



Design of an Interactive Multimedia Simulation Game for Chemistry Learning (Case Study: SMA Negeri 3 Waingapu)

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Abstract

Chemistry learning in senior high schools is often considered difficult because many topics are abstract in nature, such as chemical reactions and the fundamental laws of chemistry. Based on the results of observations and interviews conducted at SMA Negeri 3 Waingapu, the learning process is still dominated by the lecture method, and laboratory practical activities are limited. As a result, many students experience difficulties in understanding the subject matter. Of the 36 students, approximately 65% had not achieved the Learning Objectives Achievement Indicator (IKTP). Therefore, a more interactive and engaging learning medium is needed to help students understand chemistry concepts more effectively. This study aims to design and develop an interactive multimedia simulation game as a learning medium for chemistry, implement the Decision Tree algorithm within the game system, and improve students' understanding of chemistry concepts. The expected benefits of this study are to provide a more engaging learning medium for students and to assist teachers in delivering chemistry lessons more effectively. The development method used in this research is the Multimedia Development Life Cycle (MDLC), which consists of six stages: concept, design, material collecting, assembly, testing, and distribution. Data were collected through observations, interviews, and questionnaires. The application was developed using Unity with the C# programming language and deployed on the Android platform. System testing was carried out using the Black Box Testing method. The proposed solution is an interactive multimedia simulation game that provides learning materials, chemical reaction simulations, and interactive quizzes. The system inputs consist of menu selections and quiz answers provided by users. The system processes include presenting learning materials, running chemical reaction simulations, and evaluating quiz answers using the Decision Tree algorithm. The outputs generated include quiz scores, learning evaluation results, and feedback to students regarding their learning performance.

Keywords: Educational Game, Interactive Multimedia, Interactive Simulation, Chemistry Learning, Decision Tree, Multimedia Development Life Cycle

1. Introduction

The rapid development of information and communication technology in the digital era has brought significant changes to various aspects of life, including education. The integration of technology into the learning process no longer serves merely as a teaching aid but also as a learning medium capable of creating a more interactive, innovative, and engaging learning environment. The use of educational technology is expected to help students understand learning materials more effectively and improve the quality of learning outcomes. Multimedia-based learning can facilitate students' understanding by integrating visual elements, text, audio, and animations that complement one another [1]. One of the subjects that plays an important role in education is chemistry. However, in practice, many students perceive chemistry as a difficult subject to understand. This is mainly due to the abstract nature of chemistry concepts, which involve three levels of representation: macroscopic, microscopic, and symbolic. The macroscopic representation refers to observable phenomena, the microscopic representation describes particles that cannot be observed directly, while the symbolic representation involves chemical symbols, formulas, and chemical equations. These three representations are often difficult for students to comprehend when instruction relies solely on lecture-based methods without adequate visualization or hands-on practical activities. Based on interviews conducted with a chemistry teacher at SMA Negeri 3 Waingapu, it was found that the Grade X chemistry curriculum covers various fundamental concepts. However, this study focuses specifically on chemical reactions as the primary topic for developing the educational game.

The results of the learning evaluation showed that, out of 36 students, approximately 65% (23 students) had not achieved the Learning Objectives Achievement Indicator (IKTP), while only 35% (13 students) had successfully met the expected learning outcomes. These data were obtained from students' daily assessment results on the topic of chemical reactions, indicating that most students still experienced difficulties in understanding the fundamental concepts of chemical reactions. In developing this interactive multimedia simulation game, the Decision Tree algorithm is implemented as a decision-making method in the learning evaluation process. The Decision Tree algorithm

is used to classify students' learning abilities based on several attributes, including the number of correct answers, the final score obtained, and the level of question difficulty successfully completed. Based on the classification results, the system determines an appropriate learning pathway for each student. For example, students who achieve good performance are provided with more advanced questions with a higher level of difficulty, whereas students who still experience learning difficulties are directed to review the learning materials before proceeding. Therefore, the Decision Tree algorithm functions not only as a scoring mechanism but also as a classification and adaptive decision-making method that provides personalized learning pathways according to each student's level of understanding.

