes and th phenomenon that occurs when pressure is added and reduced on the color change of the gas	23	C4

This research was conducted at a high school in central Yogyakarta during the odd semester of the 2024/2025 academic year. The research subjects used for the effectiveness test were 108 students. The validity of the research was in the form of theoretical and empirical validity, where theoretical validity was carried out qualitatively and quantitatively by subject matter experts and media experts. Qualitative assessment took the form of input and suggestions based on the products developed. Quantitative assessment was carried out by processing data in the form of a Likert scale by calculating the percentage by dividing the total score obtained by the maximum score. The data obtained was then interpreted based on product quality categories.

Table 2. Product Quality Percentage Categories

Percentage (%)	Category
81 – 100	Very Good
61 – 80	Good
41–60	Fair
21–40	Poor
0 – 20	Very insufficient

Next, empirical validity was carried out by testing the science process skills test instrument on students outside the research sample who had already learned about chemical equilibrium. The results obtained from the empirical test in the form of science process skills questions were analyzed using the Rash Model with the Winstep application to determine the validity and reliability of the items. Items were declared valid if they met at least two of the criteria in the following Rasch Model analysis (Sumintono & Widhiarso, 2015).

Table 3. Item Fit Criteria for the Rash Model

Criteria	Description
0.5 < MNSQ < 1.5	Accepted *MNSQ* value
-2.0 < ZSTD < +2.0	Accepted *ZSTD* value
0.4 < Pt Measure Corr ≤ 0.85	Accepted *Pt Measure Corr* value

Development testing using data analysis techniques with a comparison of average scores obtained using a Likert scale for each ideal validation category using the following formula:

$$\bar{x} = \frac{\Sigma x}{n}$$

Description:

Mi = Ideal average = ½ (ideal highest score + ideal lowest score)

Sbi = Ideal standard deviation = 1/6 (ideal highest score - ideal lowest score)

A virtual laboratory based on Augmented Reality on chemical equilibrium material can be considered feasible if it has an actual score on the validation sheet of at least in the good category.

The analysis of test instruments in the form of pretest and posttest items is carried out by calculating the average obtained from each aspect of the instrument. The test instruments are analyzed using the following formula.

$N = \Sigma X/n$

N: Science process skill score

ΣX: Total score

n: Number of items assessed

The *N-Gain* score obtained will be converted using the categories in Table

Table 5, N-Gain Score Categories

***N-Gain* Range**	**Category**
$g > 0.7$	High
$0.7 > g > 0.3$	Medium
$g < 0.3$	Low

Results and Discussion

Product development results

The define stage involved several steps to describe the requirements and gather various information related to the development of virtual laboratory products. There was an initial analysis based on interviews with two chemistry teachers at the school where the research was conducted, who had not yet maximized the use of technology in chemistry learning, even though there were several supporting facilities such as computers and the internet. The main learning resources commonly used in the learning process were worksheets from teachers, textbooks, and video links for independent learning. Chemistry learning at the school predominantly uses the DI learning model with lecture and group question and answer methods. The teacher also said that he had never implemented the development of an AR-based virtual reality laboratory. The results of the observations and interviews described above require an innovation that supports learning activities, especially in the scientific process skills and self-efficacy of students. One of the innovations developed is an augmented reality-based virtual reality laboratory media. This media is very practical and can be accessed via smartphones, tablets, laptops, and computers. Students' chemistry learning abilities were obtained based on interviews with chemistry teachers, field observations, and questionnaires given to students who had studied chemical equilibrium material. Teachers reported that students' overall chemistry learning abilities met the minimum competency standards (KKM) on average, but there were also some students who did not meet the KKM in their class. The researcher conducted field observations while the teacher was teaching in class. The results showed that students tended to be passive in learning, with only a few students being enthusiastic from the beginning to the end of the lesson. Task analysis was based on the main competencies given to students in this study. In this study, there were two aspects to be assessed, namely cognitive and affective. The KPS aspects to be analyzed in this study included observing, classifying, interpreting data, communicating, concluding, predicting, controlling variables, planning experiments, formulating hypotheses, and measuring. Concept analysis is carried out at this stage to identify the main concepts contained in the material, learning activities, and AR-based practical simulations needed to develop the product. The learning objectives were formulated based on the results of the concept analysis, task analysis, and learning outcomes listed in the Merdeka Curriculum. The learning objectives were able to determine how the developed product, namely the augmented reality-based virtual reality laboratory, influenced science process skills.

