Implementation of Gamification in Mathematics m-Learning Application to Creating Student Engagement

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Implementation of Gamification in Mathematics m-Learning Application to Creating Student Engagement

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***Abstract*—Mathematics is one of the main subjects in school. In some schools, the learning methods used are still using conventional methods, namely lectures and exercises. The main difficulty in learning mathematics is how to make the material presented more interesting so that it does not make students bored and easy to understand the material. The use of an attitude of interest in games that knows no age and the various advantages of games gives rise a combination of learning mechanisms called gamification. Gamification is the process of applying game mechanics to non-game activities to increase user interactivity. Gamification in the m-learning mathematics application was developed using the Attention, Relevance, Confidence, and Satisfaction (ARCS) learning model and the octalysis framework gamification method. Gamification in this mathematics m-learning application applies a game strategy using a system of levels, missions, challenges, points, progress bars, leader boards, and badges. The results of this study indicate that this application can be used as an alternative medium for learning mathematics and student engagement with the result that gamification applied to the m-learning mathematics application can increase student interest by 35%, increase student motivation by 33%, and improve understanding 42% of students towards learning mathematics.**

***Keywords*—Gamification; m-learning; mathematics; attention; relevance; confidence; and satisfaction (ARCS) model; octalysis framework; student engagement**

I. Introduction

Mathematics is one of the disciplines that is studied at all school levels, given from elementary students to higher levels [1]. Mathematics is considered a difficult subject because the characteristics of mathematics are abstract, logical, systematic, and full of confusing symbols and formulas [2]. This is because mathematics learning is still conventional, which causes teachers to have difficulty developing the material contained in the book because of the large number of materials to be taught, while from the student aspect, students' lack of interest in learning mathematics, understanding of concepts that are not mature, enthusiasm for learning is high. less and students are not motivated when learning mathematics, and many students view mathematics as a difficult and boring subject[3].

The development of ICT has helped a lot in the field of mathematics education [4]. Computer-assisted mathematics learning applications have been widely developed as alternative learning media [5][6]. Mobile application development (m-learning) is one of the media that is currently widely used in the development of learning applications other than e-learning [7]. This is supported by easy access [8], a more flexible learning process [9], as well as its ability to provide interactive and communicative mechanisms [10] to be one of the causes of the development of e-learning learning models toward m-learning [11].

Gamification is the process of using in-game mechanisms or rules for non-game activities to increase user interactivity [12]. Gamification offers application design that embeds game elements so that it has more appeal to application content because game concepts are known to be fun and easy to understand. [13]. This is because the gamification application model must have the characteristics of attracting the attention of students to use it, able to build student motivation and competence, build student confidence and be interactive to build reasoning and mindset when completing tasks and satisfaction, namely students feel happy when they complete their assignments. [14][15]. To develop a gamification mechanism in a learning application, a reference model is needed [16]. The ARCS learning model unites several forms of student attitudes, namely attention, relevance, confidence, and satisfaction [17], where this model is designed to encourage student learning motivation by prioritizing attention to students [18], as well as applications that adapt the subject matter to the student's learning experience, which can create student confidence and create a sense of satisfaction for the student to study harder [19]. In order to develop the ARCS model, an octalysis gamification framework is needed where the gamification concept is designed by analyzing eight aspects of game psychology [20], which is a gamification concept with an emphasis on human-focused design [21], to optimize human motivation in a system, as opposed to function-focused design [22].

From the previous literature, the implementation of mobile applications, gamification techniques, and the ARCS learning model is still being developed partially, there has been no research that has tried to combine these three elements in a unified system. Therefore, the objective of this research is to develop a model and application of gamification-based mathematics m-learning by integrating the ARSC model and octalysis framework. The implementation of the application is carried out to test and prove whether the concepts and

applications that have been developed previously can increase student involvement in mathematics.

II. Literature Review

A. Gamification

Gamification is a product, a way of thinking, a process, an experience, a way of design, and a system that is involved, which uses game elements to solve non-game problems. [23][24]. In the world of education, it can also be said that gamification is a process of changing existing activities or studying activities and making learning content like a game [25]. Gamification is using game mechanics to provide practical solutions by building specific group engagement [26]. In more detail [27], defines gamification as a concept that uses game-based mechanics, aesthetics, and game thinking to engage people, motivate action, promote learning and solve problems. In addition, gamification also provides additional motivation to ensure that students participate in complete learning activities [28]. The concept of gamification in an educational environment has the aim of maximizing students' learning comfort, thereby inspiring and motivating them to continue their learning process [29]. The Gamification Model proposed in 2015 (Fig. 1), consists of elements Mechanics which refers to the elements that comprise gamification, Measurement which refers to how progress in gamification is evaluated. Behavior - refers to the desired actions that players will cultivate as a result of playing the game, and Rewards - refers to the types of incentives given to players for fulfilling a requirement or task in the game [30].

B. ARCS Learning Model

Attention, Relevance, Confidence, and Satisfaction (ARCS) is a learning model developed as an alternative that can be used by teachers to motivate student learning by carrying out learning activities well [31]. This learning model contains four components that are an integral part of learning activities, namely (1) generating and maintaining student attention during the learning process (Attention), (2) providing subject matter relevant to students (Relevance), and (3) providing truest self to students (Confidence), and (4) foster student satisfaction with the learning process (Satisfaction) [32]. Within the teaching framework, the motivational analysis must be an ongoing process, to ensure that gamification matches the motivational factors as learning takes place [33]. The ARCS model has provided several specific steps to examine the relevant motivational features in the use of various media in the learning process [34][35]. Fig. 2 shows the ARCS Model applied to an educational game-based learning application.

C. Octalysis Gamification Framework

Octalysis is a gamification framework developed by Yu-kai Chou in 2015. The Octalysis method has two levels, where the first level is an analysis of game elements from the Octalysis framework, while the second level is the application of game elements in four phases that have been provided. Octalysis is based on a gamified framework designed using eight core drives [36]. Fig. 3 shows the gamification framework using the octalysis method at the first level, which consists of eight core drives in the octalysis framework, namely: (1) Epic Meaning and Calling: in this drive, someone is convinced that they are doing something great or feel that they are the chosen ones for doing something, (2) Development and Accomplishment: internal drive to make progress, develop skills and overcome challenges, (3) Empowerment of Creativity and Feedback: users engage in creative processes such as trying different combinations, (4) Ownership and Possession: these drives make users motivated because they feel like they have something, (5) Social Influence and Relatedness: drives that come from the environment, (6) Scarcity and Impatience: the drive to get something for not having it, (7) Unpredictability and Curiosity: the drive to know what will happen next, and (8) Loss and Avoidance: this drive is based on avoiding something negative happening [37].

