

Fillquation: A Game-Based Learning Material in Numeracy Education

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Abstract

The study indicates that educational games can significantly enhance learning motivation and effectiveness. This study employed descriptive – qualitative method to evaluate the features and acceptability of a proposed game-based learning material by three expert teachers. It also examined the material's effectiveness on the interest of (n=24) students in grades 4 to 6 at Tabugon Elementary School. The evaluation utilized the Department of Education's standard LRMDS instrument, alongside a modified math interest inventory checklist. Findings revealed increased the student level of interest in solving basic math operations, with students showing positive attitudes towards its use. The study concluded that the game-based learning material effectively boosts students' interest and aids in learning basic math concepts.

Keywords: Gamification, Math-Interest Inventory Checklist, Basic Operations, Math Intervention

INTRODUCTION

UNESCO defines numeracy as the ability to add, subtract, multiply, and divide, and includes the knowledge and skills necessary to manage various mathematical demands involving objects, pictures, symbols, numbers, formulas, diagrams, graphs, maps, tables, and text [1]. Similarly, numeracy includes understanding and applying numbers [2].

In 2018, the Philippines participated in the OECD's Programme for International Student Assessment (PISA). Fifteen-year-old students were assessed in reading, mathematics, and science. The country's average score in mathematics literacy was 353, compared to the OECD average of 489, placing the Philippines second to the lowest among participating countries [3]. The 2019 Trends in International Mathematics and Science Study (TIMSS) results were consistent with PISA's findings. The Philippines participated in the fourth-grade mathematics assessment, focusing on number, measurement and geometry, and data, scoring 297 and ranking lowest among 58 countries [4].

A local study determined the numeracy skills of 563 junior high school students in Laguna using the Numeracy Inventory Tool for Laguna Learners [5]. The test, consisting of 40 items on whole numbers, integers, rational numbers, and decimals, found that 65.9% of respondents were considered numerate, with 14.74% advanced and 14.03% highly numerate [5].

Considering these findings, both local and international, students often perceive mathematics as a difficult subject [6]. It has been emphasized that student interest significantly influences achievement in mathematics, as does their attitude towards the subject [7], [8]. To improve performance, students must develop a positive outlook on mathematics, changing their views and beliefs [8]. Instructional materials play a crucial role in either engaging or demotivating students [9]. Therefore, teachers should use well-planned, selected, and refined instructional materials [9].

Game-based learning is an effective way to engage students in mathematics, increasing their interest, motivation, and confidence through challenge, curiosity, and fantasy [10]. Students often struggle with basic mathematical operations, such as addition, subtraction, multiplication, and division [11]. Additionally, problems involving integers and negative numbers are confusing for many students, yet this knowledge is fundamental for succeeding in algebra and higher-level mathematics [12].

Game-based learning promotes engagement and active learning by situating problems in a playful context [13]. The use of game-based learning helps improve student interest and engagement in mathematics [14]. Given the difficulties students face with basic operations, the researchers propose a game-based learning material designed to increase student interest in learning these fundamental skills.

Lastly, the proposed game-based learning material focuses on solving equations involving three basic operations in mathematics: addition, subtraction, and multiplication, including negative and non-negative integers. The targeted users are students in grades 4-6 in primary education. This grade level was selected because students are expected to perform these skills at their grade level. The learning content standard and performance standard of the K-12 Mathematics curriculum guide in the Philippines serve as the foundation for the proposed game-based learning material.

OBJECTIVES OF THE STUDY

The study aimed to utilize Fillquation game-based learning materials to enhance students' interest in numeracy education, specifically in the three basic operations (addition, subtraction, and multiplication).

The specific objectives of the study were:

1. To determine the features of the proposed game-based learning material, Fillquation.
2. To assess the effect of Fillquation on the level of interest of the respondents in solving basic operations.

MATERIALS AND METHODS

This study utilized descriptive quantitative and qualitative methods. To determine the level of interest of students from Grade 4 to 6 in solving basic operations in mathematics, the researchers obtained permission from the principal of Tabugon Elementary School to perform data gathering, including survey checklists and interview questions with selected students, and survey checklists with selected mathematics teachers to determine the level of acceptability of the proposed game-based learning material of the study.

