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SAGD-VL Framework: A Framework for Serious Adventure Game Development in A Virtual Laboratory

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Abstract

A virtual laboratory is an instructional approach to facilitate learning on a scientific procedure or experimental procedure to motivate students to think critically and to improve problem-solving skills through virtual media. A serious adventure game is a game with a severe purpose, for example, Education but with an adventure genre that allows the user to go on adventures and explore within the game. The merging of a virtual laboratory and a serious adventure game will contribute to the progress of the education field and motivate students in virtual practicum activities. But currently, there is no particular software development framework for developing a serious adventure game for a virtual laboratory. This study aims to produce a serious adventure game framework for a virtual laboratory called SAGD-VL (Serious Adventure Game Development for Virtual Laboratory). SAGD-VL is obtained from analysis of characteristics of virtual laboratory, adventure game, similar software, existing game development methods, and game mechanics mapping framework so that an appropriate development framework will obtain and improve student ability. SAGD-VL consists of pre-production, production, testing, and post-production, and each of these steps has specific components. The SAGD-VL Framework was tested by building a game according to the proposed Framework. The proposed game mechanics is also the result of testing players repeatedly to get optimal game mechanics. This test aims to see the effectiveness of the game produced with SAGD-VL on improving the player's abilities and determine the importance of specific components in game design. The game was tested on 128 high school students by dividing them into reading groups and playing groups and tested by doing pre-test and post-test. The results show that the game produced by the SAGD-VL Framework indicates a better positive impact than learning by reading and obtains an increase in post-test results achieving 115.74%.

Keywords: virtual lab, serious adventure game, Framework, education game

I. INTRODUCTION

Improving the quality of learning in school can be done by adding a virtual laboratory and a serious game into teaching support elements. A virtual laboratory or virtual lab can digitally emulate conventional equipment. A virtual laboratory uses to support students in understanding the concept of a sub-competency more effectively. Practical use of a virtual laboratory provides students with a visual exploration of mathematical models of unobservable phenomena (particle movement, shape change), onto a dynamic real-time monitor of fast or slow processes, for a wide variety of parameters from the analysis [1].

A study [2] states that virtual laboratory media have the same or even better effectiveness than a traditional laboratory. The application of a virtual laboratory supports improving learning process skills, especially in predicting and measuring. It is because the virtual lab media can provide opportunities and flexibility for students to experiment with the level of ability and learning speed of each student, anytime and anywhere. Thus, a virtual lab is feasible to use as an alternative method to learning. In addition, research

[3] states that using a virtual laboratory can reduce the purchase of laboratory equipment, and learning with a virtual laboratory can be done anywhere and anytime without disturbing class time.

A study [4] analyzes the learning curve in a virtual laboratory. The results showed an increase in knowledge of 20%-50% and a decrease of 40%-60% in the time it took students to complete the assessment. A virtual laboratory is also considered a tool that can support learning ideas if it meets the following conditions [5]: contains validity; make research tools easy to divide complexity; visualize complex data; help computer communication. The results of other studies show that a virtual laboratory can improve problem-solving skills, critical thinking, creativity, concept understanding, students' science process skills, lab skills, motivation, interests, perceptions, and student learning outcomes[3]. Increased knowledge has also been studied in science learning with the results of paired t-tests with a significance value of 0.000. There is a significant difference between the average score of students' thinking skills before and after learning using an inquiry-based science virtual laboratory in science learning [6].

A serious game has great potential in the educational field [7]. A serious game is effective in training and Education to complement conventional methods because serious games are effective in maintaining the motivation of participants or students [8]. Serious game development to help adapt to new habits also has a positive effect and increases soft skills in adapting to new environments [9]. Other studies have developed a challenging game of Education suitable for use as a learning aid [10]. The study measured the value of the attractiveness of the application having a mean value of 1.91 (excellent), content clarity with a mean value of 1.93 (excellent), efficiency with a mean value of 1.78 (excellent), and accuracy with a mean value of 1.68. (excellent). Meanwhile, stimulation and novelty have a mean value of 1.56 and 1.06 (good).

While in the game, the adventure style adapts to a game genre that focuses on exploration. This genre supports the function of a virtual laboratory. Previous related research is to make a biology laboratory by combining it with an adventure game and getting a positive response [11]. Serious adventure game seeks to integrate the positive aspects of an adventure game with serious goals such as education [12]. An adventure game developed in the research [13] can increase the theoretical test score by 79.22%.

The Serious Adventure Game (SAG) has the character of exploring that is fun for learning, and a virtual laboratory makes up for the weaknesses of exploration in a conventional laboratory. Both have characteristics that support the learning process. When combined, the two will provide significant benefits. Game design is the key to the success of a game. For educational game design, developers must balance learning and entertainment so that players will find learning fun. However, currently, there is no framework for building a serious adventure game in a virtual laboratory. The development of an adventure game in the virtual lab in the study [11] did not explain how the development method. While in research [12], the proposed Framework is a conceptual framework for the serious adventure game, it is not focused on developing serious games in a virtual laboratory.

