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Developing Web Based System For Procedural Generation of Exercises in Geometry For 5th Grader in Elementary School

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Abstract: *This study is intended to contribute to further procedural 5th grade geometry problem generation development. The requirements analysis is done with two UML diagrams, which are Use Case Diagram and Activity Diagram. This design is also comes with interface design for three actors involved, which are admin, teacher, and student. The results of this design can be a starting point for further research about the use of interactive media with competitive, adaptive and developments elements in educational context.*

Keywords: *Gamification, Software Development, UML*

1. INTRODUCTION

1.1. Background

Today, the use of interactive media and game mechanics used in contexts other than games has attracted the attention of many parties and has been applied to various fields in order to motivate and attract many people to do an activity and solve various kinds of problems [1]. Interactive media applications can be found in various situations, such as shopping, marketing, networking, entertainment, sports, recycling, and learning [2].

As educational tools, interactive media are used to facilitate learning, to increase motivation and engage participants, to increase the sense of participation and interactivity of lessons, and to stimulate students to expand their knowledge [3]. If implemented properly, interactive media can increase intrinsic motivation and interest in learning [4] and become a very useful tool for teachers at every level of the education system [5].

Although it has a lot of potential and many enthusiasts, the use of interactive media in education is still much to be researched [6]. Among existing research studies, some researchers have used gamification in physical contexts, such as the use of pen and paper [7], while research on gamification using interactive media is more often carried out using university-level participants [5].

Some researchers argue that gamification alone is not sufficient to produce the desired learning outcomes and the effects of various game elements and their implementation require more research and empirical evidence [6]. In other words, the researchers argue that more effort is needed to identify ways to efficiently implement various game elements that can increase student interest, motivation, and performance. Moreover, in gamification, it is often agreed that one way

of teaching cannot be suitable for all participants. While one element of the game (such as competition) can increase scores for some participants, it can also have the opposite effect for other participants, even if both groups of participants take the test in the same class [8].

Jagušt, Botički, & So (2018) have proven that the use of gamification using interactive media in learning mathematics at elementary school grades 2 and 3 in Croatia resulted in an average score that increased by 4.3% compared to before using the system [9]. The main design decisions that will be studied are gameplay that pits each player's ability against each other to motivate players to be better than their classmates, change the difficulty level of the questions according to the player's ability to answer previous questions, and motivate users by extrinsic "prize".

This design aims to replicate part of the system used in the study in the previous paragraph for 5th grade geometry material. This decision was based on research in Turkey which stated that grade 4 and 5 elementary school students who scored higher in mathematics were also noted to have lower levels of anxiety [10] and because the elementary mathematics curriculum in Turkey was quite similar to the elementary mathematics curriculum in Indonesia [11].

This study involved three 5th grade students at SD Negeri 47 Jambi who had below average math scores. All three admitted that they had problems with mathematics because they did not master the material. This research is expected to be able to help students who have problems with mastering mathematics subjects to be able to master them.

1.2. Problem Statements

Based on the background of the problems described above, the problems to be discussed in this study are as follows:

1. How to take advantage of the automation process owned by computer software to minimize or eliminate the reasons children do not like to learn geometry?
2. How to prove whether the implementation of the designed software will be able to answer the problem of grade 5 elementary school students' grades.

1.3. Research Objectives

The goal of this reseach was:

1. Develop computer games that utilize the automation process owned by computer software to minimize or eliminate the reasons children do not like to learn mathematics.
2. Proving whether the implementation of the designed software will be able to answer the problem of grade 5 elementary school students' grades.

1.4. Scope of Problems

Based on these problems, it is necessary to limit the analysis of application development plans so that the design can be designed effectively and efficiently as follows:

1. Problems created by the system only require one type of variable. Then the type of questions that have two or more are not included.
2. The design of this system is only focused on flat-building materials and building a 5th grade elementary school

1.5. Benefit

Benefits of this research can be viewed from two perspectives. There are benefits from academic perspective and benefits from practical perspective:

1. Academic Benefits
   From this research, it is expected to provide the following benefits:
   a. Describe the design of a web-based gamification system
   b. As a reference and further consideration related to the development of a web-based gamification system.
2. Practical Benefits

- The results of the study can be further developed to be used as recommendations for 5th grade mathematics teachers.

