Design and Implementation of a Virtual Lab in Ethanol Oxidation Learning by Chrom in Physical Chemistry II Laboratory

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Abstract - The development of technology and knowledge globally drives the creation of creativity and innovation in the learning process. One form of innovation that can support the learning process is Virtual Laboratory (V-Lab) technology or virtual laboratories. Constraints often encountered in physical laboratories include the need for laboratory equipment refurbishment, delays in the delivery of materials or substances required for experiments that may disrupt the learning schedule, and challenges faced by students such as the inability to repeat experiments due to time constraints, availability of materials and equipment, or errors in conducting experiments. In this final project, the MDLC method (Multimedia Development Life Cycle) is utilized, which consists of six stages, namely conceptualization, design, material collection, construction, testing, and distribution. This final project produces software in the form of an Augmented Reality application based on Virtual Laboratory, equipped with various interesting features such as interactivity between users and the interface in the application accompanied by 3D simulations and animations for the ethanol oxidation experiment by chrome. The availability of Augmented Reality-based Virtual Laboratory applications with a design that corresponds to the laboratory manual allows it to be used as an alternative learning media to enhance understanding in experiments. This application discusses step-by-step procedures that users can practice by simulating experiments according to the provided instructions and guidance.

Keywords— Augmented Reality, Virtual Laboratory, Practicum, Simulation, MDLC.

I. Introduction

The development of technology and scientific knowledge globally drives the birth of creativity and innovation in the learning process. The implementation of efficient and effective interactive media applications can influence good learning information, which in turn affects the student learning process. One form of innovation that can support the learning process is Virtual Laboratory (V-Lab) technology or virtual laboratories. Although virtual laboratory technology is easily accessible and can enhance the learning experience, its application in education is still rarely encountered [1].

One of the benefits of virtual laboratory technology is to optimize the implementation of practical work, which is one of the core elements of learning in physical chemistry. The utilization of virtual laboratory technology in physical chemistry education has several advantages, such as overcoming limitations of practical tools and materials, as well as being more economical and safe. This becomes a solution for the implementation of practical activities.

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Virtual laboratories are a type of technology that can facilitate users because they do not require physical presence in the classroom or laboratory to conduct practical exercises. These virtual laboratories are based on augmented reality (AR). The implementation of AR in virtual laboratories allows students to experience virtual physical chemistry experiments more safely without the risk of using hazardous chemicals. Students can participate in realistic experiment simulations, manipulate objects and experiment parameters, and observe visual changes that occur during chemical reaction processes[2].

This V-Lab interactive media is designed using the 3D Blender application, and the Augmented Reality process is created using Unity and the Vuforia SDK library. The final result of this application will display simulations for the oxidation of ethanol by chromium (VI) and be able to show 3D objects of laboratory tools and materials.

Based on the results of interviews and observations during the observation of ethanol oxidation practicals by chromate (VI) in the Physical Chemistry II course in the Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang, a number of obstacles were found in the physical laboratory. Laboratory equipment that has aged requires refurbishment due to wear and tear and performance degradation, which potentially disrupts the quality of learning. Maintenance and replacement of laboratory equipment require considerable cost and time, but this is important to ensure that students receive optimal learning experiences in accordance with the development of science.

The next challenge is the delay in the delivery of materials or substances needed for the practicum, which can disrupt the learning schedule and hinder the smooth learning process.

Hazardous materials also pose safety risks to students and staff involved. In this situation, safety becomes the top priority, and a safer and more efficient solution is highly needed.

The constraints faced by students include the inability to repeat laboratory practices due to time constraints, material and equipment availability, or errors in conducting laboratory practices resulting in outcomes that do not align with the objectives of the experiment [3].

The design process of this application uses the Multimedia Development Life Cycle (MDLC) method, which consists of six stages: conceptualization, design, material collection, production, testing, and distribution. These stages can be rearranged according to needs, but the conceptualization stage is the first one to be carried out [4].

Based on that, by utilizing a virtual laboratory on smartphones, an Augmented Reality-based application for the oxidation of ethanol by chromium (VI) practical experiments was created as a learning tool for Chemistry students. This application is capable of helping students recognize and identify the process of oxidizing ethanol by chromium (VI) virtually.

II. LITERATUR REVIEW

A. Interactive multimedia.

Interactive multimedia refers to a system that utilizes various forms of presentation media, such as text, sound, animation, and video, simultaneously. This system actively involves users in issuing commands, controlling, and manipulating content [5].

B. Virtual laboratory

Virtual laboratory is a software program that provides simulations of laboratory equipment replicating real equipment. This program allows students to follow experiment procedures carefully while focusing on visual elements. With the virtual laboratory, students can conduct interactive independent practical work that can be accessed from anywhere and anytime [6].