The design stage includes instrument development, media selection, format selection, and initial product development. The result of the development was 30 science process skill questions, which were then validated theoretically by two experts and empirically by 108 students. The results obtained from the 30 questions showed that

25 items were valid and reliable based on the Rasch Model analysis. The media selected in developing the augmented reality-based virtual reality laboratory was Unity, which resulted in an application called Chembri that can be accessed on Android smartphones, Android tablets, computers,

and laptops. The 3D visualization of augmented reality concepts makes it easier for students to visualize the format selected in the augmented reality- based virtual reality laboratory. The initial product design consists of competencies, materials, AR simulations of virtual laboratory experiments, formative tests, a bibliography, and a development profile. In addition, the virtual reality laboratory also consists of images and videos that are expected to provide a better understanding to students studying chemical equilibrium material.

The development stage consists of expert validation followed by development trials in the form of practicality tests by chemistry teachers and readability tests by students. The validation, conducted by two Chemistry Education lecturers, aimed to provide an assessment of the feasibility and suggestions related to the material and media of the augmented reality-based virtual reality laboratory. The validation results showed that the developed product was feasible for use with some revisions to the chemistry content.

The dissemination stage includes effectiveness testing and dissemination of the product, the augmented reality-based virtual reality laboratory. The effectiveness test was conducted using a two-class pre-post design and random sampling technique. The virtual laboratory product was packaged in APK form and named Chemri, which can be accessed via Android smartphones or tablets. The dissemination of the augmented reality-based virtual reality laboratory product was carried out through article publications, and the product was distributed to teachers and students at the research school.

Characteristics of the Virtual Laboratory

The augmented reality (AR)-based virtual laboratory is a practical simulation packaged in APK format. The layout design was carried out using the Canva application, followed by AR animation facilitated by the Unity application until the APK display could be accessed using an Android smartphone/tablet. The main components displayed in the augmented reality-based virtual laboratory (Chemri) are competencies, materials, AR simulations of virtual laboratory experiments (consisting of 4 experiments), formative tests, a bibliography, and a development profile, as shown in the figure below:

Figure 1. Log in, Main Menu, and Competencies

Figure 2. Instructions for Use, Materials, and Sample Questions

Figure 3. *Augmented Reality Markers* from 4 Experiments

Figure 4. Experiment Simulation Display

Figure 5. Formative Test Display

Figure 6. Reference List and Development Profile Display

Feasibility of Virtual Laboratory

These results were evaluated based on material and media validation by experts, practicality testing, and readability questionnaires. The feasibility of the virtual laboratory was developed based on material evaluated by subject matter experts regarding learning aspects, material aspects, and language aspects, while media experts evaluated presentation techniques, graphic feasibility, linguistic feasibility, product usage quality, and product application quality. Qualitatively, several suggestions and inputs from lecturers were provided to improve the developed product:

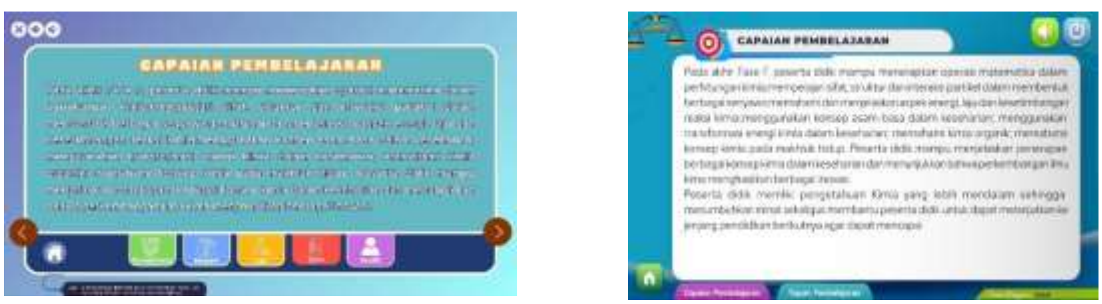

Figure 7. Improvement of layout appearance and icon color contrast

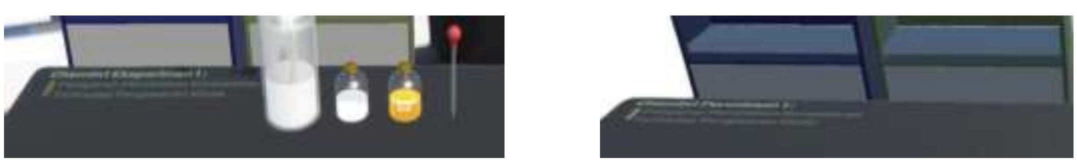

Figure 8. Improvement of the word "experiment" to "experiment"

Quantitatively, the average validation score from subject matter experts was 82, which is classified as very good in Table 2. The highest average score was obtained in the learning and material aspects. As for media experts, the average validation result was 89, which is classified as very good. The highest average was in the aspects of product usage quality, graphic feasibility, and linguistic feasibility. AR-based virtual laboratories can also be accessed anywhere and anytime, making it easier for students to use them (Logan et al., 2021).