2. LITURATURE STUDIES

Jagušt, Botički, & So (2018) investigated elementary students in Croatia and South Korea where the most effective elements for motivating student learning were competitive, adaptive, and collaborative [9]. Competitiveness is the element that compares the value of a user with the value of other users in the hope of spurring them to try to improve their value. Adaptive means that the software adapts to the user's level of understanding. The system will use a feedback loop where the questions given by the system will be simpler the more the most correct player answers wrong, and vice versa, if the player can answer the questions correctly with minimum errors, the system will provide questions with numbers. higher. Collaborative is where more than one player works together to solve a problem, with the hope that players will feel involved from helping each other work on the problem). In this design, the collaboration elements used by Jagušt, Botički, and So will be replaced by a developmental system that will be associated with adaptive elements. In the study it was found that students' performance is higher if the game adapts to their abilities. Ideas for further research include designing mechanisms for adapting gameplay depending on what students like, adapting the difficulty level based on students' abilities, and examining how students can learn from questions with incorrect answers.

van Roy & Zaman (2018) examines what can keep students motivated to play educational games. They found that further understanding of how gamification works is still needed [12]. They also found that, first, motivation is a heterogeneous concept that must have different types of motivation. Therefore, game design elements can be created to encourage these specific types of motivation. Second, game elements that encourage needs can increase student motivation, although not directly. Third, they found evidence that the nature of the motivational effect of gamification is individualistic, pointing to personal characteristics as possibly linking games and motivation.

The game is designed to train users in doing math problems. Therefore, the user should not be able to memorize the problems at hand. By using procedural generation, the computer can generate random and unlimited questions, reducing the possibility that the user will get the same question more than once. So it makes sure that the user understands how to do the problem even though he encounters a combination of numbers that he has never encountered before. Kayimbaşioğlu, Oktekin, & Haci (2016) found that increasingly accessible computer assisted learning increased class performance from 33% to 90%, with 0%-10% of students receiving scores that were considered low after the use of computer assisted learning [13].

2.1. Competitive Elements

Competition is one of the main elements in the game. Since most of the commercially available games on the market today are goal oriented, competitive situations or competitive factors are often implemented in gamification [14]. Some researchers argue that, unlike traditional media users, game users are driven by competition and achievement. Empirical evidence shows that players are more attached to the game when there is competition in the context of the game [15]. Moreover, the level of competition also affects what games players prefer [16] (Gajadhar & de Kort, 2008).

2.2. Adaptive Elements

Despite being proven to be empirically effective, learning environments often fail to

attract users' attention and many become obsolete. Many studies have proven that gamification in the context of learning can increase student motivation in an educational environment. However, each learner reacts differently to game mechanics, so adaptive elements in learning gamification are used to match the system to each user's abilities or tastes [16]. Figure 1 explains how the system changes the difficulty level of the questions given according to the user's previous scores.

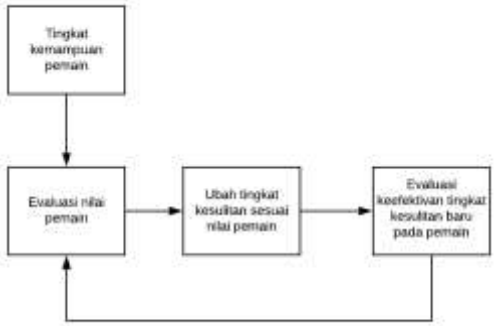

Figure 1.Adaptive Elements Diagram (Towards a Gamification of Industrial Production. A Comparative Study in Sheltered Work Environments - Scientific Figure on ResearchGate)

2.3. Development Elements

Sometimes the main mechanics of a game are not enough to continue to captivate players, therefore many games implement developmental elements as extrinsic motivation that accompanies the main mechanics [18]. Intrinsic motivation is motivation that is closely tied to the game being played, such as chasing and kicking the ball in a soccer game. Some football players think that chasing and kicking the ball is what they find fun about playing football. While extrinsic motivation is motivation that is not directly related, but is still the result of the game being played, for example some soccer players do not find chasing and kicking the ball fun, but they still enjoy playing football because getting a score when scoring a goal is enough to motivate them to continue playing [19]. This design will utilize elements of extrinsic motivation to motivate users to work on questions. Users will be given points for each question they managed to do correctly, and lose points for each question they failed to do correctly.