From these problems, we need a framework for designing a serious adventure game to be applied to a virtual laboratory to make it easier for developers. Therefore, this study aims to create a framework for a serious adventure game in a virtual laboratory that can make it easier for developers to develop similar games. This Framework is generated by analyzing the characteristics of the virtual laboratory, the adventure game, parallel applications, existing development methods, and a game component mapping framework in the education field. The proposed Framework is expected to be applied in various virtual laboratories, such as a virtual biology laboratory, a virtual chemistry laboratory, a virtual physics laboratory, and a virtual computer laboratory, to make it easier to design and develop the game.

II. LITERATURE REVIEW

A. Related Research

This study references four studies, namely Digital Lockdown [14], SIRER (Security Game) [12], Music Interval and Ear Training to Kids [15], and Musikinésia [16]. The four studies describe how to develop a serious adventure game for a virtual laboratory. This study analyzes game design in four previous studies and then combines them to produce a new game design used in SAGD-VL.

Game design in Digital Lockdown [14] allows users to solve problems with related materials. Characters consist of several types, namely players, enemies, and friends who will direct the player. The design level divides into two: level 1 (learning) and level 2 (practice). The gameplay consists of learning and assessment. The scoring depends on how many players can solve the problem. Interaction Content is created by combining 3D and 2D. This game applies the adventure side to explore the environment to overcome learning followed by learning related Information. Game mechanics in this game are fun, challenge, level, questions and answers, cascading Information, story, and assessment. According to the game's story,

human-shaped characters describe non-playable characters (NPCs). The game world combines two-dimensional and three-dimensional, depicting outer space. The story in the game is that researchers in a research place in outer space are locked and taken over by AI drones, and players must complete missions to open doors. The mission in the game is to open the door and complete all the questions. The action in the game is to explore the plane to learn and answer questions about numbers. The learning content aims to learn independently about the number system. The scoring is based on the number of doors the player can open and where the door can be opened if the player can answer the question.

Game design in SIRER (Security Game) [12] has a story and world. Players can interact with many objects in the game. Players can learn computer security by displaying objects. Learning content is offered using books, pictures, and text, interaction with game objects, and steps that players have to do. For assessment and adaptation strategies in game design, the system records player scores and actions taken. So, the teacher can see the subject that students do not understand. Players explore the game to complete missions related to computer security principles. Game mechanics in this game are fun, challenge, question, and answer, cascading Information, story, and assessment. The character of the player and NPC are human-shaped. The game world combines two-dimensional and three-dimensional and is set in a workspace. The story in the game is about an employee who accepts a mission from his boss, meets a mentor, and solves problems. The boss will check the player's work. Aircraft exploration aims to learn and answer questions about cryptography. Players learn cryptography from books, pictures, and texts and interact with objects in the game world. Scoring in this game is based on how often the player repeats the question. This assessment becomes the teacher's reference in seeing students' level of knowledge and difficulties.

Game design in Music Interval and Ear Training to Kids [15] has learning, training, and quiz. Students can explore learning musical intervals to face game challenges. Game mechanics in this game are fun, challenge, level, questions and answers, cascading Information, story, and assessment. The player is in human form. The game world is two-dimensional. Players can exit through the door, but the door is locked, and the player must complete the mission/learning in the box to open the door. Players can explore paths to find packages and answer questions. Players learn independently in the game about music. Scoring is based on how many players can answer practice questions.

Game design in Musikinésia [16] consists of stories, characters, game concepts, and aesthetics (game world). Game mechanics consist of game modes and scoring. The development of this game and the selection of game engine technology used to make the game considered. The game implements an adventure from learning to evaluating where students can explore and test MIDI Keyboards. Game mechanics use fun, challenge, question, and answer, cascading Information, story, assessment, simulating, and tutorial. Characters are players and NPCs. The game world is in 2 dimensions. The player's mission is to find a magical keyboard that has powers. Players can improve their abilities with the keyboard, explore three worlds, and improve their abilities again. The player explores the plane to learn the keyboard and plays the keyboard. The virtual teacher used to give learning content. Scoring in this game is based on how many players correctly play the keyboard.

B. Virtual Lab and Serious Adventure Game Components

The virtual laboratory adapts to the conventional laboratory and must complete the following requirements [5]:

1. For research tools, a virtual laboratory is required to have experimental equipment. This tool is adapted from the existing tools in a conventional laboratory. For example, in the biology laboratory: anatomical sculptures, microscopes, and others.
2. It contains the truth, although they are not identical in terms of visuals. However, the occurring phenomena are almost close to the original or represent the actual phenomenon.
3. Visualizing complex data that offers a visualization of a phenomenon is difficult for a conventional laboratory to perform.
4. Supporting computer communication is done so that teachers can know their students' learning progress.

A laboratory must also provide opportunities for players to explore and have the following conditions [12]:

1. The application environment is a state that will occur depending on what the player does.
2. State, Features, and Actions Each virtual laboratory component has special features and actions.