2. Library Studies

2.1. Design

Design is the initial stage in the system development process, carried out to formulate the concept, structure, and overall framework of the system before the application is developed. This stage aims to ensure that the development process is carried out systematically and in accordance with user requirements. In software development, the design phase plays a crucial role because it determines how a system will be constructed and implemented [2].

2.2. Learning Media

Learning media are tools or resources used in the teaching and learning process to facilitate the delivery of learning materials so that they can be more easily understood by students. Learning media serve as an intermediary between teachers and students in conveying information, enabling the learning process to be carried out more effectively and efficiently. Furthermore, learning media can stimulate students' attention, interest, thinking skills, and active participation in the learning process, thereby improving their understanding of the material being taught [3].

2.3. Chemistry

Chemistry is a branch of natural science that studies the structure, composition, properties, and transformations of matter, as well as the energy changes associated with those transformations. Chemistry plays a significant role in various aspects of human life, including health, environmental science, industry, agriculture, and technology. Therefore, learning chemistry at the senior high school level is essential to help students understand natural phenomena scientifically and develop critical thinking skills to solve problems related to everyday life [4].

2.4. Educational Games

Educational games are game-based learning media designed to enhance students' motivation, engagement, and learning outcomes through interactive and enjoyable activities. Game-based learning incorporates game elements such as challenges, objectives, rules, feedback, and rewards to create a more engaging and effective learning experience compared to conventional instructional methods [5].

2.5. Interactive Simulation

the Decision Tree algorithm is used to construct classification models capable of predicting or categorizing data based on their attributes. This method is widely used because it is easy to understand, simple to implement, and capable of producing clear and interpretable decision rules. In addition, Decision Trees can efficiently process both categorical and numerical data, making them suitable for various classification and prediction tasks [6].

2.6. Unity

Unity is one of the most widely used game development platforms for creating interactive applications and video games. It supports both 2D and 3D game development and enables applications to be deployed across multiple platforms, including Android, iOS, Windows, macOS, and WebGL. Unity provides a comprehensive development environment equipped with features such as a physics engine, animation system, rendering engine, user interface tools, and scripting support using the C# programming language. In this study, Unity is utilized to develop an interactive chemistry simulation game. Its comprehensive features and flexibility enable developers to create engaging, interactive, and user-friendly educational applications that effectively support the learning process [7].

3. Research Methodology

3.1 Profile of SMAN 3 Waingapu

SMA Negeri 3 Waingapu is a public senior high school located in East Sumba Regency, East Nusa Tenggara Province. Established in 2012, the school holds an 'A' accreditation. The school's curriculum encompasses both general sciences and technology, with chemistry included as one of the subjects taught. Observations and interviews with the chemistry teacher revealed that some students still struggle to grasp chemistry concepts particularly abstract topics such as chemical reactions and fundamental chemical laws. Instruction is predominantly lecture-based, resulting in low student engagement. Furthermore, practical laboratory work cannot be fully implemented

due to limited facilities, thereby depriving students of hands-on learning experiences. Consequently, some students have failed to meet the established learning achievement indicators.

3.2. Research Flow

The research workflow is systematically structured to ensure that the development process of the interactive multimedia simulation game proceeds in a focused manner and aligns with the objectives. The research stages are as follows:

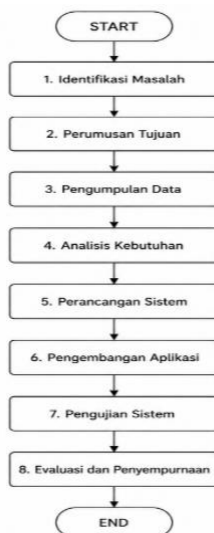


Fig. 1 : Research Flow

1. **Problem Identification**
The initial stage involves identifying issues in chemistry learning, specifically regarding students' difficulties in grasping abstract concepts such as chemical reactions and fundamental chemical laws. This identification is carried out through observation and a review of the literature.
2. **Formulation of Research Objectives**
Based on the identified problem, the research objective was established: to design and develop an interactive simulation game as a learning medium for Chemistry.
3. **Initial Data Collection**
Data was collected from students the prospective users to understand their needs and preferences regarding the learning medium.
4. **Needs Analysis**
The collected data was analyzed to determine the game features, content, and design that align with student needs.
5. **System Design**
This stage involved system design, including the interface, game flow, and application navigation structure.
6. **Application Development**
The Multimedia Development Life Cycle (MDLC) method was employed. The MDLC stages include concept, design, material collection, application creation, testing, and distribution. During this stage, the educational game application was developed using Unity software, integrating various multimedia elements such as text, images, animations, and audio.
7. **System Testing**
System testing was conducted using the Black Box Testing method. This testing aimed to ensure that every function within the application such as buttons, navigation, simulations, and quizzes operated as expected.
8. **Evaluation and Refinement**
Test results were evaluated to make necessary improvements before the system was put into use.

4. Results and discussion

4.1. Main Menu Page

The main menu page is the initial interface displayed when the application is launched. This page functions as a navigation center that connects users to all features available within the application. The main menu page contains several main buttons, namely: Materi, Simulasi, Kuis, and Exit. Each menu has a different function according to the user's needs. The Material menu is used to study the basic concepts of chemical reactions that have been arranged based on the Grade X Senior High School curriculum. The learning materials are presented systematically in stages to help students understand each topic more easily. The Simulation menu is used to run virtual laboratory simulations that demonstrate the process of chemical reactions. Through this menu, students can observe changes in substances visually without requiring direct use of laboratory equipment. The Quiz menu is used as a learning evaluation medium. The questions provided are related to the materials and simulations that students have previously studied. Meanwhile, the Exit menu is used to close the application.



Fig. 2 : Main Menu Page

4.2. Material Page

The material page is one of the main features in the application that functions as a learning medium for students before conducting simulations or taking quizzes. The materials are presented systematically in stages to help students understand the basic concepts of chemical reactions in an organized manner. All learning materials are arranged based on the Chemistry learning outcomes for Grade X Senior High School, which include the concepts of chemical reactions, chemical equations, types of chemical reactions, and factors that affect reaction rates.



Fig. 3 : Material Page

A. Chemical Reaction Concept Material

The chemical reaction concept material is the first learning material studied by users. In this section, the application explains the definition of chemical reactions, the characteristics of chemical reactions, the changes that occur during the reaction process, and examples of chemical reactions commonly found in everyday life. The presentation of the material is equipped with visual illustrations to help students better understand the process of substance changes before and after the reaction takes place.

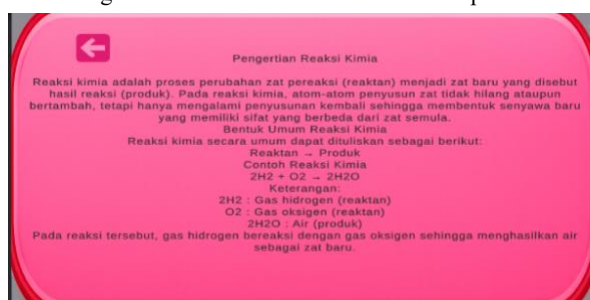


Fig. 4 : Chemical Reaction Concept Material

4.3. Simulation page

The simulation page is one of the main features of the application that distinguishes this learning media from conventional learning media. Through this page, users can conduct virtual experiments to observe the process of chemical reactions without the need to use a laboratory directly. On the simulation page, users first select one of the available simulations through the Select Simulation menu. Each simulation is designed to demonstrate different chemical reaction phenomena, allowing students to gain a more interactive and engaging learning experience.