In relation to the development elements, Operant conditioning, also known as Skinner's Box, is a type of associative learning in which a behavior is reinforced by reward or punishment. If the subject is happy when doing something the researcher wants, then the subject will feel compelled to do so, and if given a punishment for the unwanted behavior, the subject will be punished, thus encouraging the subject to try to do what the researcher wants [20]. For example, this can be done from mice that are given food every time they press a button to game players who are awarded points every time they win something in the game.

Figure 2. Operant Conditioning Diagram (Developing Critical Practice in Education: Final Project - Scientific Figure on ResearchGate)

Figure 2 describes the system providing "wages" or "punishments" based on user answers to reduce wrong answers and increase correct answers. By answering the questions correctly, the user can receive a "reward" in the form of a stimulus that the user wants, or in the form of avoiding / stopping the unwanted stimulus. By answering the question incorrectly, the user gets a "punishment" in the form of an unwanted stimulus or the system withdraws

the stimulus obtained from answering the question correctly.

2.4. Implemented Elements

The design in this research uses elements of competitive, adaptive, and developmental games. which have been mentioned previously. The following is an explanation of how these elements are implemented.

1. Competitive elements were implemented with leaderboard function. The more users answer the questions correctly, the higher the user's points will be. The names of the users who have the highest points are the ones that will be displayed at the top of the leaderboard by default. According to the theory explained in previously, this will motivate students to answer as many questions as possible to reach the top position.
2. Adaptive elements were implemented with LV function. The user's LV will be higher the more questions the user answers correctly, so as the LV increases, the questions faced by the user will also be more complicated, with higher variable values. Users who have proven that they have the ability to do the questions correctly will be given more complicated questions, if the user answers many of the questions incorrectly, the user's LV will go down and the questions given will be simpler, convincing the user only given questions according to their abilities.
3. Development was the basis of the two previously mentioned elements. Progress is implemented by increasing a stat, namely XP, every time the user answers correctly. With enough XP, the user's LV will go up, hence putting the user's name higher on the leaderboard. In addition, the questions that will be faced by users also increase in level. But apart from the other two elements, the development element is implemented so that the user get a 'prize' for doing what the system wants. Putting their name on the leaderboard and getting more complicated questions is a secondary motivation for users who prioritize increasing XP as the main motivation. The increase in XP is also the reward that the user gets the fastest, because the user only needs to do one question to get it, unlike competitive and adaptive where the user has to do many questions to increase the LV to get the prize.

2.5. Game

A video game is an electronic game that involves interaction between a user and an interface to create visual feedback on a video display device such as a TV screen, virtual reality headset, or computer monitor. [21]. The resulting design of this research can be categorized as web-based game. The use of the resulting game is for education. So it can be categorized as an educational game, which is games designed specifically for educational purposes, or inadvertently having educational value. All types of games can be used in an educational environment. Educational games are designed to help players learn a subject, expand concepts, reinforce development, understand a culture or historical event, or help them learn a skill as they play. Games can satisfy the fundamental need for learning by making players happy to play, providing motivation, satisfaction, adrenaline, creativity, and social interaction in the game itself while the learning process occurs [22].

2.6. Unified Modelling Language (UML)

In the development process, UML was used to model the design. UML is standard modeling language using object oriented approach [23]. UML has many diagrams which are divided into two major groups, namely to model the system structure and to model behavior. Structure diagrams are used to describe static data and relationships in information systems. Behavior diagrams depict dynamic relationships among instances or objects that represent business information systems.

In this research only 2 kinds of diagram used to model the sofware which are use case diagram and activity diagram.

Use Case Diagrams are models that describe the functions that the system can perform from the point of view of external users [24]. Use Case Diagrams answer the question "what can the system do?" not “how does the system do that?”. Graphically describes a collection of use cases and their relationship to existing actors. In this study the Use Case Diagram will describe who are the actors involved in the system, what things can be done by the system, and how the relationship between actors and use cases is. Things that the system must be able to do, such as logins, and special things that can only be done by certain actors, such as updating tables that can only be done by admins, and conducting tests that can only be done by teachers will be described in this research.