These two things will be adapted into a condition that a serious adventure game in a virtual laboratory must meet. To complete the elements it must exist, an analysis of the adventure game is needed. The following are the elements of the adventure game [17]:

1. Emotional Settings: The game is done as a single player and has no time limit.
2. Interaction Model, players use avatars (roles).

3. Camera model, first- and third-person point of view, but the first-person point of view is considered better.
4. The role of the player is to solve the puzzles presented.
5. Stories have stories from beginning to end but the stories presented are not so systematic.
6. Challenges, challenges that arise are conceptual (puzzles).

These six elements will serve as a benchmark in designing a serious adventure game for a virtual laboratory. The results of the serious adventure game identification were reformulated by looking at their compatibility with the characters from the virtual laboratory.

C. Game Development Life Cycle Methods

A study [18] analyzed and classified the current game development life cycle (GDLC) consisting of GDLC for entertainment and GDLC for a serious game. In the Fig. 1 are the results of the classification:

	GDLC Version	Type	Pre-Production	Production	Testing	Post-Production
Entertainment Game	Heather Chandler	Iterative	Pre-Production	Production	Testing	Post-Production
	Doopler Interactive	Iterative	Design	Develop/Re-Develop	Evaluate, Test, Review Release	Release
	Blitz Game Studio	Iterative	Pitching, Pre-Production	Main Production	Alpha Testing, Beta Testing	Master
	Arnold Hendrick	Linear	Prototype, Pre-Production	Production	Beta Testing	Live
	Rido Ramadan	Iterative	Initiation, Pre-Production	Production	Testing, Beta	Release
Serious Game	Eelco Braad	Iterative	Analyze, Design	Develop	Implement	Evaluate
	Elaachak Lotfi	Iterative	Need Analysis, Design	Prototype & Development	Validation	Evaluation
	Arturo Barajas	Linear	Requirement	Design, Development	Testing	Postmortem
	Andre Barbosa	Iterative	Requirement	Design, Learning Mechanism	Testing	Release

Fig. 1 Game Development Life Cycle Classification

All GDLC, whether for entertainment or a serious game, have the same stages: pre-production, production, testing, and post-production. Although some of them are linear, the majority of GDLCs are iterative. The iterative type will repeat the pre-production stage to testing before finally going to the final step.

D. Learning Mechanic-Game Mechanic Framework

Learning Mechanic-Game Mechanic (LM-GM) Framework [19] maps game mechanics into a serious educational game. The LM-GM Framework maps the game mechanics based on the level of learning achievement targets according to the BLOOM's ordered thinking skills. In Fig. 2 is shown the Classifications based on Bloom's ORDERED Thinking Skills.

GAME MECHANICS	THINKING SKILLS	LEARNING MECHANICS	
○ Design/Editing ○ Status ○ Infinite Game play ○ Strategy/Planning ○ Ownership ○ Tiles/Grids ○ Protégé Effect	CREATING	○ Accountability ○ Ownership ○ Planning ○ Responsibility	LOTS to HOTS
○ Action Points ○ Game Turns ○ Assessment ○ Pareto Optimal ○ Collaboration ○ Rewards/Penalties ○ Communal Discovery ○ Urgent Optimism ○ Resource Management	EVALUATING	○ Assessment ○ Reflect/Discuss ○ Collaboration ○ Hypothesis ○ Incentive ○ Motivation	
○ Feedback ○ Meta-game ○ Realism	ANALYSING	○ Analyse ○ Identify ○ Experimentation ○ Observation ○ Feedback ○ Shadowing	
○ Capture/Elimination ○ Progression ○ Competition ○ Selecting/Collecting ○ Cooperation ○ Simulate/Response ○ Movement ○ Time Pressure	APPLYING	○ Action/Task ○ Imitation ○ Competition ○ Simulation ○ Cooperation ○ Demonstration	
○ Appointment ○ Role-play ○ Cascading Information ○ Tutorial ○ Questions And Answers	UNDERSTANDING	○ Objectify ○ Tutorial ○ Participation ○ Question And Answers	
○ Cut scenes/Story ○ Behavioural Momentum ○ Tokens ○ Pavlovian Interactions ○ Virality ○ Goods/Information	RETENTION	○ Discover ○ Guidance ○ Explore ○ Instruction ○ Generalisation ○ Repetition	

Fig. 2 Classifications based on Bloom's ORDERED Thinking Skills

In a virtual laboratory in the school curriculum, the achievement of thinking skills comes to analysis, so the appropriate game mechanics are feedback, meta-game, realism, and game mechanics at the previous level.

III. RESEARCH METHOD

This research was conducted by conducting systematic steps to solve the problem. The proposed Framework is then named the SAGD-VL (Serious Adventure Game Development) framework. The steps taken are identifying problems; studying literature; analyzing characteristics of the serious game, characteristics of the virtual lab, similar apps, game development methods, and Framework for mapping game mechanics in the education field; designing the SAGD-VL Framework, and evaluating (including testing).

