Students’ creative-innovative thinking skill in solving rainbow antimagic coloring under research based learning model

B Sulistiyono\textsuperscript{1,2}, Slam\textsuperscript{1,3}, Dafik\textsuperscript{1,2}, Y Wangguway\textsuperscript{1,2} and Z L Al Jabbar\textsuperscript{1,2}

\textsuperscript{1} CEREBEL-University of Jember, Indonesia
\textsuperscript{2} Departement of Mathematics Education Post Graduate, University of Jember, Indonesia
\textsuperscript{3} Departement of Information System, University of Jember, Indonesia

Email: budi.sulis347@gmail.com

Abstract. The study aims to investigate students’ creative-innovative thinking skill in solving rainbow antimagic coloring on research based learning model. The method used in this study is a mixed method, i.e. combining the qualitative and quantitative methods. The research subjects were 4th semester of students of higher education consisting of 41 students of experimental class and 30 students of control class. The instruments of this research are test, an observation, and an interview. Qualitative method is applied to analyze observation and development research, while quantitative method is applied to analysis the difference in student achievement result among two classes. The result show that there are significant difference between the two classes that applied research based learning and conventional learning models. The statistical result indicates that the (2-tailed) significance of the independent sample t-test in the post-test was 0.000 or p ≤ 0.05. It implies that the implementation of RBL, significantly influenced the students’ creative-innovative thinking skill in solving rainbow antimagic coloring.

1. Introduction

Education is one of the main factors in the development and progress of a country, especially education at the university level. That is because education at the university level has a strategic role in improving the quality of human resources. Education at the university level is required in order to grow and develop all the skills possessed by students [9]. Education that only prioritizes the knowledge of students begins to be abandoned. The impact of economic progress, globalization, and technology demands functional graduates, meaning that students are not only equipped with knowledge but also equipped with new skills. These impacts require educators to teach new skills besides the core lessons. This has led to the emergence of a new learning paradigm that educators need to teach the skills needed in the 21st century [4].

In this 21st century, communication and information technology play an important role in life, including the teaching and learning process especially at the university level. Firma believes that critical thinking, problem solving and communication skills are very important in this 21st century life [13]. Education is currently directed to be able to grow and develop all the skills exist in every student. One of the skills of students that is expected to grow through the educational process is the ability of 4Cs which includes communication, collaboration, critical thinking and problem solving, and creativity and innovation. Rotterdam and Willingham [14] argue that Partnership 21 (P21) was made so that everyone can learn and master 21st century skills. One of the skills needed in the 21st century is creative and innovative. According to P21 [15] creative and innovative spirit is a requirement for personal and professional success.
Meyer classifies thinking into three main components, namely (1) thinking is a cognitive activity occurs in a person's mind, not seen but can be concluded based on the observed behavior, (2) thinking is a process involves a lot of knowledge in a cognitive system, (3) thinking activity directed to produce solutions to the problems encountered [5]. In line with this, Siswono argues that thinking is a mental activity experienced by someone if they face a problem or situation that must be solved [6]. Krulik and Rudnick explain that creative thinking is original, reflective, and produces a complex product. While Munandar explains creative thinking is the ability to find many possible answers to a problem [2]. From the explanations above, it can be concluded that creative thinking is a mental ability of a person which includes ideas that can be integrated and developed so as to create a new product that is useful for oneself and the environment. Creative thinking means being confident in taking risks to create new ideas or generate new ways of looking at and finding many possible answers to a problem faced.

Many of the experts expressed their opinions on the characteristics and indicators of creative thinking. According to Munandar there are four kinds of characteristics of creative thinking, namely: (1) fluency, (2) flexibility, (3) originality, and (4) elaboration [5]. While Silver believes that there are three kinds of creative thinking, namely: (1) fluency, (2) flexibility, and (3) novelty. Next Siswono expressed his opinion that the criteria for creative thinking can be measured through: (1) completion, (2) fluency, (3) flexibility, and (4) novelty. Characteristics and indicators of creative-innovative thinking used in this research based on P21 included:

| No. | Characteristics                     | Indicator                                                                                     |
|-----|--------------------------------------|-----------------------------------------------------------------------------------------------|
| 1.  | Think creatively                     | 1. Use large scope to create ideas such as arguments                                            |
|     |                                      | 2. Create something new that is useful both ordinary and extraordinary concepts                 |
|     |                                      | 3. Collaborate their ideas to improve creative results                                          |
| 2.  | Work creatively with others          | 1. Develop and implement and communicate new ideas to others                                    |
|     |                                      | 2. Open, response to something new and different                                                |
|     |                                      | 3. Work intensively in groups and provide input on work results                                |
| 3.  | Implementation of innovation         | 1. Work in creative ideas to make something real and useful in a study where innovation will occur |

According to Susiani, research based learning is a learning model that is associated with various activities such as analyzing, synthesizing, and evaluating [8]. These activities enable students and educators to improve assimilation and apply their knowledge. Dafik argues that research based learning is a learning method that uses contextual learning, authentic learning, problem solving, cooperative learning, hands on minds on learning, and inquiry discovery approach [7]. The target of the application of research based learning is to encourage the creation of higher-order thinking skills for educators and students. Based on Arifin research based learning generally consists of three stages, namely: (1) exposure stage, (2) experience stage, and (3) capstone stage. Exposure stage is the activity of gathering information through literature or articles related to the problem or material to be discussed [7]. Experience stage is an activity of identifying and finding formulas of problems based on literature and experimental activities. Capstone stage is an activity of presenting ideas and methods that will be used to find solutions to the problems. In relation with that, Peter Tremp explains that the stages of research based learning are as follows [10]:

| No | Phase                   | Activity                                           |
|----|-------------------------|----------------------------------------------------|
| 1  | Formulating a general questions | Provide a formula in the form of a problem                        |
| 2  | Overview of research literature | Examine the references from the related literature          |
| 3  | Defining the questions   | Formulate a hypothesis                                |
| 4  | Planning research activities, clarifying | Determine a research method                          |
The purpose of this study was to determine the effect of research-based learning compared to the conventional model on creative-innovative thinking skills in solving rainbow antimagic coloring problems. The material used in this study was graph. In general, a graph is a set of pairs \((V, E)\) where \(V\) is a non-empty set of vertices (vertices or nodes) and \(E\) is a set of edges (edges or arcs) that connects a pair of vertices on the graph.

**Definition 1.** For instance, \(G\) was a non-trivially connected graph and defined by a coloring side \(c: E(G) \rightarrow \{1,2, ..., k\}, \, k \in N\), so that the two adjacent edges might have the same color. The \(u \sim v\) path \(P\) in \(G\) was called as rainbow path if there were no two sides in \(P\) that had the same color. Graph \(G\) was said to be rainbow connected if every two different vertex on \(G\) were connected by a rainbow path. Edge coloring which caused \(G\) to be rainbow connected was called rainbow coloring. Obviously, if \(G\) was rainbow connected, then \(G\) was connected. Conversely, each connected graph had a trivial edge coloring so that rainbow connected had a different edge coloring. Rainbow connection number of the connected graph \(G\), was written as \(rc(G)\), defined as the minimum number of colors needed to make graph \(G\) to be rainbow connected [1]. An antimagic labeling is a bijection \(g: E \rightarrow \{1,2, ..., q\}\), such that the induced vertex sum \(g^+ : V \rightarrow N\) given by \(g^+(u) = \Sigma g(uv):uv \in E\) is injective. A graph is called antimagic if it admits an antimagic labeling [11]. When the edge weights \(w(e) = g(u) + g(v)\) become the color on each edge and there is always a rainbow path between the two vertices in the graph, edge coloring is called rainbow antimagic coloring. Rainbow antimagic connection number of the connected graph \(G\), is written as \(rc_A(G)\) is defined as the minimum number of colors needed to make graph \(G\) to be rainbow connected with the rule of edge weights \(w(e) = g(u) + g(v)\) used as the edge color for each edge in \(G\).

### 2. Research Methods

This research used mixed method research. Johnson said that mixed method research was one type of research in which the researcher or research team combined the parts of qualitative and quantitative research [3]. The purposes of mixed research were to complement and reinforce the results of the research. In this study, quantitative research was used to analyze the data obtained from learning outcomes with research-based learning model while qualitative research was used to analyze the data obtained from the observation and interview.

