The Use of Relations and Functions Games Based on Balanced Design in Mathematics Subjects to Improve Student Learning Outcomes

Diena Rauda Ramdania¹, Maisevli Harika², Sandi Rahmadika³, and Gina Giftia Azmiana⁴

¹Informatics Engineering, UIN Sunan Gunung Djati Bandung
²Computer Engineering and Informatics, Politeknik Negeri Bandung
³Interdisciplinary Program of Information Security, Graduate School PKNU Pukyong National University, Busan, South Korea
⁴Department of Phenology, UIN Sunan Gunung Djati Bandung

*diena.rauda@uinsgd.ac.id

Abstract. Game Relations and Functions are digital game-based learning in junior high school mathematics subjects. In this study will discuss how to use the game Relationships and Functions that have been designed using the Balanced Design method. The research method used was a quasi-experiment with the One group Pretest Post-test design. A total of 40 junior high school students were involved in this study to determine differences in student learning outcomes in the cognitive domain before and after using the Relationship and Function games. The instrument used is a type of multiple choice objective test of 20 questions with details of 8 questions related to relations material and 12 questions related to functions material. The results showed that there were differences in the improvement of student learning outcomes before and after using the game Relations and Functions in Mathematics subjects.

1. Introduction

Based on the results of a survey conducted by the Organization of Economic Cooperation and Development (OECD) on student learning outcomes in Mathematics, Indonesia ranked 63rd out of 69 countries. This result is an increase from the previous survey in 2012, where Indonesia ranked 64th out of 65 countries. Whereas in 2009, Indonesia ranked 59th[1]. One of the causes of the low ranking obtained by Indonesia in the survey was the difference in understanding of learning content. In the OECD survey, mathematics lessons aim to measure understanding of their identification and use in daily life[2]. Whereas in practice in Indonesia, mathematics studies elaborate about formulas without explaining what its use in the real world is like. Learning media is present as a solution to overcome these problems. One of them is with games. This paper will describe how to use the Mathematics game on the level of understanding and student learning outcomes in the subject relation and function mathematics subjects. Games are created using the Balance Design method and have been through usability testing[3][4]. A total of 40 junior high school students were included as research samples. The study used the one-group pre-test posttest method where the level of understanding of students will be assessed before and after using the games.
2. Balanced Design
Balanced design is an approach to for game design education. This approach focuses on instructional design approaches to integrate best practices in the design game. The emphasis lies on the proportionality between the contents of games with game design[5].
There are 3 models in Balanced Design, namely content model, task model, and evidence model. Content models define what knowledge, skills, and abilities students must achieve. The task model aims to describe what tasks students will perform as players in the game. The difference with other methods located on the existence of Evidence Models that emphasize what performance will be achieved to reach learning objectives. Therefore the evidence of the model is closely related to measurement[5].

3. Learning Outcomes
Learning outcomes are basically an ability in the form of new skills and behaviors as a result of training or experience. Learning outcomes as a level of mastery of a knowledge achieved by students in participating in teaching and learning programs in accordance with the educational goals set. Learning outcomes are divided into three parts, namely: cognitive, affective, and psychomotor domains. Cognitive domains are the realm of discussion related to understanding and knowledge. Assessment of aspects of cognitive indicators is intended to measure the achievement of learning outcomes in terms of intelligence and the ability to explore and process information or knowledge. Cognitive assessment consists of six stages known as Bloom Taxonomy, where this theory was previously revised by Anderson, L. W and Krathwohl in his book "A taxonomy for learning, teaching and assessing: A revision of Bloom's Taxonomy of Educational Objectives"[6].

4. Analysis of Mathematical Lessons of Relation and Function Materials
In accordance with the curriculum 2013, the material of Relations and Functions intended for 8th grade students of junior high school. Based on Balanced Design method, the content model is obtained from the main competencies to be achieved in both of these games, namely presenting functions in various forms of relationships, pairs ordered by formulas, functions, tables, graphs, and diagrams. From these core competencies, the learning objectives for each game are formulated into evidence models. In the game Function, the proof of the model is: students are able to solve real-life problems using relations, and state the relation of two objects. Whereas in the game Function, the proof of the model is that students are able to solve real problems using functions. Detailed learning using games is shown in Table 1.

| Game     | Domain | Indicators                                                                 |
|----------|--------|-----------------------------------------------------------------------------|
| Relations| Cognitive | Level 1 C1 (Knowledge): students able to show relation.                     |
|          |        | Level 2 C2 (Understanding): students able to distinguish relationship two type object with use relation. |
|          |        | Level 3 C3 (Application): student able to determine relation between two type objects with method drag and drop. |
| Functions| Cognitive | Level 1 C1 (Knowledge): Student able to show function.                      |
|          |        | Level 2 C2 (Understanding): Student able to estimate function.              |
|          |        | Level 3 C3 (Application): Student able to use functions through game.      |

Assessment of students' understanding will be seen through scores obtained by students in the game. Achieving competencies is divided into several assessment ranges as follows:
- 76 - 100: Students are very capable of understanding all indicators of achievement,
- 51 - 75: Students are able to understand all indicators of achievement,
- 26 - 50: Students are quite capable of understanding 50% achievement indicators,
- 0-25: Students have not been able to understand achievement indicators.
In addition, students will also be given a quiz in the form of a number of questions that are carried out in the posttest process after students play the game.