Activity Diagrams are used to describe the behavior in business processes required in the system. Activity Diagrams are also commonly referred to as sophisticated Data Flow Diagrams (DFD), but in Activity Diagrams there are notations for modeling parallel activities, and complex decision processes. This diagram can also be used to model high-level business workflows that involve many use cases to individual use cases, so it can be said that Activity Diagrams can be used to model all types of processes [25]. Activity Diagram in this study will describe a series of processes that occur in the question generation system. Examples are the question-making process, the answer-checking process, the leaderboard display process, and others.

2.7. Database and Programming Language

Database was used in the resulting implemented web-based game. A database, is an organized collection of data. Databases are usually stored and accessed electronically from computer systems. More complex databases are often developed using formal design and modeling techniques [25]. In this research, the designed database will be modeled using ER Diagram, and will be managed using MySQL.

3. RESEARCH METHODS

The goal of this research was to develop a web application prototype that helps 5th grader elementary school students to learn geometry by doing exercise. According to Yuksel-Sahin (2008) and Saputra (2014), students who like mathematics and students who have mastered the material being tested have lower levels of anxiety than students who do not like mathematics and have not mastered the material [10] [27]. So this system is designed to make learning math more fun to reduce anxiety levels in 5th graders by implementing game elements like competitive elements, adaptive elements and development elements in its design.

The approach used in this research was experimental research, developing a web application prototype that designed to reach its goals.

The steps of this research began with identifying the problem, literature research, analysis, design, implementation, testing, deployment and validation. The steps steps for this research can be seen on Figure 3.

Figure 3. Research Steps

The results of the first, and second steps has been explained in the previous chapters of this writings. So this chapter will focus on the third steps to the end.

The third to the seventh steps as shown in figure three follows the Software Development Life Cycle (SDLC) using the waterfall method. The selection of this method is based on that the system development process refers to the specifications that have been set from the beginning of planning. In general, the stages that are passed in the waterfall method are shown in Figure 4.

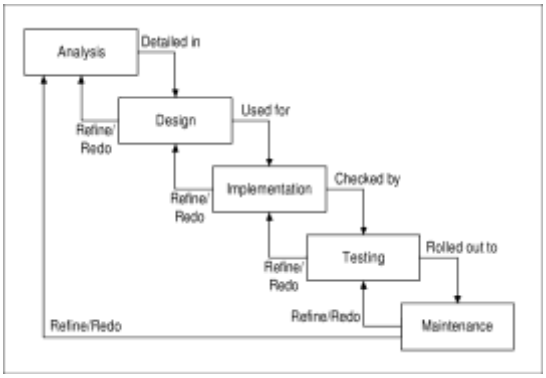

Figure 4. Waterfall Method (Whitten, Jeffery, D, Lonnie, C, & Kevin, 2004)

3.1. System Analysis

At this stage, an analysis of system requirements is carried out which will produce lists of features needed to build a geometry problem generation system for 5th grader elementary school students. Beginning with an "as-is" modelling of the system and trying to come up with the suggested models of the system.

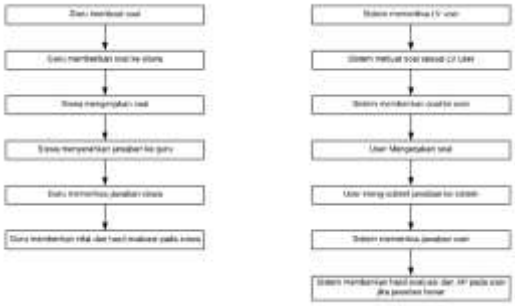

Figure 5. Comparison of the current system and the proposed system

According to figure 5 on the left, In a physical class, a teacher must give the same questions to all students even though the level of understanding of these students is not the same. In addition, one teacher must check the answers of all students one by one, the teacher also cannot bear the responsibility of his students all the time. On the suggested system on figure 5 on the right, by using interactive media in generating geometry questions, the system can adjust questions for each user and provide evaluations to all users who use it directly.

