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Development of Virtual Laboratory Chemistry Based on Guided Inquiry on Buffer Solution Material for Senior High School

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ABSTRACT

A buffer solution contains many concepts that are both microscopic and macroscopic, as well as symbolic, so a practical approach is needed to make it easier to understand. This study aims to develop a guided inquiry-based chemistry virtual laboratory learning media on buffer solution material. This research uses the 4D development model, including define, design, develop, and disseminate. The instrument used is a product quality assessment sheet, including validation sheets for material experts, media, and practitioners, as well as student responses. The results of the guided inquiry-based chemistry virtual laboratory assessment on buffer solution material by material experts, media, practitioners, and student responses successively obtained an idealized percentage of 98%, 98%, 89%, and 88% in the very good category. Based on the results of the assessment, it can be concluded that the virtual laboratory chemistry learning media based on guided inquiry on buffer solution material developed is feasible to use as an alternative learning media for buffer solution material for grade XI high school students.

1. Introduction

The use of various technological tools and applications allows learning to be more adaptive, interactive, and responsive to the needs of learners (Surya & Moramowati, 2023). In addition, the application of technology in learning has the potential to be a key factor in improving learning outcomes, as technology can facilitate the learning process and provide access to more diverse and extensive resources (Sarnoto et al., 2023; Wijayanti & Widodo, 2021). Research conducted by Yulkifli et al., (2023) shows that technology integration in the learning process can increase students' learning independence and chemical literacy. Technology integration in the learning process can be achieved by utilizing technology to create learning media (Khotimah, 2019).

One of the learning media integrated with technology is a virtual laboratory (V-lab) (Rosmiati et al., 2020). V-lab is a platform, software, or multisensory media that simulates conventional laboratory activities. In use, virtual laboratories require hardware such as computers, devices, consoles, and virtual reality devices (Lestari et al., 2023). V-lab can be used to support the learning process to improve students' understanding of material, and as a solution to anticipate laboratory unpreparedness (Hikmah et al., 2017). V-lab offers an opportunity for learners who cannot attend laboratory sessions to learn empirically, and allows them to repeat experiments with different cases (Bajpai & Kumar, 2015). In addition, V-lab can also save costs (Fatimah et al., 2020), is safer than direct practice in the field (Nugroho, 2021), and allows exploring phenomena that occur in a short time or are dangerous by modifying existing variables (Petrov & Atanasova, 2020). V-lab integrated with the guided inquiry learning model can improve students' concept understanding (Faresta et al., 2023; Kurniawan et al., 2019).

The guided inquiry model is a learning process that facilitates students to search and investigate systematically, critically, logically, and analytically (Budiyono & Hartini, 2016). The guided inquiry model requires students to be able to carry out thinking activities, such as formulating problems and testing proposed hypotheses, which encourages students to be active in building their concepts (Muhali et al., 2021). At this stage, students get guidance from the teacher to get the answer to a question (Iswatun et al., 2017). Guided inquiry can improve critical thinking skills (Lindriani & Suwarna, 2023), chemical literacy (Faizin et al., 2024), creative thinking skills (Hutami et al., 2024), and student learning independence (Hamid et al., 2023). Therefore, the guided inquiry model is suitable for chemistry learning (Ariani et al., 2015).

Chemistry is a field that is closely related to students' daily lives (Mitarlis et al., 2018). Learning chemistry is an interesting and fun learning because it includes an understanding of the uniqueness of God's creation, such as the structure, composition, properties, and changes in matter (Waruwu & Sitinjak, 2022). Learners are expected to have a thorough understanding of chemical materials so that they can connect various forms of representation (macroscopic, submicroscopic, and symbolic) that often appear in everyday life (Sinaga, 2022). Adequate knowledge of students in the field of chemistry provides various benefits, including an understanding of phenomena such as changes in color and phase of substances, as well as contributions in other relevant disciplines (Juwairiah, 2013). Chemistry learning is often considered difficult by students because it involves abstract concepts (Nugroho & Prayitno, 2021; Putri & Gazali, 2021). This is also in line with a survey conducted by researchers at high schools in Bantul Regency, which shows that many students have difficulty learning chemistry because the concepts are difficult to understand. Most chemistry materials require high-level cognitive abilities, one of which is buffer solution material (Devi et al., 2018).

