Computer-based “Color-Mixing Maze Game” to stimulate symbolic thought for the development of learning science in early childhood

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Abstract. The purpose of this study was to determine the differences in the effectiveness of the computer-based “color mixing maze games” to stimulate symbolic thinking for the development of learning science in early childhood in the new era of industry 4.0. 23 samples in one kindergarten in Surabaya were used for this study consisted of 13 children (TK A1) for the experimental group and 10 children (TK A2) for the control group. This research was a type of quantitative experimental research using the Quasi-experiment method and the Non-equivalent Control Group Design. The Independent Sample T-Test was used for the data analysis technique and N-Gain with SPSS 21 was used for the effectiveness test. The results of the effectiveness test depicted a result of the Sig≤0.05 value and thus Ho was rejected and Ha was accepted, which means that there were significant differences in effectiveness computer-based “color mixing maze games” compared with paper-based games to stimulate symbolic thinking in the development of learning science in early childhood. Computer-based games are stated to be able to provide the right understanding in the learning process including science learning in recognizing mixing colors.

1. Introduction

In the new era of industry 4.0, all matters will be related to technology that continues to develop and become part of the harmony between human life and technology or machinery. Klaus stated that industrial revolution 4.0, emerged around 2010, developed through the internet which was the center of all things becoming a link between technology or machines and humans [1]. The fourth industrial revolution is not only a trigger for developing technology but also for human resources. Humans must continue to adapt and innovate in living systems so that they can be in harmony with existing technological developments, including in the process of education or learning. The existence of the fourth industrial revolution gives rise to the term of education 4.0 which is a way of integrating learning and technology [2]. Interesting learning content is one of the developments in digital games which is one of the uses of technology [3]. As an initial education, PAUD (Early Childhood Education, which is roughly equivalent to "pre-school or ECE" in English) becomes the most important period in a child's development. Learning that does not utilize technology in the process at school makes PAUD's goal to prepare children for further education is not maximally carried out yet.

The success of humans in adapting to the development of the era is very dependent on the childhood which is the root in human life. Children are very easy to be given stimulation to practice their abilities, including cognitive abilities to develop children's scientific capabilities in symbolic...
thinking about color. The ability to think symbolically in children is the recognition and the use of the symbols on an object [4]. Color is one of the symbols that is very pivotal for children because knowing color can be a benchmark or early detection effort for color blindness. Recognizing colors and mixing colors are one of the science learning needed for early childhood but there are still many children who have not been able to distinguish colors and understand their mixing.

The process of arranging children's sense of sight in recognizing color symbols is part of science learning for early childhood. Early childhood science learning aims to train children to be able to use all five senses as a tool in recognizing various events and objects both living and dead objects [5]. Learning science is very important to be introduced early on to children because of the development of the era so it demands humans to improve their ability to master technology and science [6]. Science learning about mixing colors will be easier to understand if we can take advantage of the game as an effective media. Games are very attached to the world of children which is one factor in knowing the world [7]. The game aims as a communicative, fun, and educative media [8]. Game is one of the important tools for children in developing their cognitive aspects so that children can improve their knowledge skills by playing the game [9]. Games will be very interesting if it can be maximized by using computer technology or other electronic media. The way of providing learning through computer media must be familiarized with early on. The challenge that must be faced by educators in providing computer-based science learning for early childhood is that not all children know about how to use computers. The rule of the game will be different when it compares to the media of paper and also an understanding of the content of the material provided. Initial observations showed 82% of Kindergarten A group in one school in Surabaya did not know about mixing colors and the school did not utilize computer facilities in learning science in children.

Color Mixing Maze Game is a computer-based game with learning materials about colors and their mixing. This game is made by using maze so that children should pass the maze as a challenge other than the child must choose the correct answer. This game aims to be a computer-based learning media to develop children's science so that children are not only able to recognize primary colors (red, yellow and blue) and secondary colors (green, purple and orange), but also know mixing primary colors so that they become secondary colors (yellow + blue = green, red + blue = purple, and yellow + red = orange).