Mean and percentage techniques were used to determine the average and percentage of the approved, revised, and deleted indicators of the instruments, i.e., the math interest inventory checklist and evaluation rating sheet. Additionally, the researchers used a T-test for dependent groups to determine if there is a significant difference between the mean scores of paired samples.

A qualitative method was used to perform an in-depth analysis of the features of the proposed game-based learning material to increase students' interest in solving fundamental operations in mathematics. In-depth analysis enables researchers to thoroughly examine a topic and produce fresh perceptions or insights about the topic [15]. The research utilized existing studies and related articles to determine the features of the game. Based on these findings, the researchers took the following steps: (1) compared the evident connections and differences between existing games and the proposed game; (2) generated a thesis statement outlining the components of the proposed game; (3) conducted research to uncover evidence and support for the thesis statement; and (4) incorporated facts acquired into the conclusion.

The researchers developed the math inventory checklist to determine students' interest levels in solving basic operations in mathematics. A pretest and posttest survey checklist were given to the students to determine the effect of the game on their interest level. The researchers also adopted the LMRDS Assessment and Evaluation of DepEd to determine the acceptability of the proposed game.

Three experts evaluated the material and provided their recommendations and suggestions. These experts met the requirement for years of teaching experience as mathematics teachers, consisting of two teachers and one school principal. They were present when the proposed game-based learning material was

used. The material was highly accepted in all indicators of the evaluation instrument: the content quality received a perfect rating of 4.00, instructional quality was rated 3.70, and technical quality was rated 3.60. All comments and suggestions from the evaluators were acknowledged and incorporated before the proposed material was used with the students.

The researchers purposely selected students from grades 4-6 to be the respondents in the study. In accordance with the mathematics curriculum guide by the Department of Education (DepEd), the learning competency of performing fundamental operations on integers is expected at this grade level. The researchers asked the teachers for a list of students who are less interested in mathematics to be the respondents in the study. Each grade level was divided into two groups to participate in the game.

The researchers presented the game to the students and experts during the students' allocated vacant time to avoid disrupting classes. After giving proper instructions on how to play the game, the researchers allowed the students to play in groups while the experts monitored them. Following the gameplay session, the researchers conducted a survey interview to gather the teacher-experts' opinions, advice, and suggestions regarding the proposed game-based learning material. These served as qualitative input data for the study. The researchers then undertook the following tasks: (1) compiling all the experts' comments and recommendations; (2) organizing and relating the acquired information; and (3) categorizing the information.

As supplementary data, a qualitative method was used to explore the testimonies of teachers and students before and after the utilization of the game Fillquation. This served as additional input and provided modifications for further enhancement of the developed game.

The study's instruments underwent content validation. Based on the results, 77% of the indicators in the instrument for interest level were approved, while 23% were suggested for revision. Similarly, 86% of the indicators in the instrument for the level of acceptability were approved, with 14% recommended for revision. Additionally, the instrument used for interest level underwent a reliability test. The computation yielded a Cronbach's Alpha of 0.90, which is interpreted as excellent and indicates a standardized test.

For ethical reasons, the researchers issued a letter to the school principal to conduct data gathering with the students and to request the cooperation and open feedback of the respondents. The researchers explained to the study respondents that all pertinent information would be kept private and used solely for the purpose of the study.

RESULTS AND DISCUSSION

The significant and important features of the proposed game-based learning material, Fillquation, were adopted from existing educational games and findings from related studies that focused on developing game-based learning materials. Table 2 explicitly discusses some adopted features from reviewed articles and existing educational materials.

Table 1. Adapted Features of the Proposed Game-Based Learning Material to the Other Existing Game

| Game | Definition | Adapted Features |
|---------------|---|---|
| Scrabble | A board-and-tile game where 2 to 4 players compete in forming words with lettered tiles on a 225-square board. | - Putting the tiles onto their tile racks |
| Chess | A board game for 2 players, White and Black, controlling armies of chess pieces with the goal to checkmate the opponent's king. | - Drawer to keep all the tiles |
| Playing Cards | Most card games are round games played by any number of players, starting from 2 or 3, with enough cards for all. | - Cards cut into halves to serve as tiles in the game |

Table 1 summarized the definitions and adapted features of three games: Scrabble, Chess, and Playing Cards. Scrabble is a word game where 2 to 4 players use lettered tiles to form words on a 225-square board, with the adaptation of using tile racks to organize their tiles. Chess is a strategic board game for 2 players, White and Black, aiming to checkmate the opponent's king, and includes a drawer to store all the chess pieces.