After further analysis, there are three actors involved in this system, namely admin, teacher user, and student user. The admin as the main controller of the system can perform all existing use cases, but the main task of the admin is to manage a database that contains information about students, teachers, and tests. The teacher can see the grades of all students and conduct a test. Students can see their own scores and work on practice questions and test questions.

These features can be seen as Use Case Diagram on figure 6.

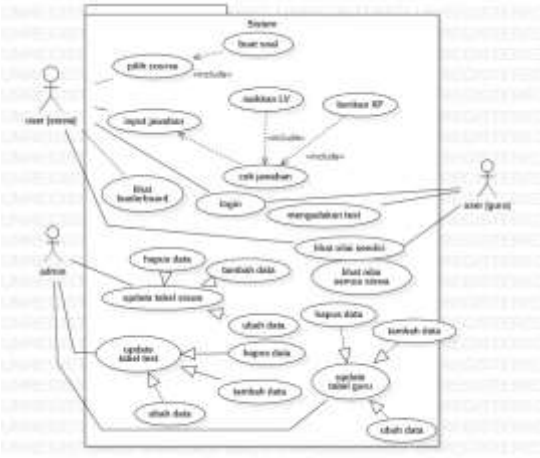

Figure 6. Use Case Diagram

The competition element implementation was implemented as leaderboard system. So there was a use case for user actor to see the leaderboard. While the adaptive and growth elements was implemented in LV and XP mechanic that included in Naikkan LV and Berikan XP Use Case.

3.2. System Design

After identifying all the features to be developed in the previous phase, the next step was to design the solution for each identified features. The resulting design was categorized into 3 categories, which are user process design, database design and interface design.

3.2.1 Process Design

The process design of the system was modelled by using Activity Diagram. The overall process design can be viewed in figure 7. The drawing in figure 7 shows description of the entire menu in the system and who the actors can access it. Admin can perform data management activities for students, teachers, and tests. The teacher can carry out the activity of holding a test. Students can do activities to do the questions.

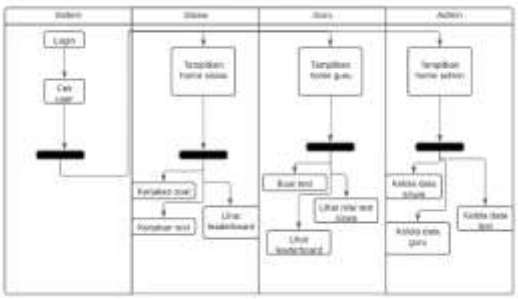

Figure 7. Overall Process Activity Diagram

The implemented adaptive and development elements were in the Kerjakan Soal Process. The Process of Generating the Questions can be seen in figure 8.

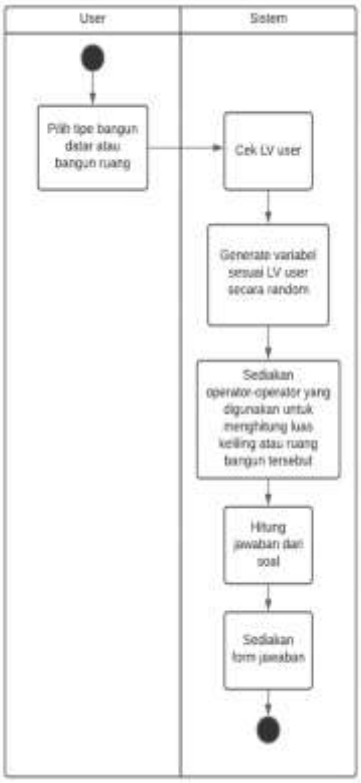

Figure 8. Activity Diagram describing Generating Questions Process

The figure 8, shows the process of generating questions. The system generates numbers based on how many variables are needed for each flat or spatial shape. If the user chooses a question that requires two variables, the system will generate two variables. The generated number corresponds to the user's LV. At LV 0, the system generates variables between 1-10, and for each user level, the

variables generated by the system will increase by ten. So user LV 1 will get a variable between 11-20, while user LV 2 will get a variable between 21-30. After that the system will adjust the operators used in the selected questions. If the formula for the selected problem is 'variable1 * variable 2 / constant', then the system will assign the first operator as 'times' and the second operator as 'divide'. This corresponds to the developmental mechanics described in chapter II. After the system determines the variable, the system prepares the key operator. After that the system calculates the answer to the question to compare it with the user's answer. Finally, the system gives the user a form to answer the questions.