Buffer solution is one of the chemistry topics that requires a thorough understanding at the macroscopic, microscopic, and symbolic levels (Andriani et al., 2017; Orgill & Sutherland, 2008). Buffer solution material is closely related to the previous material, namely acid-base (Al Qadri et al., 2019). The subject matter of buffer solutions includes a discussion of the definition and components of buffer solutions, the working principles of buffer solutions, the calculation of the pH of buffer solutions, and the application of buffer solutions in everyday life (Dewara & Azhar, 2019). In understanding buffer solution material, students are required to understand the concepts well, be able to relate the material to relevant concepts, and be able to apply these concepts to solve calculation problems (Nurhujaimah et al., 2016). One way to understand buffer solution material that is full of concepts is to use interactive learning media (Aisyah & Fatisa, 2022). But learning media to help understand buffer solution material is still lacking (Ardianto et al., 2019).

2. Methodology

This research is research and development (R&D). The model used in this research adapts the 4D model, which consists of define, design, develop, and disseminate. The define stage is the initial stage of research and data collection. This stage was carried out through interviews with chemistry teachers, observations, and the distribution of questionnaires to students. The design stage is the stage of designing the product to be developed. At this stage, it is done by determining the media to be developed according to the needs at the define stage and designing media response instruments. The development stage is a stage that aims to produce learning media that have been revised based on input from experts. At this stage, the product is made by the design at design stage. The products that have been made are then tested by material experts and media experts who aim to assess and provide input on the products that have been developed. Products that have been revised and assessed by experts are then assessed and validated by chemistry teachers and responded to by thirty high school students in grade XI.

The data analysis technique was carried out by converting qualitative data from media experts, material experts, and chemistry teachers into quantitative data using a Likert scale with answer choices: Very good, good, enough, less, and very less. Each answer choice has a score of 5, 4, 3, 2, and 1. Furthermore, the average value for each aspect and the overall assessment is calculated based on the score obtained. The formula used to calculate the average value is as follows:

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

$\bar{x}$ = average score
Σx = total score
n = number of validators/raters
Then the percentage of product ideality is calculated using the formula:

$$\text{Percentage of result} = \frac{total\ score\ obtained}{total\ max\ score}\ x\ 100\%$$

The scores obtained are then converted into qualitative values following the reference as in Table 1.

Table 1. Product Eligibility Criteria

No	Percentage	Criteria
1.	81-100	Very Feasible
2.	62-80	Feasible
3.	41-61	Feasible Enough
4.	21-40	Less Feasible
5.	< 21	Very Unfeasible

The student response data obtained was converted into quantitative data using the Guttmann scale in score form. Then the percentage of idealization was calculated using the formula:

$$\text{Percentage of result} = \frac{total\ score\ obtained}{total\ max\ score}\ x\ 100\%$$

The scores obtained are then converted into qualitative values following the reference in Table 1.

3. Results and Discussion

This study aims to develop a guided inquiry-based chemistry virtual laboratory learning media on buffer solution material. This research was conducted by adapting the 4D model. The stages of the development process are carried out as follows:

a. Define

Define stage aims to analyze the needs and identify the product to be developed. At this stage, interviews and observations were conducted with five chemistry teachers in grade XI at SMA N 2 Bantul, SMA N 3 Bantul, and SMA N 1 Sewon. The purpose of this interview is to find out the problems in learning chemistry at school. Based on the results of interviews with chemistry teachers, it was found that learning is often limited to the classroom and rarely supplemented with practical activities. This is due to the limited laboratory facilities. School laboratories that are generally old and have not met the standards for ideal practicum are one of the obstacles.

In addition, limited tools and materials also hamper the implementation of practicum. Therefore, learning media that can facilitate practicum activities are needed. The results of questionnaires and observations with students show that students are less interested in the learning presented by teachers in class and tend to pay more attention to social media during learning. The next step is task analysis, which is carried out by analyzing the chemistry curriculum in the independent curriculum. The material used in this study is buffer solution.

b. Design

Design stage aims to design media based on the results of the define stage. This stage is carried out by preparing instruments, selecting media, selecting formats, and making initial media designs. The first step is the preparation of product quality assessment instruments using a Likert scale and student response instruments using a Guttman scale. The assessed aspects of the product include the feasibility of content, presentation, grammar, graphics, technical quality and use, as well as the characteristics of the chemistry virtual laboratory. The next step is to determine the media needs following the results of interviews and observations. The media chosen to be developed is a guided inquiry-based chemistry virtual laboratory on buffer solution material. The developed media consists of virtual laboratory applications and LKPD. The last step at this stage is the creation of an initial media design that aims to facilitate the process of developing the media to be developed.