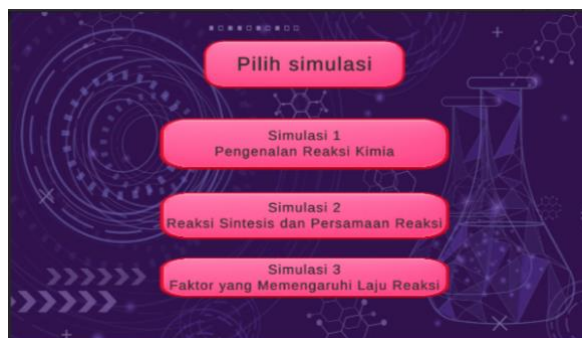


Fig. 5 : Simulation Page

a. Simulation 1

Simulation 1 is an interactive simulation designed to introduce the basic concepts of chemical reactions to users through a virtual experiment. In this simulation, users are invited to observe the process of transforming two reactant substances (Reactant 1 and Reactant 2) into a reaction product (Product). The simulation is presented in a virtual laboratory environment, providing a more engaging learning experience compared to learning methods that only use text-based media. When users select Simulation 1, the application displays a virtual laboratory environment consisting of a laboratory table, mixing container, test tube, and workspace area where the simulation takes place. At the top of the screen, usage instructions are displayed in the form of the message: "Place the mixing container in the workspace area to start the chemical reaction simulation." These instructions serve as guidance to help users operate the simulation according to the predetermined steps.

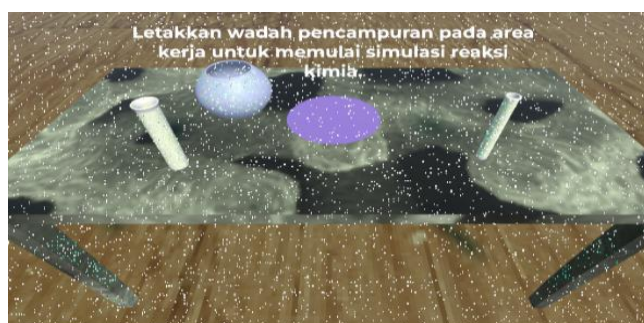


Fig. 6 : Simulation 1

4.4. Quiz Page

The quiz page is an evaluation feature used to measure the user's level of understanding after studying the learning materials and completing the interactive simulations. Through this quiz, users can determine the extent of their understanding of the chemical reaction concepts that have been learned. In addition to serving as an evaluation tool, the quiz is also designed to improve critical thinking skills and train users to apply chemical concepts in various problems presented in the form of multiple-choice questions.



Fig. 7 : Quiz Page

4.5. Quiz Result Page

The quiz result page is displayed after users complete all questions in the quiz menu. Once all questions have been answered, the system automatically calculates the quiz results based on the number of correct and incorrect answers obtained by the user. Furthermore, the system displays information including the final score, the number of correct answers, the number of incorrect answers, the result category, and the completion time. This information is used as an evaluation reference to help users determine their level of mastery of the learning materials that have been studied.



Fig. 8 : Quiz Result Page

4.6. System Testing Results

System testing was conducted using the Black Box Testing method. This method was used to evaluate each function of the application without considering the internal program code structure. Instead, the testing focused on verifying the conformity between the given inputs and the expected outputs produced by the application.