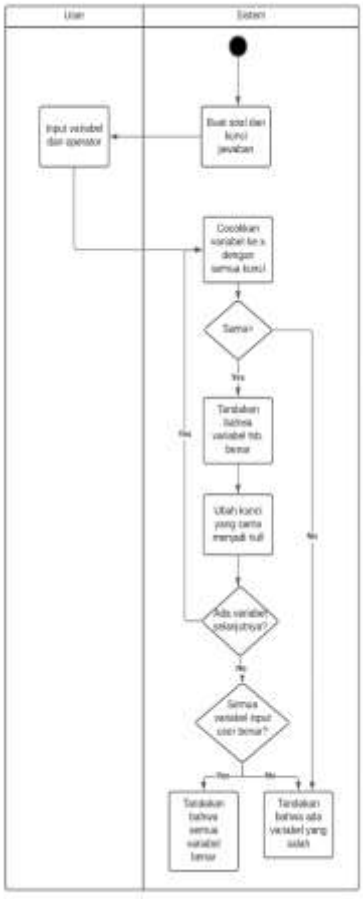

Figure 9. Activity Diagram describing Check Variable Answer Process

When the user has entered the answer to the question, the first thing to do in checking the answer is a variable. The system checks whether the first variable entered by the user matches any key variable generated by the system when creating the question. If yes, the system indicates the suitable variable is not matched again with the next variables. This continues until all user variables have been checked. If all the variables entered by the user have pairs with key variables, then the system marks the variable entered by the user as correct, if only one is wrong, then the system marks that something is wrong. These processes that check the answer is shown in figure 9.

After finishing checking the variables, the second thing to do in checking the answers is the operator. The system checks whether the first operator entered by the user matches any key operator generated by the system when creating the question. If so, the system indicates the suitable operator is not matched again with the next operators. This continues until all user operators have been checked. If all the operators inputted by the user have a pair with key able operators, then the system marks the operator entered by the user as correct, if only one is wrong, then the system marks that something is wrong. Figure 10 describes these processes in checking the operators.

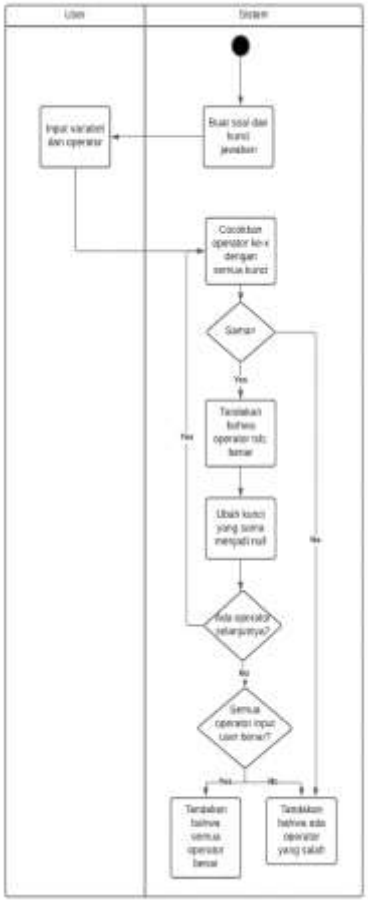

Figure 10. Activity Diagram describing Check Operator Answer Process

After checking the variable and operator process, the system prints the user's answer. If errors are found in both processes, the wrong variable or operator will be printed in red. After that, the user prints the correct answer from the answer key so that the user can compare the answer and the answer key next to each other. These processes can be viewed in figure 11.