Playing Cards encompass various card games that can be played by 2 or more players, with the adaptation of cutting the cards into halves to serve as tiles for the game. These adaptations enhance gameplay by focusing on organizing and storing pieces for Scrabble and Chess, while Playing Cards showcase a creative transformation of cards into tiles, demonstrating innovation in game design. The developed game adopted these features, see the figure 1 below showing the prototype material of the study.

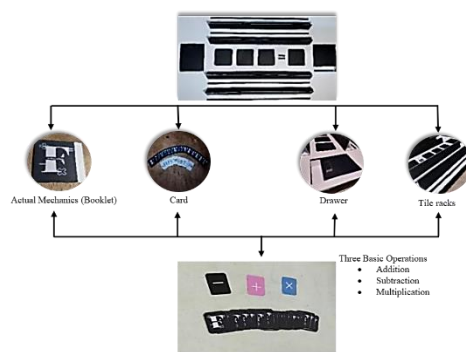


Figure 1. Features of Fillquation

Based on the illustrated figure or the prototype of the proposed game-based learning material "Filquation" designed to increase students' interest in solving basic operations, the following important parts and features are highlighted:

The board, a square piece of wood or stiff cardboard, is used for playing games like chess or Scrabble. Board games can induce laughter and fun, reducing anxiety and promoting enthusiasm in other life areas. Playing board games brings people closer, strengthens relationships, helps meet new people, and is a perfect way to spend time and strengthen bonds with others [16].

The cards are rectangular pieces of cardboard with identical patterns on one side and different numbers and symbols on the other, used in various games. The researchers improved the designs by cutting the cards in half and including numbers, operations (addition, subtraction, and multiplication), and the game logo. Card games are excellent for socializing, improving relationships, and fostering relaxing interactions and healthy rivalry. Playing card games also enhances memory as players memorize cards and moves, using their memory to play strategically [17].

While, game mechanics are the rules and procedures that guide players and determine the game's responses to their actions. They structure the game and direct players towards victory, including scoring and determining the winner. The researchers provided instructions on the game mechanics and how to play. Game mechanics support repetitive play, fairness, motivation, exploration, learning, skill improvement, and focus [18].

The scoring reflects a player's performance in the game, giving them a sense of gaining abilities that allow progression. The Filquation game uses an earning point system. When a player "steals," they must supplement the appropriate number to complete the equation, earning points. This system encourages active engagement and reinforces learning through play. Players' focus on attaining the game's goals can be measured through scoring, which frequently acts as a link between players and games. In other words, scoring serves as a success indicator. Game designers commonly create scoring systems to direct players through the game since scoring encourages players to take action [19].

Lastly, the Filquation game-based learning material involves placing cards to complete mathematical equations. The game revolves around solving equations that involve basic operations (addition, subtraction, and multiplication) with negative and non-negative integers. Playing games encourages strategic mathematical thinking as students find different strategies for solving problems and deepen their understanding of numbers [20]. Filquation is designed to increase students' interest in learning fundamental operations in mathematics. Before the game begins, the teacher must first explain the fundamentals of how to add, subtract, and multiply negative and non-negative numbers. With a solid understanding of these core concepts, learners can quickly grasp the game mechanics.

Additionally, it aids students in applying their knowledge afterward. The proposed game-based learning material emphasizes the importance of basic mathematical concepts, based on Bloom's taxonomy for cognition and learning, which incorporates math equations in the cognitive level taxonomies [21] & [22]. In terms of content quality, the researchers focused on solving basic operations in mathematics. For instructional quality, the researchers used challenging and stimulating mechanics, which, an effective educational game should include challenge, curiosity, and fantasy [19]. In terms of technical quality, the researchers developed a strong prototype with a design relevant to the desired learning outcomes.

The creation of the game-based learning material is essential because it has the potential to increase students' interest in attaining mathematics learning outcomes. It also plays a significant role in creating an exciting learning environment that enhances student engagement [23]. The game encourages students in the collaborative learning process. Collaborative learning develops higher-order thinking skills and increases understanding of diverse concepts. It will greatly help students who face learning challenges in solving basic operations, allowing them to improve their performance [24].