The initial design of learning media is made with the help of several software, including Canva, CorelDraw, Unity 3D, and Google Drive. Canva is used to make LKPD because there are various design templates that can be used so it makes it easier to make LKPD. CorelDraw is used to create an application display design or UI (user interface) design in chemistry virtual laboratory applications because of its easy and flexible ability to create designs that suit your needs. Unity 3D is used as a place to combine components that have been made before so that it becomes a virtual laboratory application. While Google Drive is used to store LKPD so that it can be accessed and used by anyone, anytime, and anywhere without the need for the LKPD hard file.

Media development begins with making LKPD using Canva which functions as a supporting medium in using the virtual laboratory chemistry application. LKPD is made with a guided inquiry learning model and refers to the independent curriculum on buffer solution material. Next, UI design is made on the chemistry virtual laboratory application. UI is a visual display of the product that connects the system with the user that serves as the main point of user interaction. The design is then implemented in the Unity 3D application by creating a new empty scene. Next, the UI model that has been prepared will be integrated into the scene.

The final product is a chemistry virtual laboratory application named “Buffer Zone”. This application is equipped with various features, including the start menu, home, learning outcomes, general instructions, materials, virtual experiments, and assessments. In addition, there is also a settings menu that includes bibliography, developer profile, sound settings, and an exit button. The writing layout, font type and size, logo selection, icon selection, and background design are made as attractive as possible, as shown in Figure 1.

Figure 1. Home Menu of “Buffer Zone” App

The experiment menu is the most important in the Buffer Zone application. The experiment menu contains three types of virtual practicum, consisting of practicum on buffer and non-buffer solutions, making acidic buffer solutions, and making basic buffer solutions, as shown in Figure 2.

Figure 2. Experiment Menu View

The virtual experiments presented in each experimental option have instructions according to the practicum to be carried out. The practicum instructions can be adjusted in size and can be shifted when doing the practicum. This is made so that students can do the practicum independently by looking at the instructions directly. The appearance of the practicum room can be seen in Figure 3.

Figure 3. Practicum Room View

The learning outcomes menu serves to display the learning outcomes and objectives of the learning that will be carried out using the Buffer Zone application in accordance with the independent curriculum. The display of the learning outcomes menu can be seen in Figure 4.

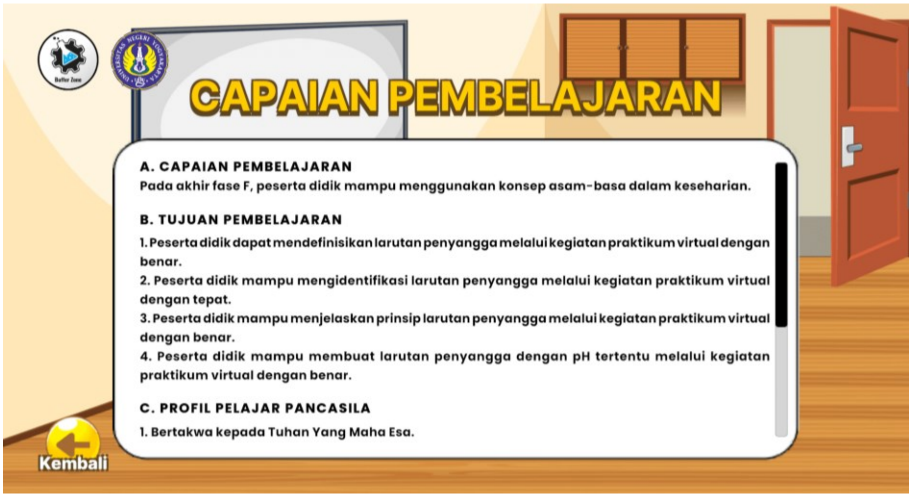

Figure 4. Learning Outcomes Menu View

The general instructions menu contains a brief description of the instructions for using the "Buffer Zone" chemistry virtual laboratory and a link associated with Google Drive to download the LKPD. The general instructions menu can be seen in Figure 5.

Figure 5. General Instructions Menu View

The Google Drive link provided in the general instruction's menu is intended so that Buffer Zone application users who do not have the LKPD hard file can download the LKPD soft file on the user's smartphone so that they can use the Buffer Zone application optimally.

The material menu serves to display brief buffer solution material. The material menu contains brief material about understanding, types, how to determine pH, and how to make buffer solutions. The material menu display can be seen in Figure 6.