5. Game Scenario
Each game has a narrative story that is made so that users feel a strong attachment to the game. Actors in the game were also presented to build an interesting atmosphere. Game play for Relations and Function material is as follows:

Game Relations
Title: building an irrigation dam
Game play:
Aptana for help student (user) to build the irrigation dam. The dam plan to be built is available. The task of the user is to calculate how many crystal stones are needed by each form to build a dam. If the amount is right then the dam is successfully built, if the amount is not right then the dam will collapse.

![Figure 1](image1.png)
**Figure 1.** The Relations opening game.

![Figure 2](image2.png)
**Figure 2.** Instructions mission interface.

![Figure 3](image3.png)
**Figure 3.** Win condition interface.

![Figure 4](image4.png)
**Figure 4.** Lost condition interface.

Game Function
Title: Collect crystal stones to build bridges
Game Play:
Students (user) is asked to help Abya build irrigation dams. The construction of this dam was carried out jointly by all villagers. The task of the user is to distribute Crystal stones that have been collected to the villagers. Every villager has a different power capacity to share Crystal stones so that the user has to share properly.
Figure 5. The Functions opening game.

Figure 6. Game interface.

Figure 7. Win condition interface.

Figure 8. Lost condition interface.

6. Research Method
The method used in this research is a quasi-experimental method, which is a form of experiment whose main characteristics of validation do not do random assignments, but instead use existing groups which in this case are ordinary classes. As stated by Mohammad Ali[7]: Quasi experiment is almost the same as the actual experiment, the difference lies in the use of the subject, that is, quasi-experiments are not randomly assigned, but by using an existing group (intact group).
The reason for this random assignment was not because researchers could not change the class that had existed before so that researchers could determine which research subjects entered the experimental groups. Groups that are in one class are usually balanced so that if researchers make a new class group, it is feared that the class's natural atmosphere will be lost. To avoid the loss of the natural atmosphere of the class, the researcher uses a quasi-experimental method using classes that are already in the population[7].
The research design used in this study is the One Group Pre-test Post-test design, which is a form of research design in quasi-experimental methods. The experimental group was chosen without random assignment then pretests were held before treatment and post-test after the treatment. Design model as follows in Table 2.

Table 2. Research design model.

| Pre-test | Treatment | Post-test |
|----------|-----------|-----------|
| O1       | X         | O2        |

Informations:
O1 : Initial test
X : Giving games Relations and Functions
O2 : Final test
7. Hypothesis Testing  
There are two hypotheses on this research, namely[6]:

1. Zero Hypothesis (H₀: μ₁ = μ₂)  
   There are no significant differences in learning outcomes before students learn to use the game Relationships and Functions with after students use the game Relations and Functions on aspects of understanding Mathematics.

2. Working Hypothesis (H₁: μ₁ > μ₂)  
   There are significant differences in learning outcomes before students learn to use games Relationships and Functions with after students use the game Relations and Functions on aspects of understanding Mathematics.

Hypothesis testing has been done in 2 ways, namely: z-test and t-test. The t-test is conducted to test the significance of the difference in mean of one sample. As for what is compared in this hypothesis test is the average score of the pretest score before being given treatment with a post-test value after giving treatment to the Mathematics subjects.

8. Research and Analysis Results
The data obtained from this study is quantitative data. Quantitative data were obtained from students' cognitive learning outcomes after pretest and post-test. This will give an overview of the ability of mastering the material from the experimental group. To obtain the quantitative data, it is necessary to do a series of calculations, including the following.