C. Augmented Reality

Augmented reality is a combination of real-world objects and virtual elements within the real environment that interact in real time [7].

D. Marker Based Tracking

Marker-Based Tracking is an Augmented Reality technique that involves detecting markers and analyzing their patterns to integrate virtual objects into the real world [8].

E. Unity 3D

One of the easy-to-use game engines allows developers to create objects easily and assign functions to execute those objects. Each object comes with its own set of variables that need to be understood in order to produce high-quality games [9].

F. Vuforia SDK

Vuforia is an SDK (Software Development Kit) for software development utilized in creating augmented reality applications. This SDK employs computer vision technology to identify and track markers or target images [10].

G. Black Box Testing

Black-Box Testing is a software testing technique that focuses on the functional specifications of the software. Black-box testing allows software engineers to test a series of input conditions that utilize all the functional requirements of the program [11].

III. METHODS

Luther in 1994 developed the Multimedia Development Life Cycle (MDLC) as a system development method. MDLC consists of six main stages, including conceptualization, design, material gathering, construction, testing, and distribution. In this study, the distribution method used is Animation [12].

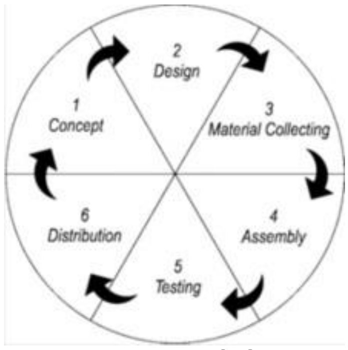


Fig 1. MDLC method

A. Concept Stage

This stage is a step to establish the goals, benefits, users, and concepts of the application to be developed. In this research, the researcher aims to build a system that will provide benefits for students of the Chemistry Department, FMIPA UNP, so they can conduct ethanol oxidation laboratory practice using an Augmented Reality-based virtual laboratory.

TABLE I
DESIGN CONCEPT

No.	Concept Category	Concept Description
1.	Application Title	Design and Develop a Virtual Lab for Learning Ethanol Oxidation by Chrom in Physical Chemistry II Laboratory
2.	Application Type	This interactive media displays tools, laboratory materials, and conducts a simulation of ethanol oxidation by chromium in an Augmented Reality-based application.
3.	Objective	Producing an Augmented Reality application as an interactive learning medium for the practical material on ethanol oxidation by chromium, while also serving as an engaging, creative, and innovative learning tool by utilizing Augmented Reality technology that assists students and lecturers in the learning process
4.	User	The faculty members and students of the Department of Chemistry at the Faculty of Mathematics and Natural Sciences who are studying the ethanol oxidation laboratory experiment using chromium.

B. Design Stage

The design phase explains the things done in creating visual displays, navigation, and the complete process of media design comprehensively.

1) Marker Design

In this stage, the design of each tool and material for practical use as markers to run the application is carried out. The marker functions as a means to help display three-dimensional objects in Augmented Reality applications.

2) 3D Object Design

Once the ideas are clear, the next step is to create a conceptual design using 3D design software such as Blender 3D.

3) Storyboard

The storyboard serves to provide an overview of the application to be produced [13].

Fig 2. Storyboard

4) Interface Design

Interface design is used to select the overall appearance of the program.

C. Material Collecting Stage

This stage is a continuation of the Interactive Multimedia design. In the material collection phase, the process of gathering content is carried out, including course materials, questions, animations, images, videos, music, buttons, and other elements that will be used in the learning application [14].

D. Assembly Stage

In this stage, all multimedia objects or materials that have been created or designed are assembled into an application. The development of this application is based on the design stage where all multimedia materials or files are organized according to the design stage using the Unity 3D application. And in this stage, coding of the application is also carried out so that all buttons and icons can function properly.

E. Testing Stage

The testing phase is conducted after completing the assembly stage by running the application or program and checking for any errors. This is done to ensure that what has been created earlier is indeed correct or accurate before implementation.

F. Distribution Stage

At this stage, the duplication and distribution of results to users are carried out. This visualization needs to be packaged well according to the extent of its dissemination media.

IV. Results and Discussions

A. Design Result

The result of the application design is the final stage after designing an application. This stage aims to determine whether the designed application can function properly.

1) Concept

The concept stage in the design of interactive learning media applications based on augmented reality is the initial step where the basic idea of the application is designed and its concept is detailed. At this stage, the designer will formulate the learning objectives, the selection of materials to be presented through augmented reality, and the user interaction with the technology. Additionally, the application concept also includes initial thoughts on interface design, graphic elements, and the overall user experience.