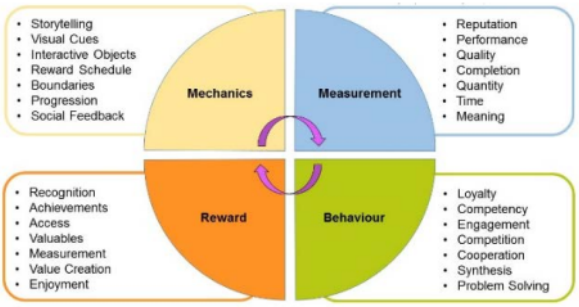

Fig. 1. Gamification Model of Learning. Available from: http://ivantehrunningman.blogspot.com/2015/04/gamification-oflearning.html.

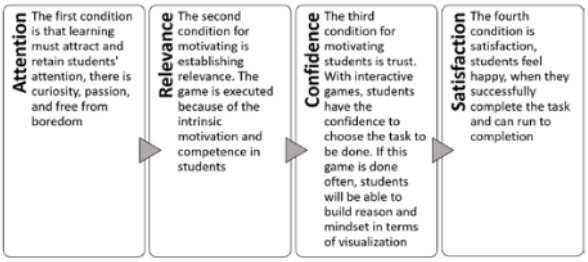

Fig. 2. ARCS Model in Educational Game Learning Media.

Fig. 3. Level I Octalysis Gamification Framework.

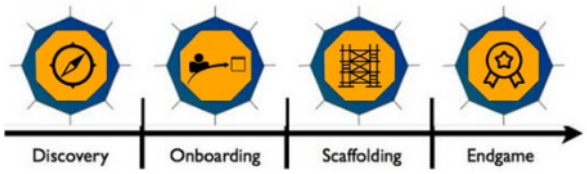

Fig. 4. Level II: Octalysis Level II Gamification Framework.

After applying the game elements that will be used, the elements are arranged into four phases which are part of the octalysis framework, level II. Fig. 4 The following shows the four phases of the second level octalysis framework [38]: (1) Discovery phase which is the initial stage where new users enter the application system and introduction of the application, (2) The onboarding phase is the phase where users begin to get to know the flow and application rules, (3) The scaffolding phase is the phase where users start using the application after getting to know the flow and the main mission of the application, and (4) The endgame phase aims to keep players using the application after the goal of the application has been achieved.

D. Multimedia Development Life Cycle (MDLC)

In the field of learning, the use of multimedia has been widely used, starting from the use of text, images, animation, video, and audio, to motivate students to like teaching materials. Fig. 5 shows the software development method used, namely the Multimedia Development Life Cycle (MDLC) introduced by Luther [39] and developed by Sutopo [40].

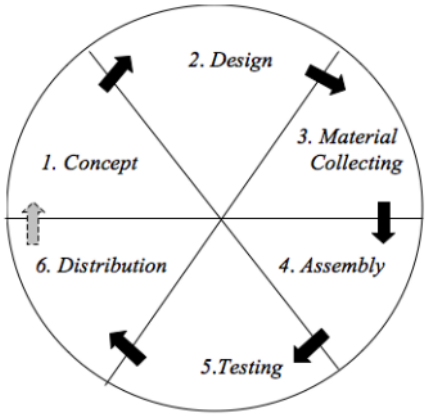

Fig. 5. Multimedia Development Life Cycle.

The concept is the activity to determine the purpose and who are the users of the program [41], Design is the stage of making specifications regarding the program architecture, style, appearance, and material/material requirements for the program [42], Material collecting is the activity of collecting materials following the needs being worked on [43], Assembly is the activity of making all multimedia objects or materials. Application development is based on the design stage, such as storyboards, flowcharts, and/or navigation structures [44], Testing is carried out after completing the assembly activity by running the application program and seeing whether there are errors or not [45], and distribution where the application will be stored in a storage medium. This activity can also be called the evaluation part to develop a finished product to make it better. The results of this evaluation can be used as input for the concept stage of the next product [46].

III. Research Method

This research was conducted using a quantitative descriptive research method [47] namely a research method that provides an objective description of an existing problem analytically and measurably [48].

Fig. 6 shows the five stages of research design carried out in this study, namely problem formulation, data collection, software development using MDLC, and conveying the results.

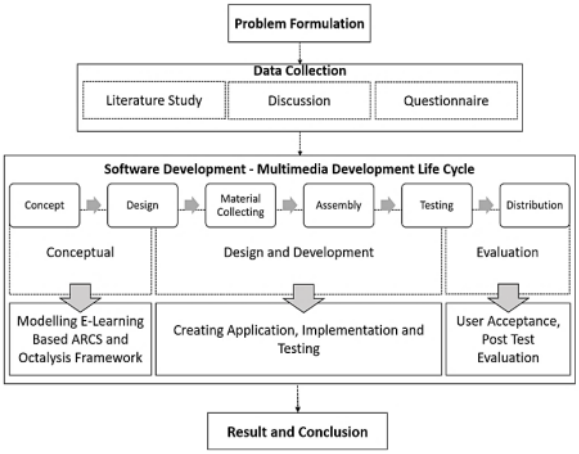

Fig. 6. Research Design.

The first stage is problem formulation which is an attempt to uncover various things related to the problem to be answered or solved. In this study, the formulation of the problem was carried out by identifying the existing mathematics learning problems, what are their shortcomings, and the solutions offered for their completion. This is the aim of the research conducted.

The second stage is the collection of research data utilizing literature studies, discussions, and questionnaires. The literature study was carried out by collecting previous studies related to the ARCS learning model, the theory and implementation of gamification, and the mechanism of MDLC software development. In addition, discussions with the school, namely teachers and students in mathematics, were carried out to collect data on learning materials, get input and describe the desired solution. Meanwhile, the use of questionnaires was carried out for scientific measurement of the results obtained from this research.

The fourth stage is the development of m-learning mathematics software. In this research, software development is carried out using the MDLC method, which starts from the conceptual section which contains the system model to be developed, the users, and its functions in it. Followed by the design and development section, where the system design is

carried out, making the assets in the system developed, coding the system, and conducting initial testing. The last part at this stage is an evaluation by testing the system both functionally and in terms of acceptance of its users.

The fifth stage is to summarize the results that have been obtained, provide conclusions, state the limitations in the system built, and direct the development of further research.

IV. Result and Discussion

A. Analysis of Current Learning Conditions

Based on the discussion conducted by the researcher using interviews and field observations (Fig. 7), there are two things found in the learning process of mathematics subjects, namely that the learning process is still done conventionally. The teacher provides learning materials through books, blackboards, and written exams. Meanwhile, students receive learning by listening and doing the tests given by the teacher. On the other hand, there are no alternative tools that can be used by students in the learning process, limiting students to be able to learn and understand mathematics subject matter.

Based on these problems, a solution was developed to build m-learning applications for mathematics subjects that can be used by students to learn from anywhere, with more interactive and interesting content in the form of gamification in mathematics subjects.