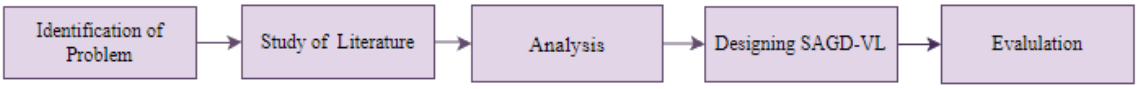

Fig. 3 Research Method

A. *Identification of Problems*

At this step, the identification of various phenomena, events, and Information obtained in various ways and sources related to the research conduct. This research aims to produce a framework for building a serious game in a virtual lab named SAGD-VL (Serious Adventure Game Development-Virtual Lab) that was obtained using the composite logic method to be used as a reference in making similar software.

B. *Study of Literature*

The literature study aims to collect and study information materials from books, papers, journals, serious games, virtual labs, and existing findings related to this research. The collection of this material is to retrieve components that have influence and are necessary for serious games and virtual labs.

C. *Analysis*: *Serious Game, Virtual Lab, Similar Apps, Development method, and Framework for mapping game mechanics in the education field*

At this stage, the analysis of serious games, virtual labs, similar applications, game development methods, and game mechanics mapping frameworks in Education is referred from the literature in the previous stage. This analysis aims to produce the necessary components and steps in a serious game in a virtual laboratory.

D. *Designing SAGD-VL*

The outcome of the analysis in the previous process combines into a SAGD-VL framework design that is suitable for making a serious game in a virtual lab.

E. *Evaluation*

The proposed Framework is evaluated by building an application by following the steps and components of the SAGD-VL Framework to test whether the application developed using SAGD-VL positively impacts students' practicum abilities. This evaluation uses rating criteria based on numbers interpretation [20].

TABLE I
Number Intervals Interpretation

Number Intervals Interpretation	**Criteria Evaluation**
1,00 – 1,79	Very Bad
1,80 – 2,59	Bad
2,60 – 3,39	Average
3,40 – 4, 19	Good
4,20 – 5,00	Very Good

IV. RESULTS AND DISCUSSION

This section consists of an explanation of the proposed Framework and testing of the SAGD-VL Framework. The proposed Framework is based on previous research (in the literature review section) and testing by building games with the SAGD-VL Framework. The detail of SAGD-VL framework can be shown in Fig. 4.

A. SAGD-VL Framework

Based on the game development life cycle, the steps to build the game are pre-production, production, testing, and post-production. SAGD-VL adapts this method, and the character of SAGD-VL is iterative.

1. Pre-production

Pre-production will produce analysis and a game project design as schedules, target users, platforms, game contents, and game activities in the virtual lab. Game contents and game activities are references from previous research. According to the four studies, the described elements are considered elements in developing a serious adventure game. In SAGD-VL, serious adventure games support the characteristics of a virtual laboratory. In developing a virtual laboratory, several things to consider are being able to carry out experiments repeatedly and modifying experimental parameters. Game design elements from the four studies above consist of game concepts, game mechanics, character and interaction design, game world, story, and gameplay (action, challenge, learning, and assessment). These elements are base elements in a serious adventure game, but the game elements described in this Framework are adapted to the characteristics of the virtual laboratory.