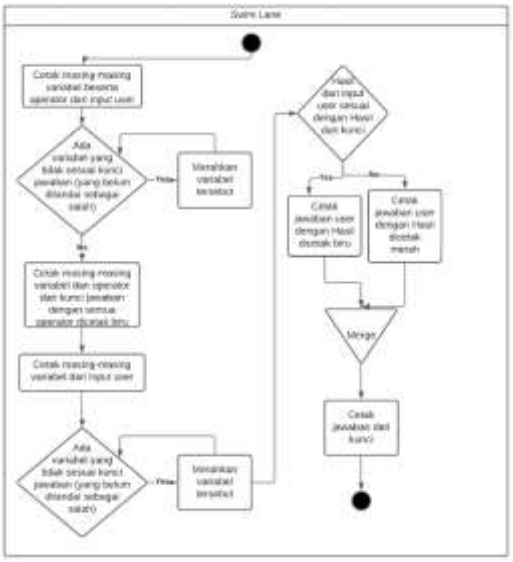

Figure 11. Activity Diagram describing Displaying the Answer Process

3.2.2 Database Design

The database design is modelled using Entity Relationship Diagram (ER Diagram). The ER Diagram of the system can be viewed in figure 12.

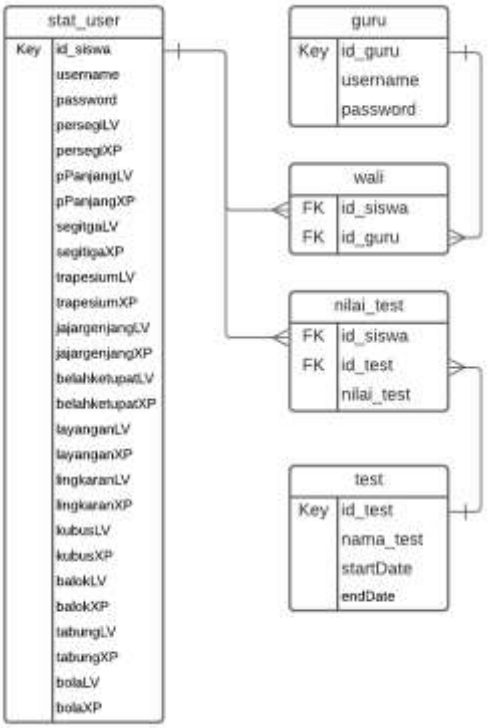

Figure 12. ER Diagram

From viewing the ER Diagram in figure 12, system database has five tables. The

stat_user table contains the student related data, with following columns, which are, student ids, usernames, and passwords, as well as students' LV and XP in all planes and spaces. The teacher table contains the teacher id, username, and password. The guardian table is to accommodate the data of parents or guardians of students. This table contains student_id and teacher_id taken from the stat_user table and the teacher table. The test table is to accommodate data about the test. This table holds id_test, which is an auto increment integer, the test_name chosen by the teacher, and the start date and end date selected by the teacher. The test_value table contains the student_id from the stat_user table and the test_id from the test table, as well as the students' scores with the student_id in the test with the test_id.

3.2.3 User Interface Design

The user interface for this research was designed as simple as possible, because the required features was not many, and to keep the users focus on their tasks. The web application starts with displaying the login page. The login page can be viewed in figure 13.

Figure 13. Login Page

After user login succeded, then the user can see the Home page. From this page the user can go to leaderboard page or do test page (questions page), for each category of geometry lesson. Figure 14 displayed the home page.

Figure 14. Home Page

If the user want to do the test, the user can choose the category of geometric figure to test. Then the Questions Page will be displayed, and the questions will be generated according to the user's previous LV and EXP. The Questions page will be displayed as shown in figure 15.

Figure 15. Questions Page

If the user manage to fill in the right answer, then the user will see the Right Answer Page in figure 16. Or the user will be shown the Wrong Answer Page in figure 17.

Figure 16. Right Answer Page

Figure 17. Wrong Answer Page

The user can choose to do next questions until the end of 10 questions answered and after shown the right or wrong answer for each questions.

From the Home page, the user can see the leaderboard page. The leaderboard page can be viewed in figure 18.

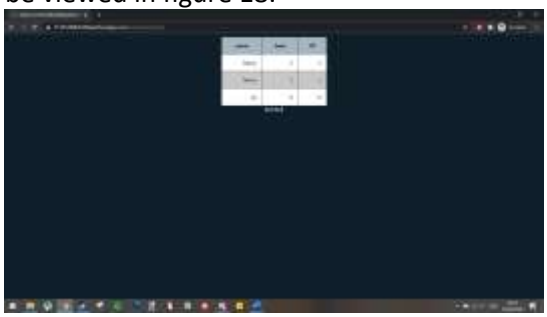

Figure 18. Leaderboard Page

These pages were all the pages that considered essential in this system. Because they are used by the main actor of the system which is students.