**2.1 Population**

The research subjects used in this research were the 4th semester students. The control class consisted of 30 people, while the experimental class consisted of 41 people. The selection of the two classes was carried out randomly. The control class was the class that where no treatment was given or, in other words, taught by using conventional method while the experimental class was the class that was given treatment in the form of research-based learning task. The research design used in this study was presented in the chart below.

**Table 3. pre-test and post-test control group design**

| Group                  | Pre-Test | Treatment | Post-Test |
|------------------------|----------|-----------|-----------|
| A (eksperimental class)| \(O_1\)  | X         | \(O_2\)   |
| B (control class)      | \(O_3\)  | -         | \(O_4\)   |
With remarks:
R = experimental and control class are randomly selected
O1 & O3 = both groups were researched use pre-test data
O2 = post-test results from experimental class
O4 = post-test results from control class

2.2 Instrument
The instruments used in this research were test, observation, and interview. The test was done twice that were pre-test and post-test in the form of several essay questions.

2.3 Task
The task given to measure the level of creative-innovative thinking skills was the task of graph material, especially on rainbow antimagic coloring. The subjects of the research must find out the value of $rc_A(G)$ of a graph. They were free to choose a non-trivial graph and then asked to color the graph side based on rainbow antimagic coloring. The examples of the students’ work can be seen on Figure 1.

![Figure 1. L_7 graph with rc_A = 7](image)

Figure 1 is a picture of ladder graph with $n = 7$ or denoted by $L_7$. The first step in carrying out the task was to label each vertex on the graph. The label given was a real number of the vertices on the graph. The next step was to sum up the adjacent vertex labels to determine the color on each edge. Based on Figure 1, it was obtained that $rc_A(D_2) = 7$ because to color the edges of graph $D_2$ based on rainbow antimagic coloring required 6 different colors. From this task, it can be predicted that $rc_{la}(L_n) = n$.

2.4 Data collection and data analysis
The data obtained from the results of pre-test and post-test both in the experimental and control classes were analyzed by using t-test to determine the effect of research-based learning on creative-innovative thinking skills in solving rainbow antimagic coloring problems. This were the data analysis by using quantitative research method. The data obtained through the observation and interview were analyzed by using qualitative research method. Both results of data analysis showed whether or not there was an influence of research based learning on creative-innovative thinking skills.

3. Research findings
Before the t-test was done, there were some assumptions which must be fulfilled in order the t-test could be done such as normality and homogeneity assumptions in the pre-test and post-test data both in the experimental and control classes. Validity and reliability tests were carried out before the data were obtained.
The diagram below showed the dissemination of the students’ creative-innovative skills both from the experimental and control classes based on the results of pre-test. The following showed the diagram drawn the spread of creative-innovative thinking skills from the pre-test data in the control class.

Figure 2. The model of triangulation model

Based on the Chart 1 below, it obtained the information that based on the levels of creative-innovative thinking skills, as much as 42% of students belonged to not creative-innovative category, 27% of students belonged to hardly creative-innovative category, 15% students belonged to fairly creative-innovative category, 10% of students belonged to creative-innovative category and 6% of students belonged to very creative-innovative category. Afterward, the diagram drawn the spread of creative-innovative thinking skills from the data of pre-test in the control class was shown. Based on the chart 1 we can see that the level creative-innovative from control class is low.
Chart 1. The distribution of creative-innovative thinking skills pre-test control class

Based on the chart 2 below, it obtained the information that based on the levels of creative-innovative thinking skills, as much as 34% of students belonged to not creative-innovative category, 16% of students belonged to hardly creative-innovative category, 15% of students belonged to fairly creative-innovative category, 15% of students belonged to creative-innovative category and 20% of hardly creative-innovative students belonged to very creative-innovative category. Based on the Table 5 we can see that the level creative-innovative from experimental class is low. Chart 1 and Chart 2 above give the information that both of control class and experimental class have low level creative-innovative thinking skills.