Finally, the proposed game-based learning material will greatly help increase students' interest in learning basic operations while situating the problem in the context of play. Game-based learning promotes students' interest, engagement, and learning [25]. They will work together to solve given equations and have fun simultaneously.

The Effect of Developed Game-based Learning Material on the Level of Interest of the Respondents Mathematics

This study assessed the impact of a developed game-based learning material, Fillquation, on the level of interest in mathematics among students. By comparing students' interest levels before and after using the game, the research aimed to determine the effectiveness of Fillquation in enhancing engagement and enthusiasm for solving basic mathematical operations.

Descriptive Analysis of the Effect of Fillquation on the Level of Interest of Respondents in Mathematics

The data presented compared the level of interest of 24 students before and after utilizing the Fillquation game-based learning material. The researchers emphasized only the two rating level categories, "Strongly Agree" and "Agree," since the majority of respondents rated their responses in these categories, see table 2 below.

Table 2. Difference in the Level of Interest of Students Before and After the Utilization of Fillquation (n=24)

| Indicators for the Level of Interest | Before | | After | | Difference | |
|--|----------------|-------|----------------|-------|----------------|--------------|
| | Strongly Agree | Agree | Strongly Agree | Agree | Strongly Agree | Agree |
| The game helps me boost my interest in solving basic operations. | 75% | 25% | 75% | 25% | 0.00 | 0.00 |
| I can share and play it with my friends. | 50% | 50% | 88% | 13% | -0.38 | 0.38 |
| The game use for learning basic operations is enjoyable. | 75% | 25% | 100% | 13% | -0.25 | 0.13 |
| The game enlightens me about basic operations. | 50% | 38% | 50% | 63% | 0.00 | -0.25 |
| The game helps me do my homework. | 63% | 13% | 88% | 13% | -0.25 | 0.00 |
| The game-based material used for learning basic operations is interesting. | 75% | 13% | 63% | 50% | 0.13 | -0.38 |
| The game lessens my fear in basic operations. | 50% | 38% | 63% | 50% | -0.13 | -0.13 |
| The game helps me learn basic operations. | 63% | 38% | 75% | 38% | -0.13 | 0.00 |
| The game stimulates my curiosity in basic operations. | 50% | 50% | 63% | 50% | -0.13 | 0.00 |
| The game used for learning basic operations is exciting. | 75% | 25% | 63% | 50% | 0.13 | -0.25 |
| I like to spend more time using the game to learn basic operations. | 88% | 13% | 88% | 25% | 0.00 | -0.13 |
| The game is worth my time. | 75% | 25% | 75% | 38% | 0.00 | -0.13 |
| The game motivates me to learn basic operations. | 75% | 13% | 88% | 25% | -0.13 | -0.13 |
| The game helps me boost my confidence in solving basic operations. | 75% | 25% | 63% | 38% | 0.13 | -0.13 |
| The game used is very useful in learning basic operations. | 63% | 25% | 88% | 25% | -0.25 | 0.00 |
| The game helps me apply what I've learned in basic operations to my everyday life. | 38% | 63% | 50% | 50% | -0.13 | 0.13 |
| The game encourages me to explore basic operations. | 75% | 25% | 75% | 38% | 0.00 | -0.13 |
| I prefer to use the game to learn basic operations than to talk about nonsense topics. | 75% | 25% | 75% | 38% | 0.00 | -0.13 |
| The game has improved my skills and abilities. | 75% | 25% | 63% | 50% | 0.13 | -0.25 |
| I discover connections between the game used for learning basic operations and real-life situations. | 63% | 25% | 75% | 38% | -0.13 | -0.13 |
| General Weighted Mean (GWA): | 66% | 29% | 73% | 36% | -0.07 | -0.08 |
| Standard Deviation: | 0.13 | 0.14 | 0.14 | 0.15 | | |

The general weighted mean (GWA) indicates that before using Fillquation, 66% of students "Strongly Agreed" and 29% "Agreed" with the interest indicators. After using the game, these figures rose to 73% "Strongly Agree" and 36% "Agree," indicating an overall increase in interest levels. The standard deviation showed a slight increase, suggesting slightly more variability in responses post-intervention.