Meanwhile, the comparison of average scores with the validation categories used for the development test (practicality test and readability response test). Based on the results of the practicality test by teachers, the average total score for all aspects was Based on the results obtained from the overall average of the assessment aspects for the teacher's practicality test, which was 108, where X > 100, which is classified as the Excellent category, with the highest average score in the learning and media display & operation aspects.

Similarly, the results of the readability test given to 72 students were directly proportional to the product's practicality test, with an overall average score of 82.73, where X > 76, which falls into the Excellent category. Therefore, the conclusion is that the product developed by the Augmented Reality-Based Virtual Reality Laboratory falls into the Excellent category, with the highest average score in the learning and material aspects, as well as the display and media operational aspects. Based on these results, it can be interpreted that the developed product, the augmented reality-based virtual laboratory, has a positive impact on its users.

Effectiveness Test Results

The effectiveness test was conducted on 108 students by analyzing the results of science process skills before and after using the augmented reality-based virtual laboratory on chemical equilibrium material. Based on the data obtained, the science process skill score before using the augmented reality-based virtual laboratory product was 68, with the lowest score being 40 and the highest score being 72. Meanwhile, the science process skills score after using the augmented reality-based virtual laboratory product was 78, with the lowest score being 60 and the highest score being 86, indicating an increase. The increase was 10, which was classified as moderate when converted using N-gain with a result of 0.35.

Based on the average N-Gain results for each indicator, the results obtained for the class that was given the treatment of using the product were as follows: observing obtained 0.39, classifying obtained 0.24, interpreting data obtained 0.24, communicating obtained 0.34, concluding obtained 0.40, predicting obtained 0.33, controlling variables obtained 0.31, planning experiments obtained 0.35, formulating hypotheses 0.38, and measuring 0.40. In contrast, the N-Gain for those who did not receive treatment using the product is as follows: observing obtained 0.15, classifying obtained 0.12 interpreting data obtained 0.09 communicating obtained 0.14 concluding obtained

0.09 predicting obtained 0.09 controlling variables obtained 0.02 planning experiments obtained 0.09 formulating hypotheses 0.09 and measuring 0.08. This directly shows that learning using Chembri products (augmented reality- based virtual reality laboratories) is effective in increasing KPS compared to learning that is not given treatment or does not use augmented reality-based virtual reality laboratories in the control class. The application of AR technology in learning has been very successful. Chemistry learning is dominated by things that cannot be observed directly through the senses, so it is aided by AR technology (Ramadhanti et al., 2021). Science process skills are described as abilities that can develop curiosity, responsibility, independent learning, and can help students in conducting practical work with their process skills. This clarifies that the influence of augmented reality-based virtual laboratory products has a positive effect on science process skills (Molefe et al., 2016).

Conclusion

Based on the results of research and development, it can be concluded that the augmented reality-based virtual laboratory that has been developed is categorized as feasible by media and material experts, readable by teachers, and responsive to students. Augmented reality-based virtual laboratory products can improve science process skills based on N-Gain results of 0.35, which is classified as moderate. This reinforces that developing augmented reality-based virtual laboratories is recommended for other chemistry learning materials.

References

Alhashem, F., & Alfailakawi, A. (2023). Technology-enhanced learning through virtual laboratories in chemistry education. Contemporary Educational Technology, 15(4). https://doi.org/10.30935/cedtech/13739

Amin, I. D., & Ikhsan, J. (2021). Improving higher order thinking skills via semi second Life. European Journal of Education Research, 10, 261–274.

Azwar, S. (2012). Compilation of Psychological Scales (Edition III). Pustaka Pelajar

Azma, N., Cahyono, E., & Nuswowati, M. (2022). International Journal of Active Learning Effectiveness of Online Learning Assisted by Olabs Virtual Laboratory in Improving Students' Science Process Skills. International Journal of Active Learning. http://journal.unnes.ac.id/nju/index.php/ijal

Broyer, R. M., Miller, K., Ramachandran, S., Fu, S., Howell, K., & Cutchin, S. (2021). Using Virtual Reality to Demonstrate Glove Hygiene in Introductory Chemistry Laboratories. Journal of Chemical Education, 98(1), 224–229. https://doi.org/10.1021/acs.jchemed.0c00137

Chang, R. (2004). Basic Chemistry Core Concepts (III). Erlangga.