Chart 2. The distribution of creative-innovative thinking skills pre-test experimental class

In addition, the normality and homogeneity tests were performed in the pre-test and post-test data both in the experimental and control classes. The following is the table drawn the normality test data of pre-test both in the experimental and control classes.

| Table 4. Normality test results for the pre-test experimental class and control class |
|----------------------------------------|-----------------------------------------------|-----------------|-----------------|-----------------|
| GROUP                             | Kolmgorov-Smirnov<sup>a</sup> | df | Sig. | Shapiro-Wilk | Df | Sig. |
|----------------------------------------|-----------------------------------------------|-----------------|-----------------|-----------------|
| PRE TEST Experimental Class          | .135                                      | 41 | .059         | .978           | 41 | .586 |
| Control Class                        | .075                                      | 30 | .200         | .970           | 30 | .535 |

<sup>a</sup> Kolmgorov-Smirnov test.
The normality test was done by using Shapiro-Wilk test because Shapiro-Wilk test had the better valid results for the data less than 50. Based on the table above, it obtained that the sig of the experimental class was 0.586 and the sig of the control class was 0.535. Therefore, it can be concluded that both data were normal because 0.586 > 0.05 and 0.535 > 0.05, so the normality assumption was fulfilled.

After that, the homogeneity test was done in the pre-test data of the experimental and control classes. The homogeneity test was done through Levene Test. From the Table 5 below, obtained that the sig value was 0.059 so it can be concluded that the pre-test data from the experimental and control classes were homogeneous because 0.059 > 0.05.

Table 5. Homogeneity test results for the pre-test experimental class and control class

| Levene Statistic | df1 | df2 | Sig. |
|------------------|-----|-----|------|
| 3.691            | 1   | 69  | .059 |

After normality test and homogeneity test was done, next step is the independent t-test. From the Table 6, it can be seen that in the experimental class, the mean was 69.15 and the mean in the control class was 64.17. Based on the Table 7 below the sig was 0.154 so it can be concluded that the pre-test data from the experimental and control classes were homogeneous because 0.154 > 0.05. According to the fact, it obtained that the experimental and control classes had no difference, so the homogeneity assumption was fulfilled.

Table 6. Descriptive statistic for for the pre-test experimental class and control class

| CLASS             | N   | Mean | Std. Deviation | Std. Error Mean |
|-------------------|-----|------|----------------|-----------------|
| RESULT            |     |      |                |                 |
| EXPERIMENTAL CLASS| 41  | 69.15| 6.894          | 1.077           |
| CONTROL CLASS     | 30  | 64.17| 5.167          | .943            |

Table 7. Independent sample t-test for the pre-test experimental class and control class

| Levene's Test for Equality of Variances | t-test for Equality of Means |
|----------------------------------------|------------------------------|
|                                        | 95% Confidence Interval of the Difference |
|                                        | F    | Sig. | t    | df  | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| RESULT Equal variances assumed         | 2.081| .154 | 3.329| 69  | .001            | 4.980           | 1.496               | 1.995 | 7.964 |
| Equal variances not assumed            | 3.479| 68.945| .001|     | 4.980           | 1.431           | 2.124               | 7.835 |

The following shown the dissemination of the students’ creative-innovative thinking skills from the experimental and control classes based on the results of post-test diagram.

Table 8. Normality test results for the post-test experimental class and control class

| GROUP               | Kolmogorov-Smirnov\(\times 100\) | Shapiro-Wilk |
|---------------------|----------------------------------|--------------|
| POSTES              | Statistic | df  | Sig. | Statistic | Df  | Sig. |
| Experimental Group  | .200      | 11  | .200 | .926      | 11  | .372 |
| Control Group       | .079      | 60  | .200 | .971      | 60  | .167 |
Based on the Table 8 above obtained that the sig value of the experimental class was 0.372 and the sig value of the control class was 0.167. From this data, it can be concluded that both data were normal because 0.372 > 0.05 and 0.167 > 0.05 therefore the normality assumption was fulfilled.