B. Conceptualizing Mathematics M-Learning Gamification

Fig. 8 shows the conceptualization of the application carried out to describe what things will be done by the system along with its methods and work functions. Application development starts from user needs, implementation of the ARCS model, and gamification in the application, followed by application development to achieve the expected goals.

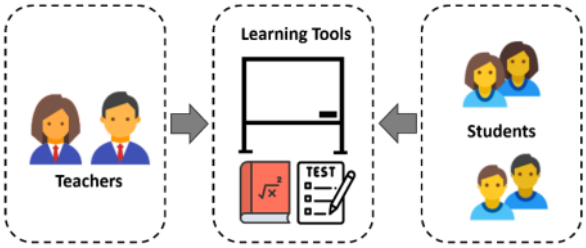

Fig. 7. Existing Learning Activities.

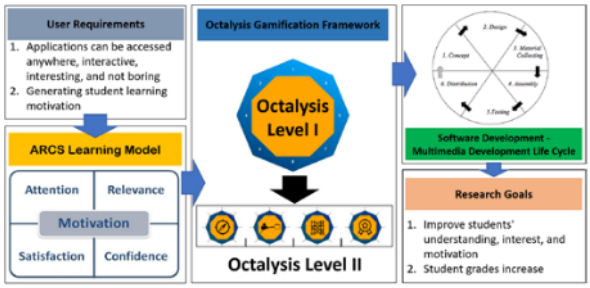

Fig. 8. Conceptual Development of Mathematics Gamification Applications.

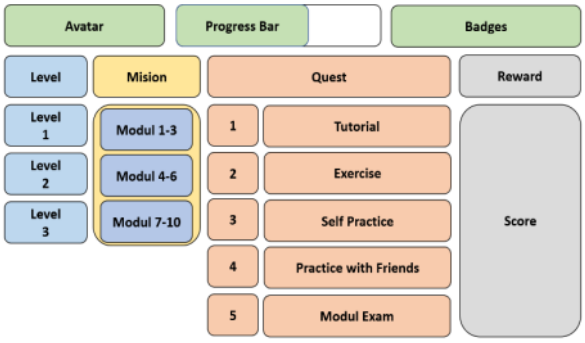

Fig. 9. Mathematics m-learning Gamification Model.

Gamification modeling in the m-learning mathematics application (Fig. 9) was developed by providing educational game effects in the form of game levels related to the learning module for mathematics materials, quests which are challenges that must be completed by students, rewards in the form of points and badges, and avatar that can be customized by students.

C. Octalysis Gamification Analysis

The octalysis method has eight core elements, each of which has a game technique that can be chosen to be implemented. Mathematics learning applications are built using the concept of gamification with the octalysis framework method. This method begins with the level 1 stage by analyzing the elements that will be applied, and then enters the second stage, namely, level 2 making gameplay.

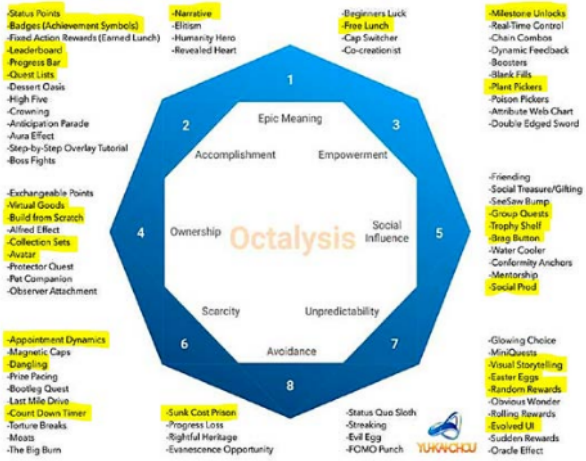

Fig. 10. Octalysis Gamification Elements are used.

Fig. 10 shows that there are 25 elements of the octalysis framework used in the development of this gamification application.

1) Elements of Epic Meaning and Calling, the application convinces the user that he is doing something bigger than himself or that he is "chosen" to do something. Game techniques used in the application to be built include:

a) Narrative, the application will start with a narrative or story that gives an idea of why the user should play the game or use this application.

b) Free Lunch, to attract users there is a limited item for 20 users at the start of the game.

2) Development and Accomplishment elements are used to encourage users to make progress, develop and overcome existing challenges or tasks. Game techniques used in the application to be built include:

a) Progress Bars, there are 2 types of progress bars in the application. The first progress bar is useful for showing the progress of the usage adventure, this progress bar illustrates how far the user has completed the existing material, for example, the user has completed 5 of the 6 chapters that are displayed using the bar. The second progress bar is used to show the user's ability or results in completing each material.

b) Achievement Symbols are used in the form of badges or badges. Every completed action or task will get feedback in the form of a badge. Status Points: each user has status points as a measuring tool or assessment in carrying out existing tasks.

c) The leaderboard is used as a facility to compare the achievements of one player with other players. The use of the leaderboard also aims to motivate players to always feel challenged to be the best.

d) Quest List, is used to displaying what tasks or challenges the user has to do in the application.

3) Empowerment is an element that is made so that users can be as creative as possible in solving problems. The following are the game techniques used in the application to be built:

a) Milestone Unlock: Correlating with the quest list, the existing materials, exercises, and exams cannot be accessed directly by the user. Availability depends on the related task, if the related task has been completed; it means that the user has met the requirements to access the material in question.

b) Plant Picker: Each user has different abilities; they can freely determine the reward they choose.

4) Ownership and Possession are elements where users are motivated because they feel like they own something. When a player feels ownership, he innately wants to make what he has better and have more of it. The following are the game techniques used in the application to be built:

a) Avatar: Each user has their avatar.

b) Virtual Goods: Correlating with the avatar game element, where the existing avatar is created based on the user's wishes, the user can choose the hair, clothes, and eyes for his avatar.

c) Build-From-Scratch: User avatars can be changed by purchasing items in the shop and using limited items from quest/task rewards.

d) Collection Sets: Users can provide feedback in the form of likes to their friends for group activities or assignments.

5) Elements of Social Influence and Relatedness are used to encourage users about guidance, competition, jealousy, group seeking, social possessions, and friendship so that users continue to use existing applications. The following are the game techniques used in the application to be built:

a) Trophy Shelves: Trophy Shelves are implemented in the leaderboard and profile where each user can see other users' searches.

b) Group Quest: There are several materials where training sessions must be carried out together, with this game technique users can interact with each other.

c) Social Prods: Implemented in the form of "likes" after doing Group Quests as a form of appreciation for fellow users.

6) The element of Scarcity and Impatience is the drive that motivates us simply because we cannot have something immediately, or because there is great difficulty in getting it. The following are the game techniques used in the application to be built:

a) Dangling and Anchored Juxtaposition: Energy usage limits the number of tasks taken per day.

b) Appointment Dynamics: This game technique is implemented using push notifications, where users will be given a message every week to use this application.