8.1. Pre-test normality test
Normality test is done by testing the results of research obtained from the pretest and post-test scores of students using the Relationship and Function games on Mathematics subjects. The results of pretest and post-test were tested for normality using Chi squared. From the results of the pre-test data, the mean value = 5.85 and the standard deviation = 5.31. The results obtained are as follows.

| Class (k) | Oi | Upper limit | Z  | Pk | fk | Ei  | (Oi-Ei)²/Ei |
|-----------|----|-------------|----|----|----|-----|-------------|
| 3.0 - 4.0 | 7  | 4.05        | 0.217 | 0.583 | 40 | 14 | 3.5         |
| 4.1 - 5.1 | 8  | 5.15        | 0.405 | 0.655 | 26 | -9 | -32,111     |
| 5.2 - 6.2 | 12 | 6.25        | 1.158 | 0.875 | 35 | 9  | 1           |
| 6.3 - 7.3 | 8  | 7.35        | 0.405 | 0.655 | 26 | -2 | -50         |
| 7.4 - 8.4 | 3  | 8.45        | -0.537 | 0.702 | 28 | -2 | -12.5       |
| 8.5 - 9.5 | 2  | 9.55        | -0.725 | 0.764 | 30 | 30 | 26,133      |
| Total     | 40 |             |     |     |    |     | -63,978     |

From the Table 3 above, the Chi square value (Xcount) is -63,978 rounded to -64. The next step is to look for the degree of equality (dk) with the formula: dk = k - 3. There are 6 classes (k) in the table above. Then we get the value dk = 6 - 3 = 3. Using the function = CHIINV (1%, 3) to Ms. Excell, the value of 3 for the 99% real level is 11,34487 ≈ 11,345. The next step is to test these two x values. It is known that the value of x_count = -64 and the value of X_table = 11.345. The value of -64 < 11.345, then according to the test criteria, namely if the value of x_count < X_table, then the test results are normally distributed. In other words, the results of pretest are normally distributed.
8.2. Post-test normality test

The result of the post-test average was 15.67 and the standard deviation was 7.89. The results obtained can be seen in the following Table 4.

| Class (k) | Oi | Upper limit | Z  | Pk | fk | Ei | (Oi-Ei)²/Ei |
|-----------|----|-------------|----|----|----|----|-------------|
| 10.0 - 11.5 | 3  | 11.55       | -0.522 | 1  | 40 | 15 | 9.600       |
| 11.6 - 13.1 | 7  | 13.15       | -0.319 | 0.622 | 25 | 3  | 5.333       |
| 13.2 - 14.7 | 7  | 14.75       | -0.117 | 0.544 | 22 | 1  | 36          |
| 14.8 - 16.3 | 5  | 16.35       | 0.086  | 0.532 | 21 | -3 | -21.333     |
| 16.4 - 17.9 | 7  | 17.95       | 0.289  | 0.610 | 24 | -3 | -33.333     |
| 18.0 - 19.5 | 6  | 19.55       | 0.492  | 0.688 | 27 | -3 | -27.000     |

From the table above, the Chi square value (X count) is -9.9 rounded to -10. The equality degree of the 7 classes above is 4. Using the function = CHIINV (1%, 4) to Ms. Excell, the value of 4 for the 99% real level is 13.276 ≈ 13.276.

The next step is to test these two x values. It is known that the value of x count = -10 and the value of x table = 13.276. The value of -10 < 13.276, then according to the test criteria, namely if the value of x count < x table, then the test results are normally distributed. In other words, the post-test results are normally distributed. From the normality test results it is known that pre-test and post-test are normally distributed.

8.3. Normalized Gain Test

This gain test is conducted to determine the extent to which student learning outcomes increase between before and after learning. The difference between the initial test score and the final test (gain) is assumed to be the effect of the treatment. The formula that can be used to calculate normalized gain is [6] like formula 1 as follows.

\[
g = \frac{\text{posttest score} - \text{pretest score}}{\text{maximum score} - \text{pretest score}}
\] (1)

Calculation of gain in learning outcomes in general can be seen in the following Table 5.

| Test | X_ideal | X_min | X_max | X  | g     | Number of students | <g>  |
|------|---------|-------|-------|----|-------|-------------------|------|
| Pretest | 20     | 3     | 9     | 5.6| 10.08 | 40                | 0.7  |
| Posttest | 20    | 10    | 20    | 15.675|       |                   |      |

Based on Table 5 it can be seen that the minimum value for pretest is 3, the maximum value is 9 and the mean value is 5.6. The maximum value of this pretest shows that the correct answer that can be answered by students is only less than 50% of the number of questions (20 questions). This is natural, because at the time of the pretest, most students did not know the material at all in the pretest questions.

Post-tests are carried out after students get treatment. The minimum score for the post-test is 10, the maximum value is 20 and the average value is 15.675. The difference for the pretest and post-test mean values is 10.08.
The normalized gain value \(<g>\) is equal to 0.7. When interpreted into the classification of gain criteria according to Meltzer, this figure shows that the gain obtained is included in the high category. That is, an increase in student learning outcomes before and after using the Vidyanusa game is included in the high criteria. This can be proven by looking at the percentage value of \(<g>\). The percentage of normalized gain value \(<g>\) can be calculated using the following equation.

$$\text{criteria} = \frac{\text{number of criteria}}{\text{number of students}} \times 100\%$$

(2)

The calculation results of the normalized gain percentage can be seen in Table 6.