3.3. System Development

The system was developed using PHP. And for database management system, MySQL was used. The implementation of each use cases can be viewed in table 1.

Table 1. Implementation of Use Cases in PHP

Use Case	File PHP
1) Update tabel	Tidak dilakukan melalui PHP
2) Pilih course	CourseSelect.php
3) Input jawaban	bangun_datar.php
4) Lihat leaderboard	leaderboard.php
5) Buat soal	bangun_datar.php
6) Cek Jawaban	action_page2.php
7) Berikan XP	action_page2.php
8) Naikkan LV	action_page2.php
9) Mengadakan Test	buatTest.php
10) Lihat Nilai	nilai_test.php

3.4. Testing

At this stage, functional testing is carried out which is associated with the scenarios in the use case. Due to the limitations of the development team, the tests were carried out by the developers themselves regardless of the system's internal algorithms. Once each use case is complete. All new use cases are declared successful if all the steps are in accordance with the process design. The test results can be viewed in table 2.

Table 2. Test Results

Use Case	Keberhasilan
1) Update tabel	Berhasil
2) Pilih course	Berhasil
3) Input jawaban	Berhasil
4) Lihat leaderboard	Berhasil
5) Buat soal	Berhasil
6) Cek Jawaban	Berhasil
7) Berikan XP	Berhasil
8) Naikkan LV	Berhasil
9) Mengadakan Test	Berhasil
10) Mengerjakan Test	Berhasil

3.5. Deployment

Application launched at 000webhost.com. Users can access the application with the URL gensolumtk.000webhostapp.com with any desktop browser.

3.6. Validation Test

To prove that the system achieve its intended goal then validation test is conducted after the application’s deployment.

Non-gamification scores were obtained from participants working on 30 questions that were randomly selected using the test function three times. The experiment was carried out for three days, with participants

working on ten questions every day using the system. Gamification scores were obtained from participants working on 20 questions after practicing using the system.

Table 3. Test Results

Peserta	Non-Gamifikasi	Gamifikasi	Perbedaan
1	80%	75%	-5%
2	84.34%	85%	0.64%
3	86.67%	90%	3.37%
Rata-rata	83.67%	83.33%	-0.34%

Table 3 is a comparison of the scores of each participant before and after the exercise using the system. The data seen from the experimental results is the difference in the value of each user between doing the test questions before and after practicing using the system. Of the three participants who took part in the experiment, one participant experienced a 5% decrease in value, one participant experienced an increase of 0.64%, and one participant experienced an increase of 3.37%. The average difference in the scores of the participants before and after the exercise decreased by 0.34%. These results give the impression that the system used was not successful in training participants to work on geometry questions for 5th grade elementary school.

4. CONCLUSION AND FURTHER DEVELOPMENT SUGGESTION

4.1. Conclusion

After going through the each steps of the research, the things that can be concluded are:

1. The resulting design can provide recommendations in the use of procedural generation for making geometry questions for grade 5 elementary school.
2. The resulting design can provide recommendations for IT developers to develop a Web-Based Procedural Generation System for Geometry Questions for Class 5 Elementary School.
3. The automation process owned by computer software can be used to check user answers and provide feedback.
4. The mechanics used are competitive, adaptive, and developmental mechanics
5. An experiment conducted with three participants resulted in a higher score for two participants and a lower score for one participant, resulting in a lower mean score compared to the pre-experiment mean.

4.2. Future Development

In the future, this research can be improved by doing more research:

1. Completing the system design with additional features that can assist the user in operating the system.
2. Develop system interface design using more interactive graphics.
3. Conducting more experiments with more participants is essential to get more insight in improving the current design.
4. It is necessary to look at the level of enthusiasm of the participants when conducting experiments to ensure that participants stay focused.
5. Develop mechanics that help participants stay focused, such as adapting game mechanics according to user preferences.

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