7) Unpredictability and Curiosity elements are user urges to find out what will happen next. The following is the game technique used in the application to be built:

a) Mystery Boxes/Random Rewards: There are mystery box items as rewards in several missions.

b) Easter Eggs/Sudden Rewards: There are limited rewards on some missions if the user reaches certain conditions.

c) Visual Storytelling: Dealing with Narrative elements where these elements are used as a visualization of the existing narrative.

d) Evolved UI: The existing UI will evolve according to the user level.

8) The Loss and Avoidance element motivates the user through the fear of losing something. For example, if our mission gets a low star rating, the user's points are reduced. The following are the game techniques used in the application to be built:

a) The Sunk Cost Prison: Due to dangling and anchored juxtaposition, the user's energy will be reduced if he exits the application while carrying out certain processes, for example in the training process.

b) Countdown Timers: related to the sunk cost prison and Dangling and Anchored Juxtaposition after the energy runs out the user cannot perform activities for a certain time.

The game elements that have been obtained at the level I are applied to four stages of gamification level II Octalysis namely discovery, onboarding, scaffolding, and endgame which can be seen in Table I.

TABLE I. ELEMENT GAMIFIKASI OCTALYSIS LEVEL II

Phase	Description
discovery	The discovery phase is the initial stage where a new user enters the application system and introduces the application. In this phase, the application uses several technical games, namely Narrative, Visual Storytelling, Free Lunch, and Avatar. Users are first presented with a story that describes why they should use this application and complete the missions according to the Narrative and Visual Storytelling game techniques. After that, the user creates his avatar as a character who will carry out the existing mission. The introduction ends with the award of points and gold as a form of Free Lunch.
onboarding	The Onboarding phase is the phase where the user gets to know the flow and rules of the application. The implementations in it are Progress Bars, Badges, Status Points, and Evolved UI. Students enter the main page in the form of a UI that displays the selected character. Then, students can see Status Points in the form of Points and Energy which are the value handles while using the application. Students can also see various assignments and their rewards on the Quest List page.
scaffolding	This phase is the phase where users start using the application after getting to know the flow and main mission of the application. Users perform activities according to the Quest List to achieve the goals of the application. Users can see the ranking of learning achievements through the leaderboard of accumulated points from completed tasks, besides that users can see the badges earned on the profile page (Trophy Shelves). At this stage, the user is presented with a challenge in which the user evaluates in the form of doing exercises and exams using the Fisher-Yates Shuffle algorithm to reduce the level of cheating. There are joint exercises as the implementation of the Group Quest and each user can give appreciation to his opponent in the form of likes as the implementation of the Social Prod. The results of practice and exams are visualized grades with stars. Each completed Quest earns rewards. Users then have activities to get Badges, according to existing conditions. Here implements Social Treasures and Collection Sets, and there is also a Milestone Unlock where this will unlock badges, as well as Easter Eggs. With the Easter Eggs mechanism, learning can be determined based on the user's decision, this is in line with the plant picker component game. The use of the application is limited according to the amount of energy remaining (The Sunk Cost Prison and Dangling and Anchored Juxtaposition), if the energy runs out the user must wait for a certain time (Countdown timer). Previously created avatars can be changed and customized via items purchased on the implementation avatar pages of Virtual Goods and Build-From-Scratch.
endgame	The last phase is the Endgame phase. This phase aims to keep players using the application after the goals of the application have been achieved. The implementation of this phase uses Appointment Dynamics where users will get notifications periodically.

D. ARCS Model and Octalysis Gamification Mapping

This stage is carried out by mapping the ARCS learning model based on the Attention, Relevance, Confidence, and Satisfaction categories, as well as the octalysis method in application development.

Table II shows the mapping mechanism of the ARCS learning model in the Attention category and the octalysis method.

TABLE II. MAPPING MODEL ARCS (ATTENTION) AND OCTALYSIS METHOD

ARCS Model - Attention			
Sub Category	***Description Category***	***Element Octalysis***	***Description***
Perceptual arousal	Media must have things that can attract users	*Narrative, Visual Storytelling*	The use of narration and visual storytelling to explain why they should use the app and learn the lessons.
		Avatar	Users have their avatar where the appearance of the avatar can change according to student achievements.
	Perception of stimulation through surprise	*Free lunch*	Students who access the app first get special rewards
		Easter Eggs (Sudden Reward)	There is a limited reward if the user reaches certain conditions
		Appointment Dynamic	Students are always reminded every week to study through notifications
	Perception of design through uncertainty	*Mystery Boxes (Random Rewards)*	Students can get random items from the mystery box
Variability	Interesting presentation of material	*Narrative, Tutorial*	Video media is used so that students do not get bored easily.
Inquiry arousal	Students can study the material independently	*Narrative, Tutorial*	With the narration in the learning video, students can learn independently
	Students can determine the learning process	*Plant picker*	The learning flow of each student is different, students can determine their process

Table III shows the mapping mechanism of the ARCS learning model in the Relevance category and the octalysis method.

Table IV shows the mapping mechanism of the ARCS learning model in the Confidence category and the octalysis method.

TABLE III. MAPPING MODEL ARCS (RELEVANCE) AND OCTALYSIS METHOD

ARCS Model - Relevance			
Sub Category	***Description Category***	***Element Octalysis***	***Description***
Goal Orientation	Explanation of learning objectives	*Narrative*	Before students can see the learning video, the learning syllabus is presented first.
Motive Matching	Explanation of the benefits of learning	*Narrative*	Before students can see the learning video, the learning syllabus is presented first.
Familiarity	Learning adaptation to students	*Narrative*	Examples of problems in learning adapted to the lives of students today

TABLE IV. MAPPING MODEL ARCS (CONFIDENCE) AND OCTALYSIS METHOD

ARCS Model - Confidence			
Sub Category	***Description Category***	***Element Octalysis***	***Description***
Learning Requirements	Learning requirements	*Milestone Unlock*	Students must meet certain requirements to carry out a lesson
		Quest List	Students can see the criteria for taking existing subjects
Success Opportunities	Provides many, varied, and challenging experiences that enhance learning success	*Group Quest*	The available exercises are divided into 2 types, namely individual training and group training (multiplayer)
Personal Control	There is feedback on student learning outcomes	*Status, Progress Bar*	Learning results can be seen through the number of stars and progress bar
		Rewards/ Achievement Reward	Every time you complete a quest, students get rewards
	Student responsibility for learning	*Dangling and Anchored Juxtaposition*	Students cannot arbitrarily carry out continuous learning, learning activities are limited by energy so students must be able to take advantage of their time
		The Sunk Cost Prison	Related to Dangling and Anchored Juxtaposition, students must be responsible if they cannot complete the learning process or leave in the middle of the process.
		Countdown Timers	Students cannot carry out the learning process, there is a time back, the rewards of the student's irresponsibility during the learning process

Table V shows the mapping mechanism of the ARCS learning model in the Satisfaction category and the octalysis method.