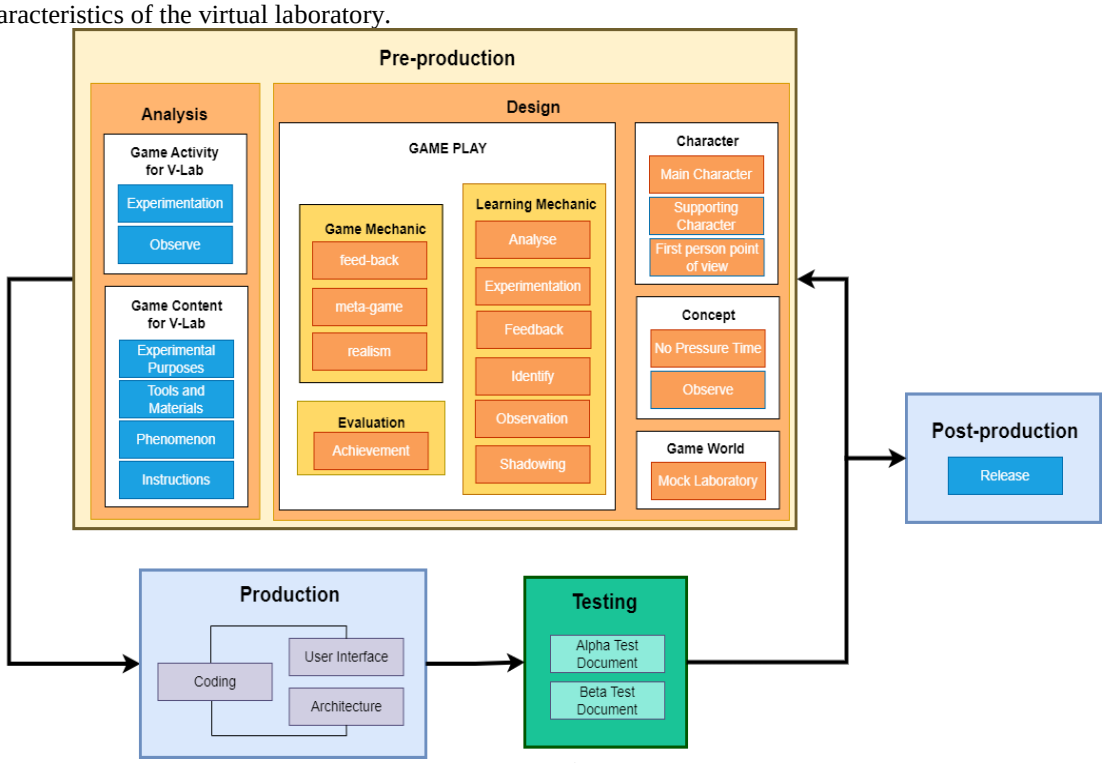

Fig. 4 SAGD-VL framework

a. Game Concept

The game concept adapts the experimental conception in a conventional laboratory and adds game mechanics. The experimental conception has tools, experiment parameters, repeated experiments, and experiments that produce the same phenomenon. The game allows players to explore/experiment with the game environment during the game. The game does not provide a time limit in the game so that the player can do the game repeatedly. The goal is that the player can experiment until the player understands the learning material. In this game, the user has a full role in the game. The game applies the adventure side throughout the game with no time limit in the game. Even though the story presented is different. Games allow players to test or explore the game environment and apply the learnings to missions. For the learning approach, practical problems in the game will support students in solving problems. So, the game is based on a series of exercises/missions that will represent the learning material.

b. Game mechanics

The game mechanics from the analysis are fun, challenging, cascading Information, story, and question and answer. Using levels depends on the game design for knowledge levels. For example, the initial level deals with the base knowledge, and the next level deals with advanced knowledge. The game mechanics are combined using the LM-GM Framework, which allows different users to describe the game based on different pedagogical approaches. Referring to the activities in the virtual laboratory, the thinking skills that must be achieved are at the analyzing level so that the game mechanisms that can be used are at the analyzing level, namely feedback, meta-game, and realism. Even though this game is serious, it still has to have a fun aspect to keep it addictive. Cascading Information is a pop-up that appears when a player is playing a game. The feedback element displays phenomena that occur due to specific parameters. In addition, the meta-game also aims to present learning by using mini-games related to learning materials. The story allows players to explore in a directed and fun way. Questions and answers are used to evaluate players' knowledge in learning through the game. This evaluation can be used to measure the ability of students after playing the game. The scoring is based on how many players correctly answer the questions. This assessment is at the end of the level before the player proceeds to the next level. Realism displays real things, be it phenomena or the game environment.

c. Character

Characters serve to represent players in the game. The analysis results from stating the main character's use in the form of a human, and the point of view used is the first-person point of view. Other characters, like NPCs, function as missionaries or teaching materials. NPCs are divided into two, namely friends and enemies. NPCs become an optional element, and this character can be raised if needed. Friends support characters are tasked with helping and directing players in the game. This character can provide a grid to the player in the game. In the SAGD-VL Framework, the characters are seen from a first-person perspective because the game is for a virtual laboratory, so that players will focus on direct experiments. In a serious adventure game, the character consists of the main character and the supporting character. The main character represents the player and is the protagonist. Meanwhile, enemy characters can provide challenges and pressure to players related to learning. The player's point of view is the first-person point of view because this point of view will make the player play his role in the game as if he were experimenting directly.

d. Game World

The game world became part of the next game design. The game world describes the world or environment in the game. From the analysis of the game world, there are various types, namely two-dimensional, three-dimensional, and a combination of both. To give a real effect, it is recommended to use three dimensions. In the SAGD-VL Framework, the game world does not need to be required to use a specific game world, but the game environment created must adapt to the real world when playing games. The goal is that the learning does not come from the original. If the game world when playing the game is made by adding a fictional world, it is feared that it will reduce the value of the learning material. However, if you want to add a fictional game world, you can do it as a world outside of the experiment.

e. Story

The story becomes an important part of the design of the adventure genre game. The story will direct the player to explore the game. The story relates to learning, and the type of the story is different. For the SAGD-VL Framework, stories can adapt to the real world or by using the fantasy genre, but further analysis is needed so that the story does not interfere with students' learning.

f. Gameplay

Gameplay in the SAGD-VL Framework consists of challenges/missions, player action, learning, and assessment. The mission and action solution design are based on the mission and action in a serious adventure game. A mission is to solve a question to achieve a certain goal, and the action is an action that supports that mission. The mission of a serious adventure game is to solve an experimental problem to achieve a major goal like an award. Action is an experiment by doing other actions following the main goal. In SAGD-VL, learning is carried out with virtual teachers who serve as experimental directors and learn by themselves through experiments. While the assessment uses a quiz/exercise at the end of the experiment where the assessment is based on how many players can answer the questions correctly. Game content must have virtual laboratory elements: objectives, tools and materials, phenomena, and instructions.