![Figure 1. Cover of the game](image1)

![Figure 2. Color mixing material](image2)

![Figure 3. Game recognizes primary colors](image3)

![Figure 4. Games recognize the mixing of two primary colors into secondary colors](image4)
2. Method

This research was conducted in one kindergarten (TK) in Surabaya which has computer facilities but has not to use the computers as a learning medium and most (82%) students do not know about color mixing. The sample in this study was 23 children (11 boys and 12 girls) aged 4-5 years who were in different classes. The first class was A1 with 13 children and an A2 class with 10 children. Children in kindergarten A1 were used as research samples for an experimental group and children in class A2 were used as a control group. Computer-based “color mixing maze games” were used for science learning activities through symbolic thinking skills in the experimental group. Color mixing maze paper-based games were used for the control group.

This research used the Quasi-experiment method and Non-equivalent Control Group Design because this research used two groups, the experimental group, and the control group, by looking at the results of the pre-test and post-test. The experimental group was given science learning through “color mixing maze games” that are used to recognize primary colors and mixing colors (secondary colors). The instrument in this study consisted of five items that were analyzed with an independent sample t-test with N-Gain because it tested the differences in the two groups that were paired with results that were normally distributed and homogeneous.

| Table 1. Research Instrument |
|-------------------------------|
| Indicator | Variable | Sub Indicator |
| The development of science and effectiveness in computer-based “color mixing maze games” | Recognizing color | Get to know the primary colors (red, blue and yellow) |
| | | Get to know the secondary colors (orange, green, and purple) |
| Mixing two primary colors | Orange | |
| | Purple | |
| | Green | |

The assessment or collection of data was carried out by observation of the results of the pre-test and post-test conducted with the assessment criteria by the provisions in the curriculum for PAUD, which used four assessment criteria. The assessment criteria in this study were very well-developed (BSB = Score 4), well-developed according to expectations (BSH = Score 3), starting to develop (MB = Score 2), and not yet developed (BB = Score 1).

These research instruments were used after conducting the reliability and validity and has passed the tests of normality and homogeneity using SPSS 21. The analysis used both for test requirements and hypotheses was a simple independent t-test with N-Gain. The effectiveness of the color mixing maze game was calculated with the N-Gain formula which was [10]:

\[ g = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \]

Information:
| Sport | Final test score |
| Spare | Initial test score |
| Smaks | Maximum score possible |

The categorization criteria at the N-Gain level corresponded to the following table:

| Table 2. N-gain Rate Categories |
|---------------------------------|
| Category | Limits |
| g > 0.7 | High |
| 0.3 ≤ g ≤ 0.7 | Medium |
| g < 0.3 | Low |

(Meltzer, 2002 in Pasangkin, 2015)
The hypotheses in this research are as follows:
Ha: There is a difference in the effectiveness of computer-based “color mixing maze games” compared to paper-based games to stimulate symbolic thought in the development of science in early childhood.
Ho: There is no difference in the effectiveness of computer-based “color mixing maze games” compared to paper-based games to stimulate symbolic thought in the development of science in early childhood.

3. Results and Discussion
The purpose of this study was to determine differences in the effectiveness of computer-based “color mixing maze games” compared to paper-based games for early childhood science development through stimulating symbolic thinking. A simple independent t-test analysis with G-Gain was the most appropriate analysis in this study.

3.1. Results
The following are the results of calculations from the N-Gain test obtained from the SPSS 21 results which are then used in the test requirements and hypothesis analysis:

| Group          | N-Gain Score | Frequency |
|----------------|--------------|-----------|
| Experimental   |              |           |
| 0.4            | 1            |
| 0.5            | 1            |
| 0.6            | 2            |
| 0.7            | 2            |
| 0.8            | 3            |
| 0.9            | 2            |
| 1.1            | 1            |
| 1.2            | 1            |
| Amount         | 13           |
| Control        |              |           |
| -0.3           | 1            |
| 0              | 2            |
| 0.1            | 1            |
| 0.2            | 1            |
| 0.3            | 3            |
| 0.6            | 1            |
| 0.7            | 1            |
| Amount         | 10           |
| Total          | 23           |

In table 3, it can be seen that the highest N-Gain value in the experimental group was 1.2 and the lowest was 0.4 so that 4 children are included in the medium category and 9 children are included in the high category. Meanwhile, the highest value in the control group was 0.7 and the lowest was -0.3, thus 5 children are included in the low category and 5 children are included in the medium category.