2) Design

The design stage in the design of augmented reality (AR) learning media applications is a key step where the concept and learning objectives are transformed into a concrete plan for an understandable AR experience. At this stage, the designer identifies the visual, audio, and interactive elements to be used, and arranges the flow of the user experience.

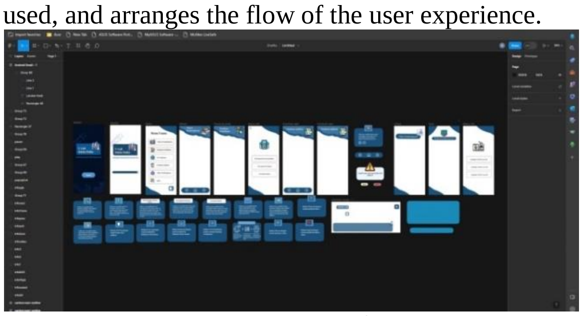
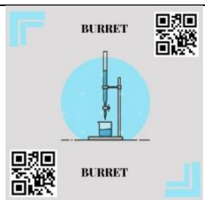


Fig 3. Application Interface

3) Material Collecting

At this stage, gather all the materials that will be presented in the designed learning media, such as 3D tools and laboratory materials, markers, learning materials contained within interactive learning media. The materials can be seen in the following table:

TABLE II
3D Markers and Objects

No.	Material Name	Information
1.	 *Marker Burret*	The function of this marker is to detect and display 3D objects from burret.
2.	 *3d burret*	The 3D burret object will be displayed in the application to be created.

4) Assembly

This stage begins with creating a license manager that utilizes provided software without payment. This software is typically referred to as Unity and Vuforia [15]. The outcome of designing this Augmented Reality-based Virtual Lab application is an application intended as an alternative learning tool for the ethanol oxidation by chrom experiment. This application comes equipped with various features such as learning materials, laboratory procedures, AR tool and material recognition, AR laboratory simulation, application guide, instructional videos, and quizzes.

B. Splash Screen and Main Menu Page

The splash screen page is the initial page of an application that appears briefly after the application is launched. Typically, the splash screen is used to display the logo, application name, or welcome message to the user while performing the initial application initialization.

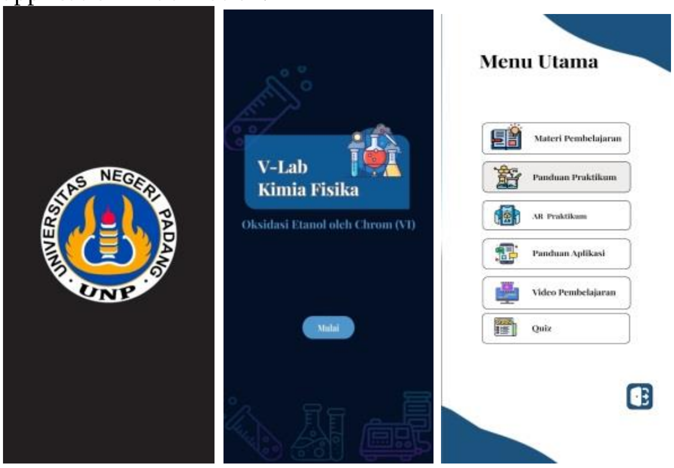


Fig 4. Splash screen and main menu page

C. Learning Materials, Practical Procedures, and AR Page

The learning material page serves to display material on the oxidation of ethanol by chrom. This page contains practical steps/procedures for ethanol oxidation by chromium.

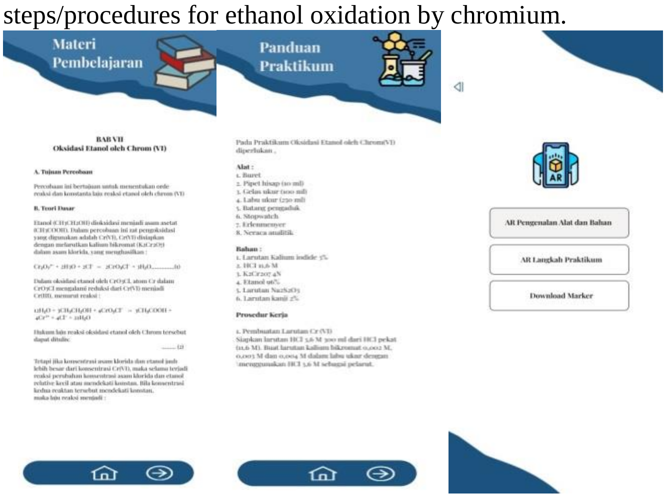


Fig 5. Learning Material, Practical Procedures, and AR Page

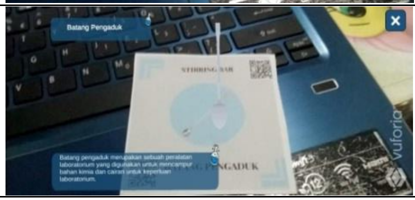
On the AR menu page there are 3 menu options including: AR menu for introduction to tools and materials, AR practical steps and marker download menu.