TABLE II
GAME CONTENTS IN SAGD-VL FRAMEWORK

Elements	Description
Experimental Purpose	Explain the purpose of an experiment in a conventional laboratory.
Tools & materials	Adapt the original tools in a conventional laboratory.
Phenomenon	Adapt the original phenomenon that occurred.
Instruction	Adapt the steps in conventional laboratory experiments, and add an element of play to these steps

Game activities aim to learn game content. This activity adapts practicum instructions in a conventional laboratory using game mechanics. The game activity consists of two: experimenting and learning. This experiment consists of performing the experiment repeatedly and changing the experimental parameters. Learning activities are carried out to direct students to conduct experiments. This learning can be done in the middle of the game by providing Information during the experiment or by experimenting.

TABLE III
LEARNING ACTIVITIES IN SAGD-VL FRAMEWORK

Activity	Requirement
Experimenting	- Have at least two parameters - Parameters have a causal relationship
Learning	- Observe - Summing up

For example, in observing the epiglottis function, a statement about the epiglottis is that the epiglottis functions as a regulator of the breathing and swallowing mechanisms. Humans will choke when food enters the trachea. So, to find out how the epiglottis does its job is to close and open. When you swallow, the epiglottis close, and when you breathe, the epiglottis open. So, the experiment that can be done is to open and close the epiglottis and put oxygen into the trachea and food into the esophagus.

1) Learning

Learning can be presented before the player plays by displaying learning material or presented when the player is in the game while carrying out the mission/action. This lesson is better given periodically. In learning mechanics, feedback is used to inform students of phenomena that occur after students experiment with specific parameters. Developers can choose learning materials that have causal properties. For example, in the respiratory system, we can choose the material to observe the function of the respiratory organs by experimenting with if one organ has 'A' then it will 'B' or if an organ does not have 'A' it will have 'C', or if an organ has 'A' it will 'B' and so on. 'A' is the experimental parameter, while 'B' and 'C' are the results when the parameter changes.

2) Challenge

In the game, challenges will generate action options. This action will produce a phenomenon. This phenomenon is the answer to the given challenge. For example, to find out the function of the nasal organ for human breathing through the nose, the developer changes the function of the nose into a challenge, such as a nose has a function to clean oxygen that enters the human body, so the challenge is how to get oxygen into the human body to be clean oxygen.

3) Action

Actions are useful for completing the challenges/missions presented. The action adapts the instructions in a conventional laboratory, but this action is modified with game mechanics. Actions can provide opportunities for players to complete challenges, study learning materials, and make learning conclusions from challenges. Every action the player takes in the game must have a causal relationship. Each level has at least two actions that the player can choose.

4) Assessment

The assessment uses exercises/quizzes at the end of the experiment or game or by assessing players during the game. In SAGD-VL, the assessment is not based on the speed of time but on how many players can answer the question correctly. Assessment can also be added by seeing how many players repeat the question until the player answers correctly. The assessment aims to provide feedback to subject teachers to find out which material is considered difficult by players/students.

2. Production

Production implements game design into a game. Production consists of coding, building interfaces, and building game architecture for the virtual lab. The game can record the player's progress so that if the player plays and stops in the middle and closes the game when the player returns, the player can continue the game. Data storage using a server can see the ability of students in a specific group by the teacher. The

concept of exploration is necessary for building interfaces. Navigation and user input should support exploration. An error message should appear after the player acts. The player can determine whether the experimental steps they are doing are correct.

3. Testing

The test consists of an alpha test and a beta test. Alpha test testing tests each function in the game to match the game design. Beta testing tests players' experience in a fun, skill improvement, knowledge improvement, and increased motivation. Pre-test and post-test can test the improvement of students' skills and knowledge. If the test results are unsatisfactory, then the process returns to pre-production so that the character of SAGD-VL is iterative.

4. Post-production

When the pre-production, production, and testing processes have produced a game that suits its purpose, the final stage is post-production. At this step, the game can be released to the public and ready to be used by players. In reality, the game is always updating its functions and features, so the process will start again from pre-production.

B. Testing the proposed Framework

The process of testing is building a game using the SAGD-VL Framework. The game is a biological laboratory game with respiratory material in humans called the Respiration Lab Game. Respiration Lab game content is derived from the conventional respiratory system learning content. The learning content in this material is the respiratory organs and their functions.