TABLE V. MAPPING MODEL ARCS (SATISFACTION) AND OCTALYSIS METHOD

ARCS Model - Satisfaction			
Sub Category	***Description Category***	***Element Octalysis***	***Description***
Intrinsic reinforcement	Internal satisfaction that can motivate students	*Badges (Achievement Symbol)*	Students get rewards in the form of badges as a visualization of their achievements
		Trophy Shelves	All learning achievements can be seen through the profile page
		Virtual Goods, Build From Scratch	*Existing avatars can be changed and created according to the user's wishes*
		Evolved UI	The existing UI changes according to user achievements
Extrinsic Rewards	External achievements that can motivate students	*Status, Leaderboard*	There is a student leaderboard to motivate which is obtained from accumulated points (status) obtained from rewards
Equity	Students can get learning feedback from other students	*Social Prod, Collection Sets*	Students can give feedback "like" after doing the exercise together

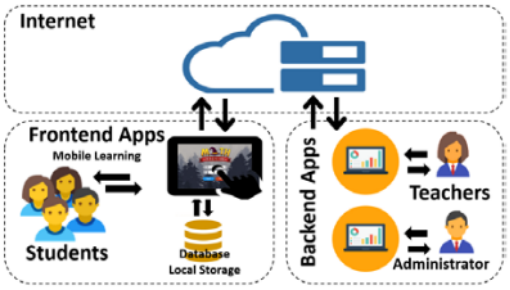

Fig. 11. Mathematics m-learning Application Architecture.

E. Analysis System Architecture

M-learning application development has three subsystem architectures in it. The first sub-system is the frontend application which functions as a gamification application used by students, a backend application used by teachers to manage the system and monitor student learning outcomes, and the internet which is used for the exchange and storage of application data. The architecture of the mathematical m-learning application can be seen in Fig. 11.

Functionally, the frontend application is an application that has gamification features. This application is used by students to learn math subjects.

Fig. 12 shows the functionalities developed in the mathematics m-learning application, where there are login functions, viewing materials, doing exercises, taking exams, viewing quests, viewing profiles, viewing the leaderboard, and creating avatars.

F. Gamification Logic Design

To develop the functionalities described in the use case diagram, a logical design is made for each function that shows the learning flow that can be carried out in the application of m-learning mathematics. The flow can be seen in Fig. 13 which starts from accessing the module to its completion, calculating scores and badges as an award for student achievement of the material that has been completed.

1) Tutorial design process: Learning materials (tutorials) are studied using a linear tutorial model and branched tutorials depending on the actions taken by students according to the application of game elements in the previous analysis. The

linear tutorial causes students can't able to choose freely to access the material they want to learn, and must follow the sequence according to the order of the existing material. Meanwhile, in the branching tutorial, students can take other materials if they have special items through random rewards. The tutorial flow can be seen in Fig. 14.

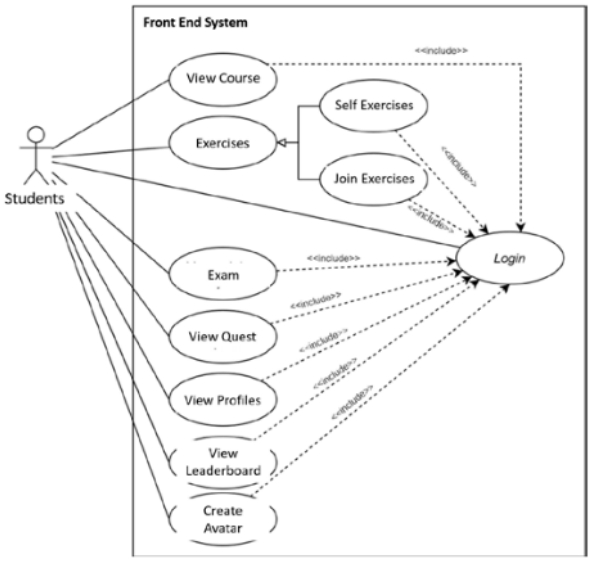

Fig. 12. M-learning Application Frontend use-case Diagram.

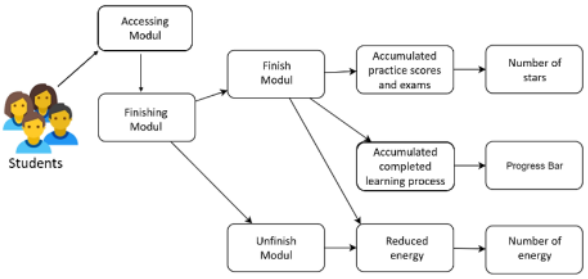

Fig. 13. Learning Flow in Gamification Applications.

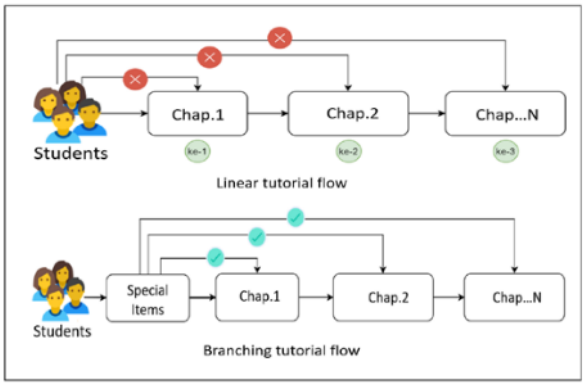

Fig. 14. Tutorial Flow.

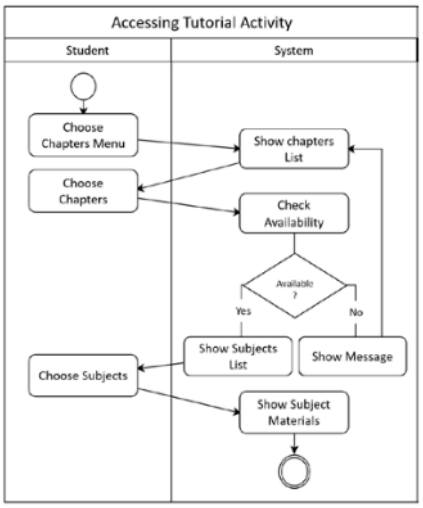

Fig. 15. Accessing Tutorial Activity Diagram.

Fig. 15 is an activity diagram that shows how students access the tutorial functions in the system. The tutorial consists of chapters and subjects of mathematics lessons that students can choose from.