Next, the homogeneity test was carried out in the post-test data of the experimental and control classes. The homogeneity test was done through Leavene Test. From the table 9 above obtained that the sig value was 0.086 so it can be concluded that the pre-test data from the experimental and control classes were homogeneous because 0.086 > 0.05. According to the fact, it obtained that the experimental and control classes had no difference so the homogeneity assumption was fulfilled.

**Table 9. Homogeneity test results for the post-test experimental class and control class**

| Levene Statistic | df1 | df2 | Sig. |
|------------------|-----|-----|------|
| 3.039            | 1   | 69  | .086 |

After the normality and homogeneity assumptions were fulfilled, then the t-test was done to find out whether or not there was an influence of research based learning model on the creative-innovative thinking skills in solving rainbow antimagic coloring problems.

**Table 10. Descriptive summary of statistics from the pre-test and post-test of both classes**

| Pair  | Pre-test          | Post-test         | Mean  | N  | Std. Deviation | Std. Error Mean |
|-------|-------------------|-------------------|-------|----|----------------|-----------------|
| 1     | Pre-test Experimental | Post-test Experimental | 69.15 | 41 | 6.894          | 1.077           |
| 2     | Pre-test Control   | Post-test Control  | 64.17 | 30 | 5.167          | .943            |

The Table 10 above showed the statistical descriptive summary from the pre-test and post-test data in the experimental and control classes. From the table, it can be seen that in the experimental class, the mean difference reached 5.07 and the mean difference in the control class was 4.4.

**Table 11. T-test result of the experimental class and control class**

| Pair  | Pre-test          | Post-test         | Mean  | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | t    | df | Sig. (2-tailed) |
|-------|-------------------|-------------------|-------|----------------|-----------------|------------------------------------------|------|----|---------------|
| 1     | Experimental -    | Experimental      | -5.073| 5.057          | .790            | -6.669, -3.477                           | -6.424| 40 | .000          |
| 2     | Pre-test Control  | Post-test Control | -4.400| 4.583          | .837            | -6.111, -2.689                           | -5.258| 29 | .000          |

The Table 11 above was the results of t-test done. From the table it obtained that the Sig.(2-tailed) from the experimental class was 0.000 and the Sig.(2-tailed) from the control class was 0.000. From this fact, it can be concluded that there was an influence of research based learning model on the creative-innovative thinking skills in solving rainbow antimagic coloring problems.

The diagram drawn the dissemination of students' creative-innovative thinking skills both from the experimental class and the control class as it was obtained through the post-test results. The following is a diagram of the dissemination of students' creative thinking skills taken from the post-test data in the control class. As we can see, the following diagram revealed that according to the levels of creative-innovative thinking, 41% of student was at the level of not creative-innovative, 20% of
students was hardly creative-innovative, 17% of students was fairly creative-innovative, 11% of students was creative-innovative, and 11% of students was very creative-innovative.

**Chart 3.** The distribution of creative-innovative thinking skills post-test control class

The following is a diagram of the dissemination of students’ creative thinking skills attained from the post-test data in the experimental class. Based on the level of creative-innovative thinking, the diagram showed that 6% of students was at the level of not creative-innovative, 11% of students was at hardly creative-innovative, 15% of students was at fairly creative-innovative, 25% of students was at creative-innovative, and 43% of students was very creative-innovative.