TABLE IV
GAME CONTENTS IN RESPIRATION LAB GAME

Elements	Description
Experiment purpose	Understand how human respiration works from the nose to the lungs
Tools and materials	Sculpture/model of human respiratory organs
Phenomenon	The phenomenon that will arise if one of the organs is functioning correctly/not
Instruction	Test its function by removing/displaying, controlling organ function correctly/not

Fig. 5 The Interface of The Respiration Lab Game – Nose Scene

The Fig. 5-8 is represented about the interface of the respiration lab game for the Nose Scene. When the player enters the nose scene, the player undergoes a mission regarding the benefits of the nose on the respiratory system. After that, the player can use the button to show or hide the nose hairs. When oxygen enters, the player will see the difference in oxygen when there is nose hair and when there is no nose hair. This animation allows players to conclude that nose hairs function to filter out impurities carried by oxygen.

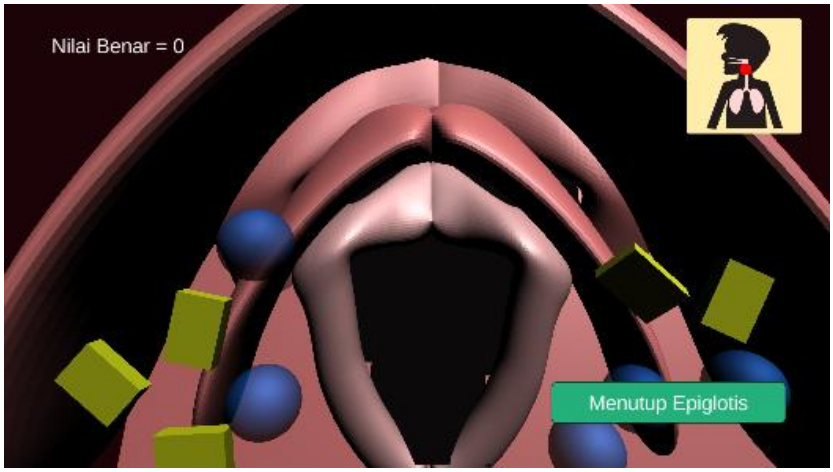

Fig. 6 The Interface of The Respiration Lab Game – Larynx Scene

At the larynx, the player's mission is to get oxygen (ball-shaped) into the respiratory tract and food (cube-shaped) into the digestive tract.

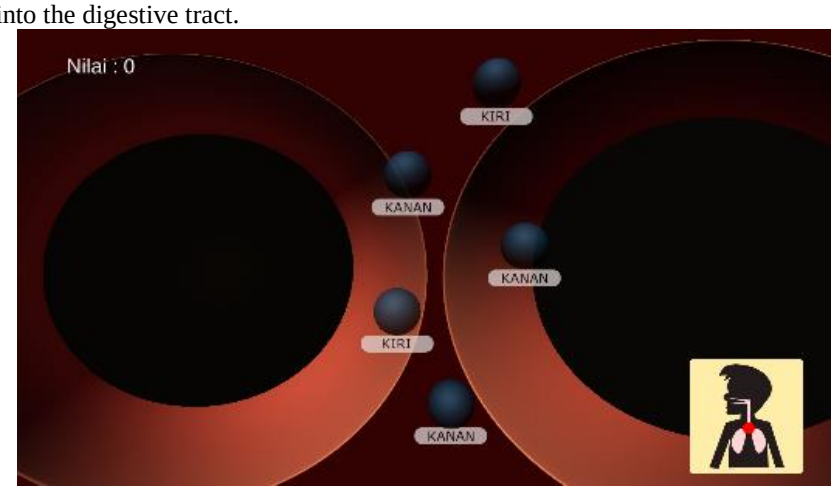

Fig. 7 The Interface of The Respiration Lab Game – Bronchi Scene

In this scene, the player must enter oxygen according to the label written on it. Before starting the game, players study learning material about the bronchi first.

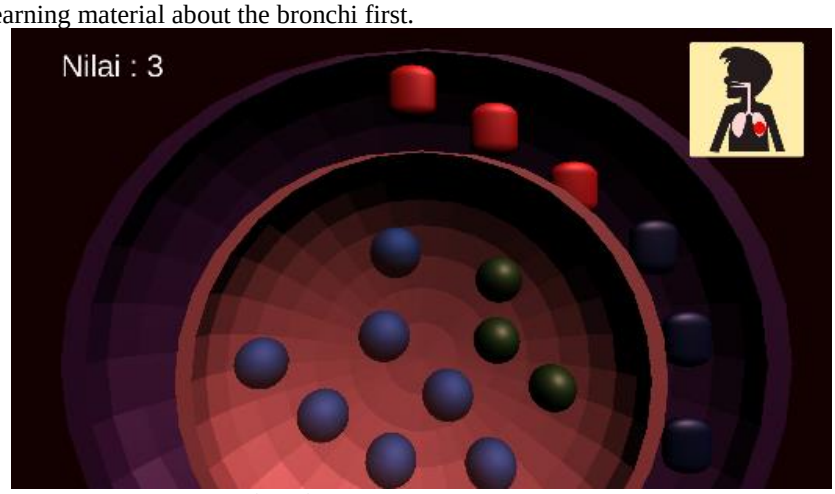

Fig. 8 The Interface of The Respiration Lab Game – Alveoli Scene

At Alveoli, players must exchange oxygen with carbon dioxide by touching oxygen to the capillaries. Before starting the game, players study learning material about the bronchi first.