2) Exercise and exam design process: The evaluation process is carried out using two methods, namely practice questions and exams. Students can do 2 practice modes, namely self-practice (Fig. 16), joint practice or multiplayer (Fig. 17), and independent exam (Fig. 18). At the time of practice, the number of questions that came out was 10 questions and 5 questions for joint practice. Meanwhile, at the time of the exam, the questions that came out were 15 questions, in which the questions were in the form of multiple choices.

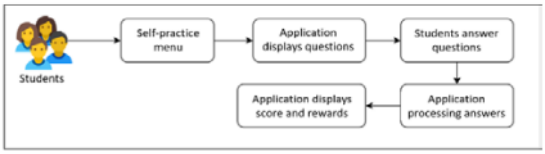

Fig. 16. Self-practice Evaluation Flow.

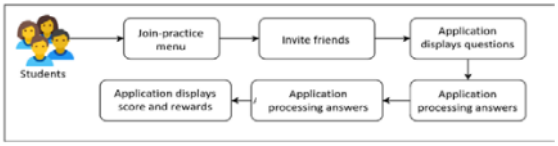

Fig. 17. Joint Practice Evaluation Flow.

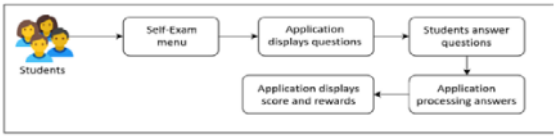

Fig. 18. Self-examination Evaluation Flow.

There is a special feedback feature after doing joint exercises, where students can give likes to other students after the exercise is finished. This is to give appreciation and socialization between students. The feedback flow can be seen in Fig. 19.

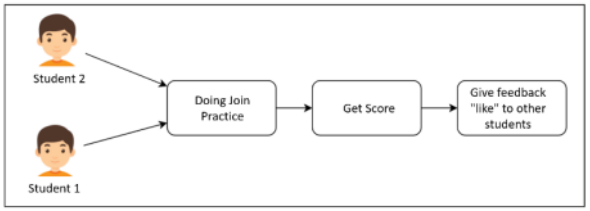

Fig. 19. Joint Practice Feedback Flow.

Fig. 20 shows an activity diagram of the exercise and exam functions that can be performed by students. The function of exercise and exam is an evaluation carried out by the system when a student has completed a chapter of learning in the system.

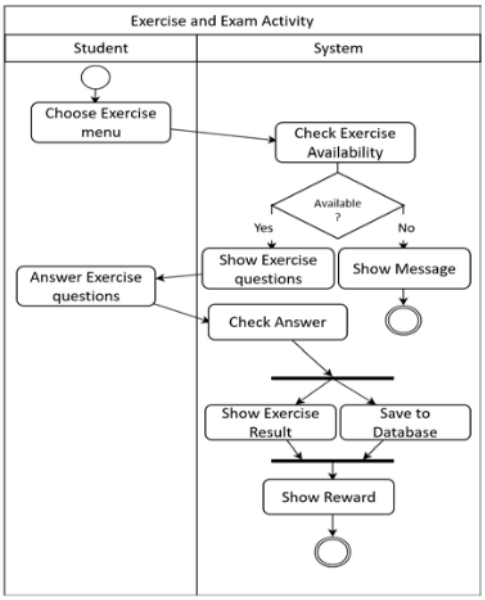

Fig. 20. Exercise and Exam Activity Diagram.

3) Quest flow design: Not all existing processes can be accessed freely by users; certain requirements must be completed first. The following is an analysis of the quest flow in the application that was built, which can be seen in Fig. 21.

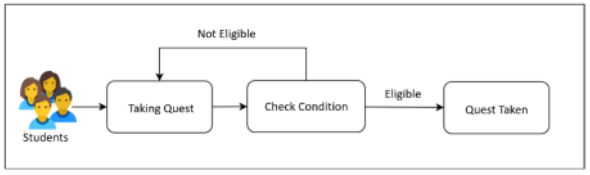

Fig. 21. Quest Selection Flow.

4) Rewards flow design: The form of rewards is adjusted to the status used in existing applications; rewards can be in the form of points or badges for students who have completed an activity. The flow of rewards can be seen in Fig. 22.

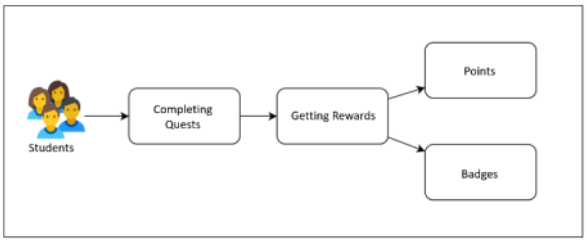

Fig. 22. The Flow of Rewards.

5) Leaderboard flow design: The leaderboard is obtained from the accumulation of student learning outcomes, obtained from the completion of tutorials, completion of exercises and exams as well as other activities. Fig. 23 shows the workflow of the leaderboard creation activity as well as an activity diagram to access the leaderboard contained in the system.

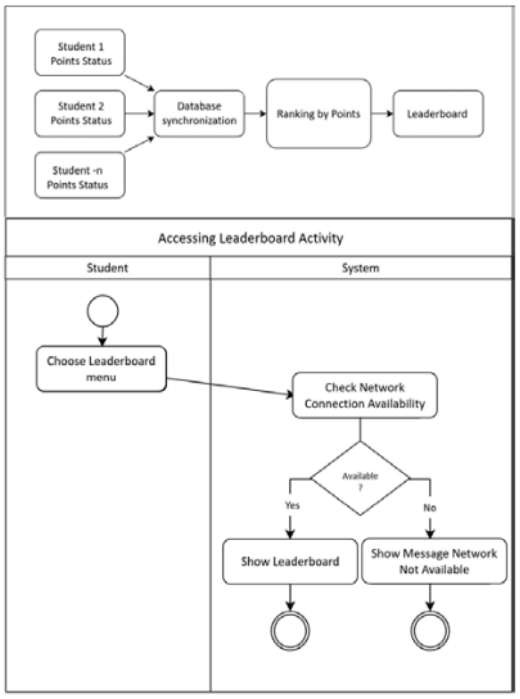

Fig. 23. Leaderboard Flow and Activity Diagram.

6) Avatar flow design: The avatar in the application can change according to the student's level status. Changes in avatars depend on student learning achievements, namely tutorials, evaluations, and points obtained. The following is the avatar flow for the application to be built, which can be seen in Fig. 24.

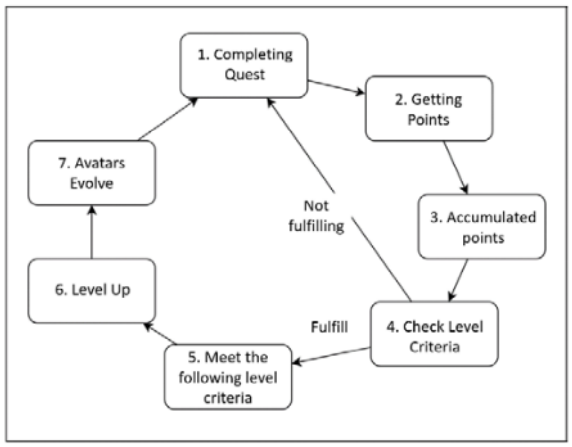

Fig. 24. Avatar Evolution Flow.