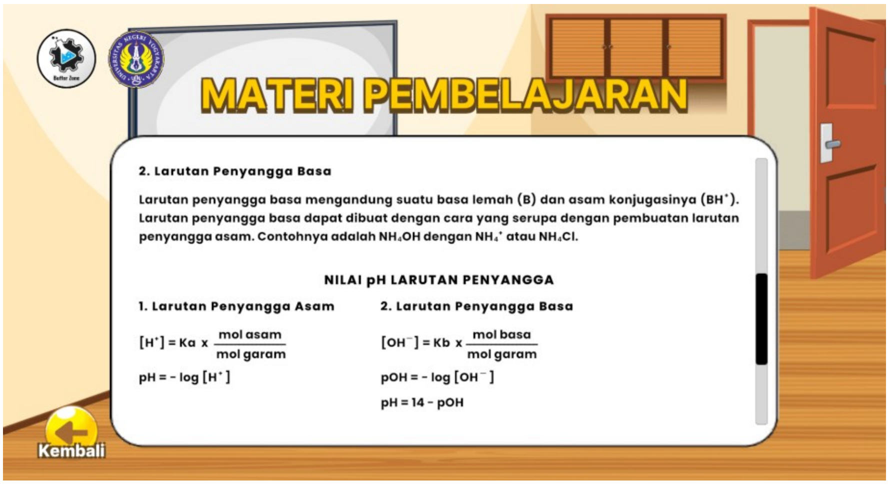

Figure 6. Material Menu View

The assessment menu serves to present a learning evaluation of buffer solution material. This menu contains three assessments containing five multiple-choice questions to evaluate student understanding after learning using the Buffer Zone application. The assessment menu can be seen in Figure 7.

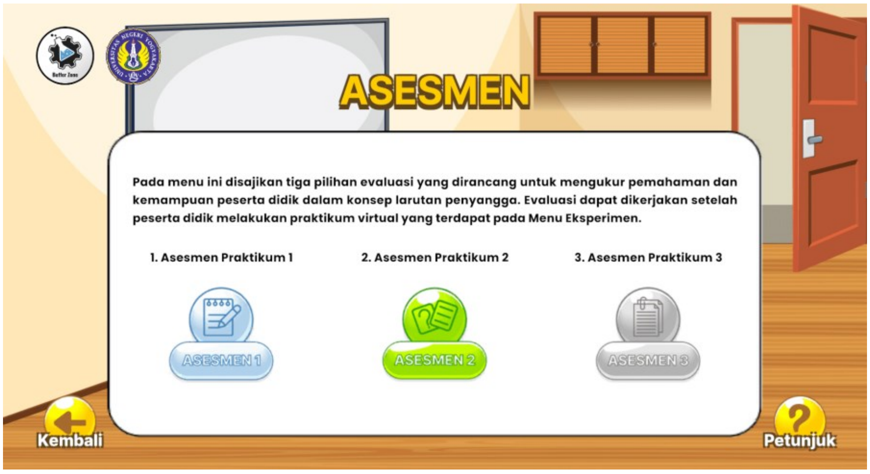

Figure 7. Assessment Menu View

Multiple choice is chosen as an evaluation question because the process is fast, but still produces the right assessment in measuring student understanding after learning is complete. When working on evaluation questions, a notification pop-up will appear when answering correctly or incorrectly and will change the total score obtained at the bottom of the question as shown in Figure 8. Then, after all the questions have been completed, the final score will appear, showing the value obtained as shown in Figure 9.

Figure 8. Notification Pop Up View

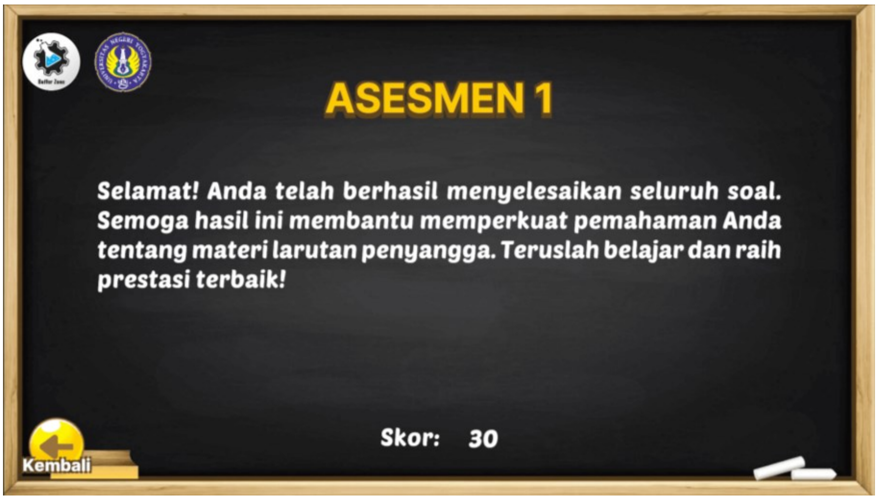

Figure 9. View of Final Score After Evaluation

In addition to these five main menus, there is a settings button in the lower right corner of the application display, which contains the bibliography menu, developer profile, sound settings, and exit button. The menu is placed on the settings button to simplify and shorten the home menu display, reducing the number of main menu buttons. The display of the settings button can be seen in Figure 10.