Specific indicators revealed positive shifts in various areas. The percentage of students who "Strongly Agree" that they can share and play the game with friends increased significantly from 50% to 88%. Additionally, 100% of students found the game enjoyable after using it, compared to 75% before. More students also strongly agreed that the game helps with homework, increasing from 63% to 88%.

Some indicators showed mixed results. For example, the game's ability to stimulate curiosity increased in "Strongly Agree" responses from 50% to 63%, while "Agree" responses remained constant at 50%. Similarly, there was a slight decrease in the excitement indicator for "Strongly Agree" from 75% to 63%, but an increase in "Agree" from 25% to 50%.

Several indicators remained stable. The interest boost remained unchanged, with 75% of students "Strongly Agreeing" and 25% "Agreeing" both before and after using the game. The perception of the game being worth the time also showed no change in "Strongly Agree" responses (75%), though "Agree" responses increased from 25% to 38%.

Other notable changes include a slight decrease in the confidence boost indicator from 75% to 63% for "Strongly Agree," while "Agree" increased from 25% to 38%. The application of learned operations to everyday life showed an increase in "Strongly Agree" from 38% to 50% but a decrease in "Agree" from 63% to 50%. Encouragement to explore basic operations saw no change in "Strongly Agree" (75%), but a slight increase in "Agree" from 25% to 38%.

Overall, the Fillquation game-based learning material has enhanced students' interest in solving basic mathematical operations, particularly in terms of enjoyment, social aspects, and practical application. The slight increase in variability suggests that while the game generally increased interest, the degree of increase varied among students, indicating a need for further customization to meet diverse student needs. Similarly, studies have found that game-based learning materials enhance students' problem-solving

abilities. Pretest and posttest results showed a discernible difference, indicating the effectiveness of game-based approaches [26], [27], & [28].

Significant Difference of the Scores on the Level of Interest of Students Before and After Utilization of Fillquation

The table 3 below presented the quantitative analysis of the study, results of a t-test comparing the level of interest of 24 students in mathematics before and after using the Fillquation game-based learning material.

Table 3. Summary Result of T-test Dependent Groups (n=24)

| Inferential: t-test dependent test | | | | | | |
|------------------------------------|--------|-------|-------------------------------|-------|---------|----------------|
| Items | Before | After | SD | Alpha | t-value | Critical value |
| Mean | 4.03 | 4.61 | 0.472 | 5% | 5.473 | 1.729 |
| Standard Deviation | 0.46 | 0.13 | <i>Reject Null Hypothesis</i> | | | |

The mean score for interest levels increased from 4.03 to 4.61 after the intervention, indicating an improvement in student interest. The standard deviation decreased from 0.46 before using Fillquation to 0.13 after, suggesting that students' responses became more consistent post-intervention. The t-value of 5.473 is significantly higher than the critical value of 1.729 at a 5% significance level, leading to the rejection of the null hypothesis. This means that the difference in interest levels before and after using Fillquation is statistically significant.

In conclusion, the Fillquation game-based learning material effectively increased students' interest in mathematics, as evidenced by the significant rise in mean scores and the reduction in response variability. This underscores the potential of game-based learning materials to enhance student engagement and interest in educational subjects [26], [27] & [28].

Post Implementation of the Fillquation: Qualitative Findings of the Study

The qualitative aspect of the study explored the respondents' feedback following their interaction with Fillquation, these findings served as the supplement findings of the study. Through interviews, a deeper understanding of students' engagement levels was obtained, complementing the numerical data acquired. When questioned about their favored features within the game, participants unanimously expressed a preference for tackling addition challenges, citing reasons like familiarity and enjoyment. Their sentiments were articulated through statements such as "*Sa pag plus po, kasi po madami*" ("*In addition, because there are many*") and "*The operation itself/cards (addition, subtraction, and multiplication).*" Moreover, students offered diverse perspectives on the most engaging elements of Fillquation, with many highlighting its educational value across various game components. Their perspectives were captured in statements like "*Sa addition po*" ("*In addition*") and "*Lahat, Kasi po may natutunan*" ("*All of it, because I learned something*").