**Chart 4.** The distribution of creative-innovative thinking skills post-test experimental class

According to the observation that was conducted during the post-test, the students worked on it well and seriously. It was seen from the written answers. An answer from one of the students would be discussed as follows. The problem discussed in this research was the problem of rainbow antimagic coloring. Rainbow antimagic coloring was one of the studies in the field of graph. The study combined the concepts of rainbow coloring and antimagic labeling. After being explained in the class, the students were asked to choose one of several types of graphs. Next, the students wrote down the cardinality of the graph. The following figure below is an example of a graph cardinality done by one of the students. The student wrote the cardinality of the Ladder graph \((L_n)\) for \(n \in N\).
After determining the cardinality of the Ladder graph, the students started coloring the edges of the graph by labeling the real numbers on each vertex of the graph. Based on the working done as shown on the Figure 4 above, the student labeled 2 at point $x_1$, 3 at $x_2$, 6 at $x_3$, 7 at $x_4$, 9 at point $y_1$, 8 at $y_2$, 5 at $y_3$, 4 at $y_4$, 1 at $y_5$. The next step was adding adjacent labels; for examples were label $x_1$ and label $x_2$, label, if they were added, $2 + 3 = 5$ would be the result. In other words, the edge-colors obtained from the addition of adjacent labels were 5, 9, 11, 13, 17. After the edge-colors obtained, the next step was checking whether or not the coloring was rainbow coloring. The examination was carried out by taking the opposite vertex, for example $x_1$ and $y_5$. The two vertices were connected by a path, for example the paths of $x_1 - y_1 - y_2 - y_3 - y_4$ which had colors of 11, 17, 13, 9, 5. It means that the selected path was a rainbow path and if two adjacent vertices were taken from the graph, it can be ensured that every two vertices had a rainbow path. From these facts, it can be seen that the coloring done was rainbow antimagic coloring with $rc_A(L_5) = 5$.

The difficulty of this task was on finding the minimum color needed for the graph to be colored with the concept of rainbow antimagic coloring. The first difficulty occurred when the students tried to label at each vertex as the total number of labels should produce a minimum color range. After the graph was able to be colored, the checking was required whether or not the color was the minimum color. Finally, the coloring of the graph side must be checked whether or not it was rainbow coloring.

To find out the students' understanding of the rainbow antimagic coloring problem, the researcher conducted an interview with one of the students. Any information about the students was kept in secret so that the interview text was only written by the researcher and student. The following is the excerpt from the research questions and answers from student that was interviewed.
Researcher : What did you first do while doing the task?
Subject 1 : First, I determine the graph and then determine the label for each vertex
Researcher : What did you do next?
Subject 1 : I try to determine the cardinality but it’s so difficult and then I discussed with my team mates.
Researcher : Do you have difficulty when determining the labels? Tell me!
Subject : At first it was difficult because I labeled it randomly so it didn’t produce a slightly different color. Next I discussed with my team mates for labelling the graphs.
Researcher : How do you find the right label?
Subject : We tried filling the label several times and finally I was able to find a slightly different color. Further, I checked the vertex sum and I find the right one.
Researcher : What do you do after finding the fewest edge color?
Subject : I checked the edge coloring.

From the interview, we can depict of the student creative-innovative process in the following phase portrait.

Based on phase portrait in Figure 5, we know that subject 1 can decide the graph well. Subject 1 still made a mistake so it requires discussion with team mates. After the discussion, subject 1 can find the cardinality well. Next, subject 1 give the label to every vertices in graph. In this section, subject 1 needs discussion with team mates. After that, subject 1 can label each vertex so that by adding two adjacent vertex labels a color on the edge the graph can be obtained.

Next, the second subject will be interview. Subject 2 can determining a graph well. Subject 2 can determine cardinality well. Next section is give a label to all vertices on the graph. In this section, subject 2 needs discussion with team mates. After that, the color of the edge can determine well.
The following is the excerpt from the research questions and answers from student that was interviewed.

Researcher: What did you first do while doing the task?
Subject 2: First, I determine the graph I will use then determine the label for each vertex
Researcher: What did you do next?
Subject 2: I determined the cardinality and it works.
Researcher: Do you have difficulty when determining the labels? Tell me!
Subject 2: At first it was difficult because I labeled it randomly. Next I discussed with my team mates for labelling the graph. We works together to labeled my graph.
Researcher: How do you find the right label?
Subject 2: We tried filling the label several times. Further, I checked the vertex sum and I find the right one.
Researcher: What do you do after finding the fewest edge color?
Subject 2: I checked the edge coloring and I find the minimum color.

4. Discussion
This research was intended to determine the effect of research-based learning on creative-innovative thinking skills in solving rainbow antimagic coloring problems. It showed the creative-innovative thinking skill of the experimental class is very creative-innovative of 43%, creative-innovative of 25%, fairly creative-innovative of 15%, hardly creative-innovative of 11%, not creative-innovative of 6%, while for control class showed very creative-innovative of 11%, creative-innovative of 11%, fairly creative-innovative of 17%, hardly creative-innovative of 20%, not creative-innovative of 41%. Based on these result the students in experimental class showed their creative-innovative thinking skills higher compare to the control class. Finally, we can claim that the research based learning can improve creative-innovative thinking skill.