Figure 10. View of Settings Button

After that, the product was corrected by the supervisor. After the finished product was improved based on the correction results, the next step was to make a research instrument. The instruments developed consisted of two kinds, namely product quality assessment instruments and student responses. The product quality assessment instrument was developed using a Likert scale, while the instrument for student responses used a Guttman scale. The aspects used in the product quality assessment instrument include content feasibility, presentation, grammar, graphics, technical quality and use, as well as the characteristics of the chemistry virtual laboratory. After the instrument is completed, validation is carried out by the instrument expert.

c. Development

The development stage aims to produce learning media products that have been revised based on input from experts. At this stage, validation and assessment of the "Buffer Zone" chemistry virtual laboratory and LKPD that have been developed are carried out. The assessment was carried out using product quality assessment instruments and student responses. The assessment was carried out by two material experts, two media experts, five high school chemistry teachers, and 30 grade XI high school students who studied buffer solution material. The results of the product quality assessment and student responses can be seen in Table 2.

Table 2. Data from Product Quality Assessment and Student Response

Product Quality Assessment/ Student Response	Assessment Aspect	∑ Score	∑ Max Ideal Score	Idealization Percentage	Category
Content Expert	Feasibility of Content	48	50	98%	Very Good
	Presentation	40	40		
	Grammar	20	20		
	Characteristics of Chemistry VLab	10	10		
Media Expert	Graphics	49	50	98%	Very Good
	Technical Quality and Use	39	40		
	Characteristics of Chemistry VLab	10	10		
Practitioner (Chemistry Teacher)	Feasibility of Content	111	125	89%	Very Good
	Presentation	88	100		
	Grammar	46	50		
	Graphics	110	125		
	Technical Quality and Use	89	100		
	Characteristics of Chemistry VLab	48	50		
Students	Graphics	144	160	88%	Very Good
	Technical Quality and Use	111	128		
	Grammar	29	32		

Based on Table 2, the results of the guided inquiry-based chemistry virtual laboratory assessment on buffer solution material are obtained. The material expert assessment received a very good category with an idealized percentage of 98% so that the material in the Buffer Zone application is suitable for use in classroom learning. The assessment from the media expert received a very good category with an ideal percentage of 98% so it is feasible to use as a learning media in the classroom. Furthermore, the assessment of high school chemistry teachers received a very good category with an ideal percentage of 89%. Assessment from teachers as media users has an important role in assessing the suitability of the media developed with student characteristics. This is because teachers who use the media need to have a deep understanding of the characteristics of students and their learning needs (Ilma et al., 2022). Then, the student response test was carried out on the developed product. The percentage of ideality in students obtained a value of 88% with a very good category. This positive response is realized because students understand more about the concept of buffer solution by using the developed product.

Based on the assessment of material experts, media, chemistry teachers, and student responses, it can be concluded that the guided inquiry-based chemistry virtual laboratory on buffer solution material is suitable for use as an alternative learning media in the classroom. The development of virtual laboratory as a learning media was also carried out by Bogar et al., (2023). The study showed that the use of a virtual laboratory can improve students' understanding of complex subject matters. In addition, Rahayu (2021) also developed a virtual laboratory as an alternative learning media for students. The study showed that the use of virtual laboratories can significantly improve students' scientific attitudes.

4. Conclusion

This study aims to develop a guided inquiry-based chemistry virtual laboratory learning media on buffer solution material. Based on the research that has been done, it can be concluded that the guided inquiry-based chemistry virtual laboratory on buffer solution material has very good quality seen from the average assessment results from material experts, media, chemistry teachers, and student responses with scores of 98%, 98%, 89%, and 88% respectively. The assessment results obtained are included in the very good category, so it can be stated that the guided inquiry-based chemistry virtual laboratory on buffer solution material is feasible to use as a chemistry learning media for buffer solution material in class XI Senior High School.

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