Table. 1: Testing Black Box

No.	Feature Tested	Test Scenario	Expected Result	Test Result	Status
1	Main Menu	Launch the application	The main menu page is displayed	Passed	Valid
2	Material Menu	Select the Material menu	The material page is displayed	Passed	Valid
3	Learning Materials	Select each learning material	The selected learning material is displayed correctly	Passed	Valid
4	Simulation 1	Run the simulation	The simulation runs and displays the transformation of reactants into products	Passed	Valid
5	Simulation 2	Arrange H ₂ and O ₂ molecules	H ₂ O is formed according to the chemical reaction equation	Passed	Valid
6	Simulation 3	Compare low and high temperatures	The timer and simulation operate according to the selected temperature condition	Passed	Valid
7	Quiz Menu	Start the quiz	Quiz questions are displayed sequentially	Passed	Valid
8	Quiz Answer	Select one of the answer choices	The system processes the user's answer correctly	Passed	Valid
9	Quiz Result	Complete all quiz questions	The final score, result category, completion time, and number of correct and incorrect answers are displayed	Passed	Valid
10	Exit	Press the Exit button	The application closes according to the user's command	Passed	Valid

4.7. User Testing Results

After the Interactive Multimedia Simulation Game for Chemistry Learning application had been successfully developed, the next stage was to implement the application with Grade X students at SMA Negeri 3 Waingapu. The students were asked to use the application directly by studying the learning materials, performing the interactive simulations, and completing the quizzes provided. The scores

obtained from the quizzes were used to measure the students' level of understanding of chemical reaction concepts after using the application as a learning medium.

Table. 2: User Testing Results

No.	Student Name	Score	Category
1	Deventri Ersinta Mora Aji	95	Excellent
2	Natalia Rambu Kudu	90	Excellent
3	Gloria Gomis Kahele	100	Excellent
4	Difantri Angelia Konda Meha	85	Good
5	Chelsi Olivia Dealova	80	Good
6	Adinda Juliyantri Rambu Lepir	90	Excellent
7	Daniel Hency De Fretes	75	Fair
8	Agnesia Triandani	85	Good
9	Iraini Yaku Danga	80	Good
10	Dewi Ratna Sari	95	Excellent
11	Kitana Putri Suryah	100	Excellent
12	Joswanto Umbu Rangga	90	Excellent
13	Maria Konga Naha	85	Good
14	Julian Rambu Naha Ana Awang	80	Good
15	Ines Saputri Meta Yiwa	90	Excellent
16	Eleosa Clarisa Rambu Ata Rundi	95	Excellent
17	Rambu Kahi Leba	70	Fair
18	Arnesa Kahi Nggaji	85	Good
19	Serliyani	80	Good
20	Arda Kamzil	90	Excellent
21	Ofhiana Ina	75	Fair
22	Apliani K. Babang	85	Good
23	Jordan Saputra	95	Excellent
24	Dini Aminarti Kaja	80	Good
25	Inestasya	90	Excellent
26	Desni Babang Matang	100	Excellent
27	Agrivani	85	Good
28	Marselina Njiara Pay	90	Excellent
29	Naftali Tay Nggalanau	80	Good
30	Julian Claudia Day Ata Hawu	95	Excellent
31	Ester Anggi Anita Ineke Nara	90	Excellent
32	Deshinta Kaita Lapir	75	Fair
33	Indah Fitri Tanggu Hana	100	Excellent
34	Aden Niwa Pandahuki	85	Good
35	Aurelia Tatu Nahu	75	Fair
36	Maria Jesika Ina	85	Good
Average		86.76	Good

5. Conclusion

Based on the results of the research on the Design of an Interactive Multimedia Simulation Game for Chemistry Learning (A Case Study at SMA Negeri 3 Waingapu), it can be concluded that the research successfully developed an Interactive Multimedia Simulation Game for Chemistry Learning using the Multimedia Development Life Cycle (MDLC) method. Based on the results of Black Box Testing, all features of the application functioned successfully according to the designed specifications. The implementation of the application for Grade X students at SMA Negeri 3 Waingapu demonstrated that the application effectively assisted students in understanding chemical reaction concepts through systematically organized learning materials, interactive simulations, and evaluation quizzes. Furthermore, based on the results of the student response questionnaire, the application received positive feedback. Most students stated that the application was easy to use, had an attractive user interface, presented learning materials that were easy to understand, and provided interactive simulations that

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