Fig. 25 shows student activities to customize their avatar. Avatars can be changed visually according to the level, badges, and rewards that students have.

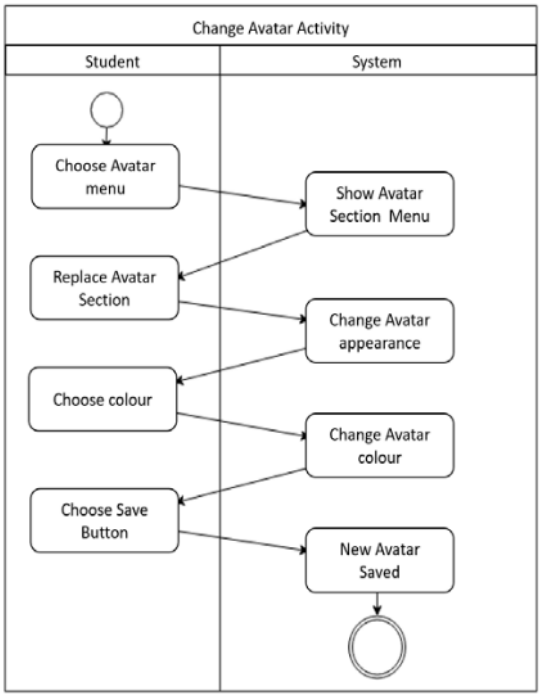

Fig. 25. Avatar Change Activity Diagram.

G. Gamification Asset Design

Assets in the application are symbols that are used to show the concept of gamification in the application that is made. Fig. 26 shows the assets used to deliver students understand the application that will be used.

Fig. 26. Introduction Gamification Asset.

Meanwhile, Fig. 27 is the badge assets that are used to show the form of rewards for student achievement in this gamification application.

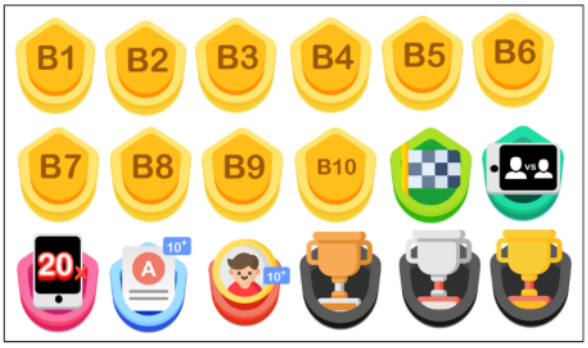

Fig. 27. Badges Gamification Asset.

Fig. 28 shows the assets associated with the Level which is divided into three where each level has a sub-level. The level is adjusted to the achievement of the learning modules that have been completed by students.

Fig. 29 shows the avatar assets that can be used by students after completing the learning stages in the application. The avatar designed in the application consists of shapes that represent the level of the game and can evolve when students advance to the next level.

Fig. 28. Level Gamification Asset.

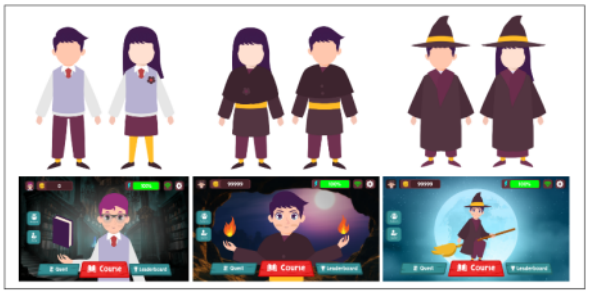

Fig. 29. Avatar Gamification Asset.

Fig. 30 shows quest assets where students can find out the flow of the game, challenges that must be completed, as well as rewards are given along with the status of achievements that have been completed.

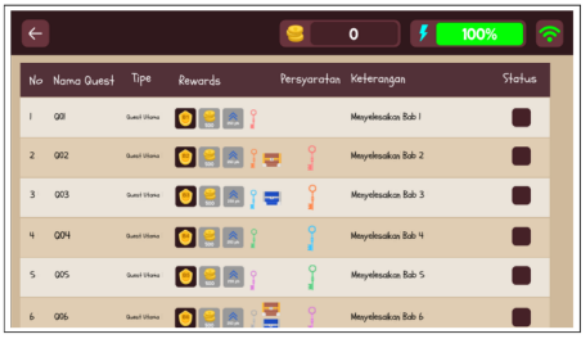

Fig. 30. Quest Gamification Asset.

Fig. 31 shows the learning assets owned by the application. Where there are features of access to materials, exercises, and evaluations. The form of the material is presented in a video tutorial, while for evaluation, it uses text and images.

Fig. 32 shows the practice and exam assets owned by the application, which are used by students to practice both independently and in multiplayer. Each question will be made random so that students will have different practice questions and exams.

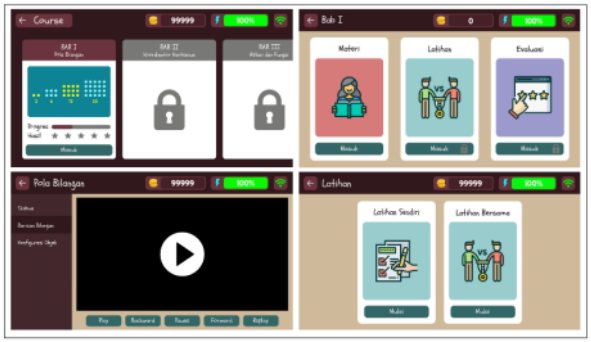

Fig. 31. Learning Materials Gamification Asset.

Fig. 32. Practice and Exam Gamification Asset.

Fig. 33. Profile and Leaderboard Gamification Asset.

Fig. 33 shows the profile assets and leaderboard in the application, this feature is used to see what items have been collected as a form of reward for completing the material and to see the student leaderboard and the points they have.

H. Application Testing

The tests carried out on the application consist of functional (alpha), beta and quasi-experimental testing. The method used in alpha testing is black box testing which focuses on the functional requirements of the system being built and in the beta stage, user assessments of the software are carried out through interviews and questionnaires. Meanwhile, quasi-experimental testing was used to measure the effect of using the application on students' understanding, interest, and motivation.

Alpha testing is a functional test that is used to test the new system. Alpha testing focuses on the functional requirements of the software. Alpha test results can be seen in Table VI.