**Table 6.** The percentage of normalized gain values \(<g>\).

| Criteria | Number of students | Percentage |
|----------|--------------------|------------|
| High     | 19                 | 47.5%      |
| Medium   | 21                 | 52.5%      |
| Low      | 0                  | 0%         |
| Amount   | 40                 | 100%       |

Table 6 shows that 47.5% of students experienced an increase in learning outcomes with high criteria, 52.2% of students experienced moderate improvement in learning outcomes, and no students experienced an increase in learning outcomes.

The number of correct answers obtained by students is then converted into scores. Student scores are obtained by dividing the number of correct answers to students with number 2 so that the maximum score that can be obtained is worth 10. Graphs for improving learning outcomes can be seen in the picture below.

**Figure 9.** Comparison of the mean score of the posttest pretest.

Based on the comparison chart of the mean values above, it can be seen that the mean score of students initially was 2.8 at the time of pretest up by 5.0 to 7.8 at the post-test.

Improved learning outcomes were obtained by comparing the difference between pretest mean scores and the overall post-test mean score against the pretest mean scores multiplied by 100%, the results obtained were 1.79%. That is, there is an increase in learning outcomes of 1.79% and for the improvement criteria obtained from \(<g>\) included in the high criteria.
8.4. Hypothesis test result

Hypothesis testing is carried out using the t-test formula. This t-test is used for one sample and the principle tests whether a certain value (given as a comparison) differs significantly or not from the average of a sample. The intended value in general is the parameter value to measure a population. Based on formula:

\[ t = \frac{(\bar{X} - \mu_0)}{s_{\bar{X}}} \]  

Then the calculation is as follows.
\[ \bar{X} = 7.8375; \]
\[ s_{\bar{X}} = 0.4448; \]
\[ n = 40; \]
\[ \mu_0 = 2.8; \]
\[ \alpha = 5\% \]

- t\_count

\[ t = \frac{(\bar{X} - \mu_0)}{s_{\bar{X}}} = \frac{(7.8375 - 2.8)}{0.4448} \]
\[ t = 11.325 \]

- t\_table

Real Level Testing = \( \alpha = 5\% = 0.05 \)

The critical point \( \rightarrow t > t_{0.05} \rightarrow t > 1.645 \), then, \( t > t_0 \) or 11.325 > 1.645 means that \( H_0 \) is rejected and \( H_1 \) is accepted.

Because the value of \( t \) is in the rejection area \( H_0 \), then the null hypothesis is rejected and the working hypothesis is accepted, namely an increase in student learning outcomes after using the Relations and Functions game bigger than before using the Relations and Functions game on Mathematics subject.

The results of hypothesis testing show the value of \( t \) count > \( t \) table, or 11.325 > 1.645. Because the value of \( t \) is in the rejection area \( H_0 \), then the zero hypothesis is rejected and the working hypothesis is accepted, namely there is an increase in student learning outcomes after using the Relations and Functions game on Mathematics subject.

9. Conclusion

In this study a game design of Mathematics subjects and relationships and functions using the Balanced Design approach was designed. Learning objectives, knowledge and skills that will be achieved by students are summarized in the content model. Task models summarize game mechanisms and game structures, namely Relationships and Functions. The last stage, namely the evidence model analyzes aspects of cognitive assessment.

The results showed that there was an increase in student learning outcomes on cognitive aspects before and after using the game Relations and Functions in Mathematics subjects.
References
[1] F. Ali, 2013 “Siswa Indonesia Peringkat 64 Dari 65 Negara, Tapi Paling Bahagia di Dunia,” Kompasiana. [Online]. Available: https://www.kompasiana.com.
[2] OECD, 2014, PISA 2012 results: What students know and can do-Student Performance in Mathematics, Reading and Science.
[3] D. R. Ramdania, A. Setijadi Prihatmanto, and M.-G. Park, 2016, “Vidyanusa Mathematic Learning Systems Based on Digital Game by Balanced Design Approach”, Journal Korean Multimedia, vol. 19, no. 3, pp. 603–611.
[4] D. R. Ramdania, A. Setijadi Prihatmanto, and M.-G. Park, 2016, “On Designing Digital Game-Based Vidyanusa Mathematic Learning Systems by Balanced Design Approach”, Journal Korean Multimedia vol. 19, no. 3, pp. 603–611.
[5] J. Groff et al., 2013, “Game-based learning: Latest evidence and future directions,” pp. 1–29.
[6] N. Syaodih, 2007, Metode Penelitian Pendidikan. Bandung: Remaja Rosdakarya.
[7] N. Sudjana and Ibrahim, 2012, Penelitian dan penilaian pendidikan. Bandung: Sinar Baru Algensindo.