Ernawati, D., & Ikhsan, J. (2023). 3D-Virtual lab to resolve laboratory work's problems during the COVID-19 pandemic. https://doi.org/10.1063/5.0130690

Falah, J., Wedyan, M., Alfalah, S. F. M., Abu-Tarboush, M., Al-Jakheem, A., Al-Faraneh, M., Abuhammad, A., & Charissis, V. (2021). Identifying the characteristics of virtual reality gamification for complex educational topics. Multimodal Technologies and Interaction, 5(9). https://doi.org/10.3390/mti5090053

Gambari, A. I., Kawu, H., & Falode, O. C. (2018). Impact of virtual laboratory on the achievement of secondary school chemistry students in homogeneous and heterogeneous collaborative environments. Contemporary Educational Technology, 9(3), 246–263. https://doi.org/10.30935/cet.444108

Haryono, H. E. (2019). Basic Chemistry. Deepublish.

Köseler, C., & Kalyon, D. S. (2020). Impact of Argument-Based Laboratory Method on Scientific Process Skills of Pre- Service Primary School Teachers and Their Views of The Nature of Science. Journal of Curriculum and Teaching, 9(4), 75. https://doi.org/10.5430/jct.v9n4p75

Logan, R., Johnson, C., & Worsham, J. (2021). Development of an e-learning module to facilitate student learning and outcomes. Teaching and Learning in Nursing.

Lubis, I., & Ikhsan, J. (2015). Development of Android-Based Chemistry Learning Media to Improve Student Learning Motivation and Cognitive Achievement. Journal of Science Education Innovation, 2, 191– 201https://doi.org/10.21831/jipi.v1i2.7504

Molefe, L., Stears, M., & Hobden, S. (2016). Exploring student teachers' views of science process skills in their initial teacher education programs. South African Journal of Education, 36(3). https://doi.org/10.15700/saje.v36n3a1279

Pane, E. P., Simangunsong, A. D. B., & Sinaga, C. V. R. (2023). Development of Hybrid Flippbook Learning Media in Basic Chemistry Practicum Learning to Improve Students' Science Process Skills. PENDIPA Journal of Science Education, 7(2), 282–288. https://doi.org/10.33369/pendipa.7.2.282-288

Purwaningtyas, D. A., Prabowo, H., Napitupulu, T. A., & Purwandari, B. (2022). The Integration of Augmented Reality and Virtual Laboratory Based on the 5E Model and VARK Assessment: A Conceptual Framework. Jurnal Pendidikan IPA Indonesia, 11(3), 449–460. https://doi.org/10.15294/jpii.v11i3.36367

Ramadhanti, D., Nuryani Suwarno, R., Kuswanto FMIPA, H., & Negeri Yogyakarta, U. (2021). Literature Review: Technology Development and Utilization of Augmented Reality (AR) in Science Learning. In Indonesian Journal of Applied Science and Technology (Vol. 2, Number 4). https://journal.publication- center.com/index.php/ijast/article/view/1158/251

Rusdi, H., Riyanti, R., & Utari, P. (2023). VILBAR (Virtual Laboratory Based Augmented Reality) as a Chemistry Practicum Medium at Maros Muslim University. In Jurnal Kependidikan (Vol. 12, Number 4). https://jurnaldidaktika.org

Salvetti, F., & Bertagni, B. (2019). Virtual worlds and augmented reality: The enhanced reality lab as a best practice for advanced simulation and immersive learning. https://doi.org/10.13128/formare-24796

Tima, M. T., & Sutrisno, H. (2020). Improving Students' Self-Efficacy in Chemical Equilibrium Material After Learning with Multiple Representation-Based Problem Solving. Indonesian Journal of Chemistry Education, 4(2), 70–77. https://ejournal.undiksha.ac.id/index.php/JPK/index

Zabala, G. M., & Dayaganon, A. J. (2023). Competency of Teachers and Laboratory Environment in an Online Setting as Predictors of Science Process Skills of Students: A Convergent Design. Science Education International, 34(3), 202–215. https://doi.org/10.33828/sei.v34.i3.4