Beta testing is a test that is carried out objectively, where testing is carried out directly on students. The method used is a questionnaire that is used to conclude the quality assessment of the application being built [49]. The following is the sampling formulation for the questionnaire:

$$n = \frac{N}{1 + Ne^2}$$

n: number of samples

N: Population (421)

e: threshold (10%)

$$n = \frac{421}{1 + 421 * (10\%)^2} = 80{,}81 \approx 81$$

Based on existing calculations, the number of samples obtained is 81 or equivalent to 2 Grade VIII classes, with an average number of students per class of 42 students. Two test classes were selected, namely grade VIII-A (40 students) and grade VIII-C (41 students) which had 81 students according to the calculation of the number of samples.

The questionnaire was given consists of nine questions related to the quality of the application which can be seen in Table VII, meanwhile for the measurement of results using a Linkert scale with weighted answers which can be seen in Table VIII.

TABLE VI. APPLICATION FUNCTIONAL TESTING

No	Testing components	Testing type	Result
1	Login page	*Black Box*	*Accepted*
2	Narrative Page	*Black Box*	*Accepted*
3	Home page	*Black Box*	*Accepted*
4	Account Settings Page	*Black Box*	*Accepted*
5	Quest Page	*Black Box*	*Accepted*
6	Course Page	*Black Box*	*Accepted*
7	Chapter Page	*Black Box*	*Accepted*
8	Study Page	*Black Box*	*Accepted*
9	Practice Page	*Black Box*	*Accepted*
10	Exam Page	*Black Box*	*Accepted*
11	Backpack Page	*Black Box*	*Accepted*
12	Avatar Creation Page	*Black Box*	*Accepted*
13	Pre-Practice Room Page	*Black Box*	*Accepted*
14	Self-Practice Page	*Black Box*	*Accepted*
15	Joint Practice Page	*Black Box*	*Accepted*
16	Leaderboard Page	*Black Box*	*Accepted*
17	Profile Page	*Black Box*	*Accepted*

TABLE VII. QUESTIONNAIRE QUESTIONS

No	Questions
1	Is the application easy to use?
2	Is the use of colors, buttons, and letters for the appearance (interface) of the application attractive?
3	Does the app encourage me to study math?
4	Can the application help me in understanding math lessons?
5	Is the material presented following the lesson given?
6	Is the material presented interesting and easy to understand?
7	Does using a ranking system motivate me to study?
8	Does the group practice system make learning interesting?
9	Does the use of avatars make the learning system interesting?

TABLE VIII. QUESTIONNAIRE ANSWER SCORE

Answer Category	Score
Strongly agree	5
Agree	4
Neutral	3
Disagree	2
Strongly disagree	1

The results of the final application assessment are the overall calculation of the questionnaire results obtained from student answers, which can be seen in Table IX, with the application quality assessment criteria shown in Table X.

TABLE IX. OVERALL QUESTIONNAIRE RESULTS

Category Answers	Score	Frequency of Answers	Total Score
Strongly agree	5	302	1510
Agree	4	246	984
Neutral	3	181	543
Disagree	2	0	0
Strongly disagree	1	0	0
Total		729	3037

P = (3037/3645) x 100% = 83%

TABLE X. APPLICATION QUALITY ASSESSMENT

No	Percentage Value	Criteria
1	0% - 19%	Very bad
2	20% - 39%	Bad
3	40% - 59%	Neutral
4	60% - 79%	Good
5	80% - 100%	Very good

Based on the results of the overall questionnaire, the application criteria showed 83%, which means that the application was in very good criteria.

Meanwhile, to determine the effect of using the application on students (student engagement), quasi-experimental testing was carried out by conducting pre-test and post-test activities through three activities, namely, understanding the material, filling out motivational questionnaires, and filling out interest questionnaires. The results of the pre-test and post-test will be compared using normalized gain score analysis which is calculated using the following formulation:

Normalized gain(g) = (post-test score– pre-test score) / (maximum score - pre-test score)

The results of the quasi-experimental testing activities obtained the results shown in Table XI and Fig. 34.

Based on the results of the tests carried out, it was concluded that there was an increase in student engagement in learning mathematics after using the gamification mechanism in the m-learning application. The increase was found in student understanding by 42%, student interest in applications by 35%, and student motivation by 33%.

TABLE XI. ASSESSMENT OF STUDENT ENGAGEMENT

Student Engagement	Score	*Pre-Test*	*Post-Test*	*Gain*
Student Understanding	Average	58,64	72,47	0,42
Student Interest	Average	58,30	73,07	0,35
Student Motivation	Average	58,84	72,57	0,33

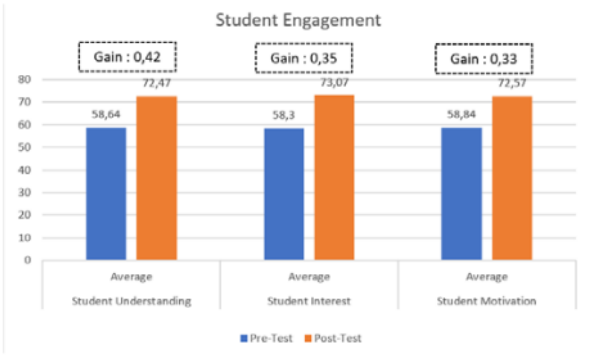

Fig. 34. Results of the Student Engagement Test on the Application.

This study is in line with research [50] where gamification can create student engagement in the learning process, as well as research [51] where there is an increase in better understanding by using gamification-based applications. Gamification-based mobile applications are also an effective and efficient alternative learning media in addition to classroom learning, because the game model can be used anywhere [52], besides that students have a competitive sense in learning because this gamification model shows rankings between participants [53].

The limitations of this research are the absence of features that facilitate schools to update the content in the application if there is a curriculum change, the ability of the application to be able to monitor and provide intelligent direction to students and teachers, and the data storage mechanism is still simple.

Therefore, the development of this research in the future will be involving elements such as artificial intelligence [54][55] to improve students' predictive abilities, in addition to applying augmented reality technology for application interaction [56] as well as having the ability to store and track data and student progress securely using blockchain technology [57][58].

V. CONCLUSION

In this study, we developed a mathematical mobile learning application that combined elements of gamification with the octalysis method and the ARCS learning model.

The purpose of this research is to see how far the role of the application can provide students' engagement in mathematics. The results obtained indicate that there is an increase in understanding by 42%, student interest by 35%, and student motivation by 33% after using the application. This is measured by a pre and post-test mechanism that is carried out on several students who use the application.

As future work, we plan to develop this application by adding interactive modules to adjust the curriculum changes that occur. Addition of intelligent monitoring and evaluation modules can monitor and provide referrals for students and teachers effectively and efficiently. Develop module content with technologies such as augmented reality, as well as secure data storage mechanisms that are easy to trace and transparent using blockchain technology.

ACKNOWLEDGMENT

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