Game activities in the Respiration Lab consist of experimenting and learning. The experiment in this game by exploring the model of the human respiratory tract and conducting experiments with the provided parameters to fulfill the purpose of the experiment. Learning is at each point of the breathing apparatus (level). The players will learn how the breathing apparatus works and how the breathing mechanism works.

Testing the design of this solution uses two types, namely pre-test and post-test, and questionnaires. The pre-test and post-test aim to test the usability of the game built using the SAGD-VL Framework. This test will test the effect on players in learning. At the same time, the questionnaire aims to test the player's experience of the game built using SAGD-VL. In this study, the respondents were 128 high school students who were taken randomly without considering the respondents' backgrounds.

1. Pre-test and Post-test

Pre-test and Post-test were conducted on students. Students are grouped into two groups: the game-playing group and the reading group. Both groups did a test first to test their initial abilities. For the test flow can be seen in Fig. 9.

Fig. 9 The test flow

The first group is the reading group, with 64 students, and the second group is the game-playing group, with 64 students. The results of the post-test minus the pre-test result divided by the pre-test will show an increase in students' knowledge. Comparing the results of the changes in the play and reading group tests will test whether the serious adventure game in the virtual laboratory supports students' learning process. Furthermore, the results of the playing and reading groups will be compared to state which one is better. The questions on the pre-test and post-test are the same. Therefore, the material obtained by the reading and playing groups is the same learning material. Pre-test and Post-test results. The formula used to calculate the increase in pre-test and post-test is as follows:

$$increase = \frac{posttest - pretest}{pretest} x100$$

TABLE V
THE VALUE OF INCREASING STUDENTS' KNOWLEDGE AFTER LEARNING

Group	Number of Respondents	Lowest increase (%)	Highest increase (%)	Average increase (%)
Playing Game	64	0.0	800.3	115.74
Reading	64	0.0	133.4	47.9

Students who play games tend to increase more than those who read. The highest increase in the game reached 800.3% from the previous value, which was 12 (only three correct answers) to 96 (24 correct answers), but this only applies to 1 person, where the other increase is from the range 0- 150. The playing group had the highest increase of 115.74% for the average increase.

2. Questionnaire Test Results

Playgroup students give a questionnaire after playing the game.

	C1	C2	C3	C4	C5	C6	C7
Valid	64	64	64	64	64	64	64
Missing	0	0	0	0	0	0	0
Mean	4.172	4.125	4.188	4.234	4.188	4.234	4.406
Std. Deviation	0.747	0.724	0.732	0.729	0.664	0.811	0.750
Minimum	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Maximum	5.000	5.000	5.000	5.000	5.000	5.000	5.000

Fig. 10 Questionnaire Test Results

Categories: 1. Help increase knowledge, 2. Like to play the game, 3. the game is easy to understand, 4. Learning is easy to understand, 5. Conduct experiments, 6. Assessments are easy to do, 7. Can conclude learning materials.

Questionnaire testing resulted that games built using SAGD-VL were able to increase knowledge with a value of 4.172 (very good), players liked games with a score of 4.125 (very good), games were easy to understand with a score of 4.188 (very good), learning was easy to understand with a score of 4.234 (very good), an experiment that stands out with a score of 4.188 (very good), an easy assessment to do with a value of 4.234 (very good), and can conclude the learning material with a value of 4.406 (very good). The results showed that the increase in knowledge was very significant in the game group compared to the reading group. So, games built using the SAGD-VL Framework have a positive effect on the learning abilities of students. The results of increasing knowledge after playing a serious adventure game in a virtual laboratory may also change. This can occur due to specific factors, such as the thinking power of students, the emotions of students when playing games, and the attitude of students when playing the game. Thus, further research is needed on this Framework by considering students' thinking power, emotions when playing games, and attitudes so that the resulting game gives an optimal positive effect on all categories of students. However, SAGD-VL can map out the necessary components for building games in a virtual laboratory.

V. CONCLUSION

The results of the study stated that the SAGD-VL Framework is a framework that is suitable for developing serious adventure games for virtual laboratories. The Framework comes from the serious game characters with adventure genre, which follows the characters of the virtual laboratory without considering the thinking ability of the student's attitude towards the game and the emotions of the students when playing the game. The Framework for building a serious adventure game in a virtual laboratory consists of four steps: pre-production, production, testing, and post-production. The test results show that the game produced by the SAGD-VL Framework has a more positive impact than reading, with an average value increase of 115.74%. So, this study states that the proposed Framework can be implemented for a virtual laboratory game and in other similar games. The game produced using this Framework also has a positive effect on students. However, further research is needed to understand abilities, students' attitudes toward games, and students' emotions when playing games.

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