D. AR Page Introduction to Tools and Materials

Fig 6. AR Page Introduction to Tools and Materials

In AR images, the camera will detect tool and material markers. If the marker is detected, a 3D object will be displayed corresponding to the marker scanned by the user, complete with a name and description accompanied by an audio explanation. For the AR display of tool and material objects, see the table below:

TABLE III
AR PRACTICAL TOOLS AND MATERIALS

No.	AR Menu introduction to tools and materials	Information
1.		AR Volumetric flask
2.		AR Stirring rod

E. AR Page Practical Steps

On this page there are 3 choices of practical steps: Preparation of Cr(VI) solution, Standardization of the solution and Ethanol and Cr(VI) Reaction.

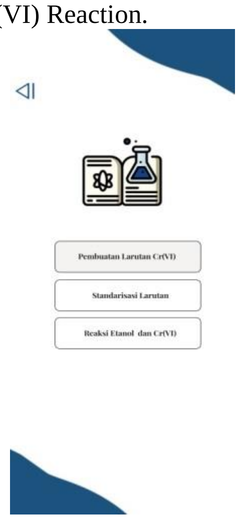
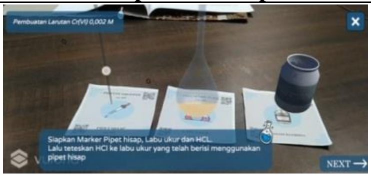


Fig 7. AR Page Practical Steps

For the AR display, the practical steps for Ethanol Oxidation by Chrom can be seen in table 4 below:

TABLE IV
AR PRACTICAL STEPS

No.	AR practical steps	Information
1.		The first step is for the user to scan the required marker according to the instructions.
2.		Then take the fluid according to the specified amount.
3.		Then put the solution that has been taken into the measuring flask.

F. Application Guide and Learning Video Page

This page contains a guide or instructions for using the application, such as: instructions for scanning AR markers, an explanation of each button or buttons in the application.

Fig 8. Application Guide and Learning Video Page

This learning video menu functions to display a practical video of ethanol oxidation by chromium

G. Quiz Page

On this page the user can answer the available questions about the material oxidation of ethanol by chromium, and if the answer is correct it will display a top up of your correct answer as well as if the answer is wrong, and at the end the user can find out the total score obtained so that it can be used as an evaluation of the material.

Fig 9. Quiz Page

H. Exit page

On this page the user can select the yes button to exit the application, and the no button to cancel exiting the application.

Fig 10. Exit page

1) Testing

At this stage the application is tested, testing is limited to validation by material experts and media experts to obtain validity and suitability as a learning medium. The results of the validation test of the virtual lab application for practical work on the oxidation of ethanol by designed chromium are classified as "valid and very feasible" with an overall average validation score of 94%

2) Distribution

This distribution stage includes duplicating and distributing the product to end users. This visualization needs to be well organized according to the media so that it can be distributed widely. The distribution section continues to lecturers at the Department of Chemistry, FMIPA UNP, where this final assignment will be used by students from the Department of Chemistry, FMIPA UNP.

V. CONCLUSIONS

The conclusion regarding the design of the Augmented Reality-based Virtual Laboratory application for the purpose of learning Ethanol Oxidation in the Physical Chemistry 2 course encompasses several aspects. First, this Augmented Reality-based Virtual Laboratory application provides detailed step-by-step guidance to users for conducting simulation experiments. Clear instructions and guidance are accompanied by practical demonstration videos featuring students from the Chemistry Laboratory Department of UNP. Additionally, this Augmented Reality-based Virtual Laboratory application is consistent with the laboratory manual, thus serving as an effective alternative learning tool. Its validity has been tested with a 95% approval rate in media validation and a 93% approval rate in material validation, indicating its suitability and validity.

VI. LIMITATIONS AND FUTURE WORK

For future researchers, it is hoped that they will expand the scope of the virtual laboratory on ethanol oxidation by chromium-based augmented reality by integrating deeper elements of virtual reality, such as realistic molecular interactions, or exploring a wider range of experimental conditions, such as various catalyst concentrations or reaction temperatures. Furthermore, it is important to consider educational aspects by designing supportive features that facilitate understanding of chemistry concepts related to ethanol oxidation.

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