3.1.1. Test Validity and Reliability
This research can be done if the existing instruments have carried out reliability and validity. Reliability and validity in this study were conducted in different kindergartens but have the same characteristics namely, aged 4-5 years, have computer facilities for learning, and live in the same sub-
district. The reliability of this study used 10 children studied in TK A (KG 1, in English) aged 4-5 years.

| Table 4. Reliability Statistics |
|---------------------------------|
| Cronbach's Alpha | Cronbach's Alpha Based on N of Items Standardized Items |
| .773 | .795 | 5 |

Based on table 4 in the Cronbach's Alpha column with a result of 0.773 which means more than 0.6, so it is stated that the research instrument was reliable. Thus, it can be used in the data collection process.

| Table 5. Item-Total Statistics |
|---------------------------------|
| Scale Mean if Item Deleted | Scale Variance if Item Deleted | Corrected Item-Total Correlation | Squared Multiple Correlation | Cronbach's Alpha if Item Deleted |
| Primary | 9.70 | 3.122 | .537 | . | .740 |
| Secondary | 10.80 | 3.733 | .610 | . | .722 |
| Orange | 9.50 | 3.389 | .492 | . | .752 |
| Purple | 10.40 | 3.156 | .573 | . | .723 |
| Green | 10.80 | 3.733 | .610 | . | .722 |

The reliability of each item can be seen in table 5 in the Cronbach's Alpha if Item Deleted column with overall results on all items more than 0.6 so that it can be stated that the existing research instruments can be used in collecting data in this study.

| Table 6. Correlations |
|-----------------------|
| Primary Pearson Correlation | Secondary Pearson Correlation | Orange Pearson Correlation | Purple Pearson Correlation | Green Pearson Correlation | Total Pearson Correlation |
| Primary Pearson Correlation | 1 | .733 * | .836 ** | .836 * | .733 * | .977 ** |
| Secondary Pearson Correlation | .733 * | 1 | .347 | .347 | 1.000 * | .780 ** |
| Orange Pearson Correlation | .836 ** | .347 | 1 | 1.000 * | .347 | .854 ** |
| Purple Pearson Correlation | .733 * | 1.000 * | .347 | .347 | 1 | .780 ** |
| Green Pearson Correlation | .836 ** | .347 | 1.000 * | .347 | 1 | .854 ** |
| Total Pearson Correlation | .977 ** | .780 ** | .854 ** | .854 ** | .780 ** | 1 |

Validity in this study can be seen from table 6 in the total column which shows that the result is more than 0.3 so that it is declared valid. Therefore, all items can be used in data collection in this study.

3.1.2. Test Requirements 973 651

| Table 7. Tests of Normality |
|-----------------------------|
| Group | Shapiro-Wilk Statistic | Df | Sig. | Shapiro-Wilk Statistic | Df | Sig. |
| N-Gain percent | Experimental | .102 | 13 | .200 | .979 | 13 | .973 |
| | Control | .163 | 10 | .200 | .949 | 10 | .651 |

Based on table 7, it can be seen that the significance value (sig) in the Kolmogorov-Smirnov and Shapiro-Wilk columns both in the experimental and control classes was more than 0.05, so it can be concluded that N-Gain data has a normal distribution and the obtained data have met the hypothesis.
Based on table 8, it can be seen that the significance value (sig) of the Levene Test for Equivalence of the Variance column was 0.544, which means more than 0.05 (0.544 > 0.05), thus it can be stated that the N-Gain variant data in homogeneous experiments and control classes are similar so that the obtained data has met the requirements for hypothesis testing.

3.1.3. Hypothesis Testing The effectiveness of “color mixing maze games”

Based on table 9 which is generated from the calculation of the simple independent test with N-Gain, it can be seen the significance of the effectiveness of “color mixing maze games” in early childhood science development, which is 0.000, which means it is smaller than 0.05 (0.000 ≤ 0.05). Based on these results it is stated that Ho was rejected and Ha was accepted which means there was a difference in the effectiveness of computer-based “color mixing maze games” compared to paper-based games to stimulate symbolic thinking in the development of science in early childhood.

3.1.4. Test the effectiveness level

In table 10, it can be seen that the average value of N-Gain in the experimental group was 0.8 and in the control group was 0.2 based on the N-gain level category in table 2, it is stated that the computer-based experimental group has a high level of effectiveness with a value of 0.8 > 0.7 (g > 0.7). Meanwhile, the paper-based control group has a low level of effectiveness with a value of 0.2 < 0.3 (g < 0.7).