In terms of navigating the game, opinions were split, although a majority found it effective for mastering fundamental mathematical concepts. Statements such as "*Masaya pong magsagot, kasi po favorite subject ko po ang Mathematics*" ("*It's fun to answer, because Mathematics is my favorite subject*") and "*It's easy to navigate the game*" reflect this sentiment. Despite encountering challenges, particularly in decision-making during gameplay, participants acknowledged the game's potential benefits for enhancing mathematical skills and fostering enjoyable learning experiences. Statements like "*Kinabahan po, kasi baka mali ang sagot*" ("*I was nervous because my answer might be wrong*") and "*Mayroon po, natututo po sa pamamagitan nito*" ("*Yes, I learned through this*") capture their reflections on the game's educational value.

These testimonials not only lend credence to the quantitative findings but also provide valuable insights for refining and optimizing Fillquation as a game-based learning tool. They serve as a foundation for further development and enhancement, ensuring that the game continues to effectively engage students and facilitate their mathematical learning experiences [26], [27] & [28].

CONCLUSION AND RECOMMENDATION

Playing games like board games helps you practice critical cognitive abilities such as decision-making, higher-level strategic thinking, and problem-solving [29]. Board games bring families and friends of all ages together to connect, strategize, compete, and have fun. The very foundation of this activity is cooperation, as it requires players to engage with each other through teamwork [30]. Therefore, the proposed game-based learning material in this study has the potential to increase students' interest in learning basic operations in mathematics. It also has the potential to address students' learning challenges in basic operations, enhancing their skills in solving and learning basic operations. Furthermore, it is recommended for teachers to utilize games in the teaching and learning process as it will enhance students' interest in learning mathematical concepts. The researchers advise future academics to focus on proposing game-based learning materials that consider how the game connects to real-life scenarios. This way, students would be able to comprehend how the game might be used in real-world situations.

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APPENDIX

Appendix 1. Experts' Evaluation of Research Instruments



Appendix 2. Result of Content Validation

| Summary Result for Content Validity of Evaluators | | | |
|---|--------------------------|-------------------------|-------------------------|
| Evaluated Instruments | Summary Result | | |
| | % of Approved Indicators | % of Revised Indicators | % of Deleted Indicators |
| Tool for Level of Interest | | | |
| Before | 92% | 8% | 0% |
| After | 62% | 38% | 0% |
| Sub Mean %: | 77% | 23% | 0% |
| Tool for Level of Acceptability | | | |
| Content Quality | 87% | 13% | 0% |
| Instructional Quality | 97% | 3% | 0% |
| Technical Quality | 73% | 27% | 0% |
| Sub Mean %: | 86% | 14% | 0% |
| General Mean %: | 81% | 19% | 0% |

Appendix 3. Result of Reliability Test using Cronbach Alpha

The image is a screenshot of SPSS output for a Cronbach's Alpha Reliability Test. The main window shows the following data:

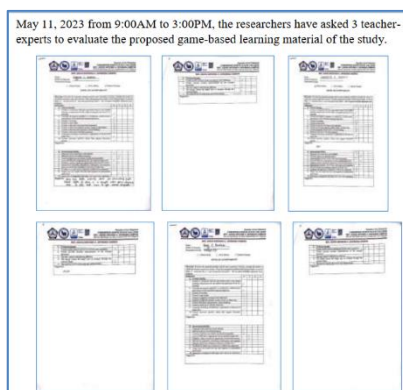
| Item number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|--------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Standard Deviation | 4.6 | 5.6 | 5.4 | 5.6 | 5.8 | 5.6 | 5.8 | 5.5 | 5.6 | 5.5 | 5.4 | 5.7 | 5.6 | 5.7 | 5.4 | 5.7 | 5.4 | 5.9 | 5.5 | 5.7 |
| Variance | 21.3 | 31.4 | 29.2 | 31.4 | 33.6 | 31.4 | 33.6 | 30.3 | 31.4 | 30.3 | 29.2 | 30.3 | 30.3 | 29.2 | 30.3 | 29.2 | 34.8 | 30.3 | 30.3 | 30.3 |

Below this, the Cronbach's Alpha is reported as 0.9, which is marked as "Excellent". There are also several smaller tables and charts visible in the background of the screenshot.

Appendix 4. Communication Letters



Appendix 5. Evaluation of Proposed Game-based Learning Material



Appendix 6. Data Gathering Procedure: Utilization of Fillquation