3.2. Discussion
Technology, including a computer, is important for education that can make teaching and learn more interesting and enjoyable for children. Learning that integrates humans and technology or machinery is a demand that must be mastered both by teachers and children during the fourth industrial revolution.
today. It is a fact that many children (82%) do not know about colors and color-mixing as important symbols in human life. This is the background of making a "color-mixing maze game" to measure how important and effective learning is through computer-based games.

Based on the calculation results of a simple independent test with N-Gain, it can be seen the importance of the effectiveness of "color-mixing maze game" in the development of early childhood science with a value of less than 0.05 (0.000 ≤ 0.05) so that it can be interpreted that Ho was rejected and Ha was accepted, which means there was a significant difference in the effectiveness of computer-based "color-mixing maze game" compared to paper-based games to stimulate symbolic thinking in the development of science in early childhood.

The results of this study are in line with a research from Shobary, et al (2014) which concluded that the applications (computer games or color-mixing maze games) can be an alternative in learning because the material is interestingly packaged and helps in the process of learning material understanding the mixing of primary colors into secondary colors significantly compared to paper-based learning [11]. This study is also in line with research conducted by Vitianingsih (2016) which based on the results of her research concluded that educational games (computer-based color-mixing maze games) can help significantly in facilitating early childhood students to recognize symbols (colors) compared to paper-based learning [12].

Computer-based color-mixing maze game is stated to be able to provide the right understanding in the learning process including science learning in recognizing colors that will train children in symbolic thinking so that in this way can improve children's cognitive abilities in the development of science learning. This is in line with the opinion of Klisch, Y, Miller, L, Wang, S and Epstein, J (2012) which states that computer-based game for education is very effective in efforts to increase knowledge about the content of the material delivered in the game including material about recognizing color symbols and color-mixing [13].

Learning in the form of computer-based games is stated to be more effective than paper-based in recognizing color-mixing because experience in playing games can contain delight elements and can be learned repeatedly without having to think about the many tools and materials to be used [14]. This supports the obtained results of the research that is based on the results of N-Gain calculations, it can be stated that the average N-Gain value of the experimental group was 0.7 with a maximum value of 1.2 and a minimum value of 0.4. The average value of N-Gain in the experimental group was 0.2 with a maximum value of 0.7 and a minimum value of -0.3. Based on the N-gain level category in table 2, it is stated that the computer-based experimental class has a high level of effectiveness while the paper-based control class has a low level of effectiveness.

Another advantage of computer-based games (color-mixing maze game) is stated by Schrader, PG, & McCreery, M (2012) that computer-based games can provide direct feedback, repetition in learning, interactivity aspects, and representations of virtual reality so that they are considered more beneficial than other learning methods and are considered effective in learning color symbol and color mixing [15]. Udosen, Alice, Uwakmfon Samuel Ekpo (2016) further strengthened his opinion that learning through computer-based games (color-mixing maze game) serves as a complement to the practices used in teaching and measuring the improvement of children's abilities including in the ability to think symbolically by recognizing color symbols and color mixing as part of learning science [16].

4. Conclusions

This study aims to determine the differences in the effectiveness of computer-based "color-mixing maze game" compared to the paper-based games for the development of early childhood science to stimulate symbolic thinking. The results of the effectiveness test showed that through analysis it was known that the Significance value was 0.00 ≤ 0.05 so that Ho was rejected and Ha was accepted, which mean that there was a significant difference in the effectiveness of computer-based "color-mixing maze games" compared to the paper-based games to stimulate symbolic thinking in scientific development knowledge in early childhood. Computer-based "color-mixing maze games" are stated to
be able to provide the right understanding in the learning process including science learning in recognizing mixing colors that will train children in symbolic thinking, so that in this way it can improve children's cognitive abilities in the development of science learning. The computer-based experimental group has a high level of effectiveness with a value of 0.8> 0.7 while the paper-based control group has a low level of effectiveness with a value of 0.2 <0.3. Learning in the form of computer-based games is stated to be more effective than paper-based in recognizing color-mixing because experience in playing games can contain delight elements and can be learned repeatedly without having to think about the many tools and materials to be used.

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