A similar research was ever done by Syaibani (2017). Their research aimed at determining the implementation of research-based learning on creative thinking skills on rainbow connection material. Another similar research was also carried out by Yudha (2018) with the objective of analyzing research-based learning models of 21st century creative-innovative thinking in solving locating dominating problems. Recently, Suntusia (2019) also conducted a similar research to improve the students’ learning outcomes through research-based learning model in solving two-dimensional arithmetic sequences problems.

This research was a follow up of those three researches since it used updated-material, rainbow antimagic coloring. Rainbow antimagic coloring material was an extension of rainbow connection material. Rainbow antimagic coloring material was a combination of rainbow coloring and antimagic labeling material. This research still used the research-based learning as it was considered as a learning model that was proven to improve the students’ learning outcomes and thinking skills, especially creative-innovative thinking skills. The suggestions for future researchers who will conduct a similar research are as follows:

- The learning model being studied is able to be replaced with the latest and updated learning model.
- Thinking ability that will be studied can use other type of thinking skill.
- The material to be studied should be suitable to the current development and the latest material.

5. Conclusion
This research was intended to determine the effect of research-based learning on creative-innovative thinking skills in solving rainbow antimagic coloring problems. It showed the creative-innovative thinking skill of the experimental class is very creative-innovative of 43%, creative-innovative of 25%, fairly creative-innovative of 15%, hardly creative-innovative of 11%, not creative-innovative of 6%, while for control class showed very creative-innovative of 11%, creative-innovative of 11%, fairly
creative-innovative of 17%, hardly creative-innovative of 20%, not creative-innovative of 41%. Based on these results, the students in experimental class showed their creative-innovative thinking skills higher compared to the control class. Finally, we can claim that the research-based learning can improve creative-innovative thinking skill.

Acknowledgment
We gratefully acknowledge CEREBEL research group for the support and supervision in completing the paper.

References
[1] Chartrand G, Johns G L, McKeon K A and Zhang P 2008 Rainbow connection in graphs Mathematica Bohemica 133(1) 85-98
[2] Happy and Listyani 2011 Improving The Mathematic Critical and Creative Thinking Skills in Grade 10th SMA Negeri Kasihan Bantul on Mathematics Learning Through Problem Based Learning Proceeding: "Building The Nation Character Through Humanistic Mathematics Education
[3] Johnson R B and Christensen L 2019 Educational research: Quantitative, qualitative, and mixed approaches (SAGE Publications, Incorporated)
[4] Kivunja C 2015 Exploring the pedagogical meaning and implications of the 4Cs “super skills” for the 21st century through Bruner’s 5E lenses of knowledge construction to improve pedagogies of the new learning paradigm Creative Education 6(02) 224
[5] Lince R 2016 Creative thinking ability to increase student mathematical of junior high school by applying models numbered heads together Journal of Education and Practice 7(6) 206-212
[6] Siswono T Y E 2010 Leveling Students' creative Thinking In Solving And Posing Mathematical Problem Journal on Mathematics Education 1(1) 17-40
[7] Suntuosi, Dafik and Hobri 2019 The Effectiveness of Research Based Learning in Improving Students’ Achievement in Solving Two-Dimensional Arithmetic Sequence Problems International journal of instruction 12(1) 17-32
[8] Susiani T S, Salimi M and Hidayah R 2018 Research Based Learning (RBL): How to Improve Critical Thinking Skills? SHS Web of Conferences 42 p 00042 EDP Sciences
[9] Syaibani H A, Dafik and Hobri 2017 The Analysis of Student’s Creative Thinking Skills in Solving “Rainbow Connection” Problem through Research Based Learning The International Journal of Social Sciences and Humanities Invention 4(8) 3783-3788
[10] Tremp P 2010 Research-based Teaching and Learning (A LERU project: Universitat Zurich)
[11] Wang T M and Hsiao C C 2008 On anti-magic labeling for graph products Discrete Mathematics 308(16) 3624-3633
[12] Wardani P L, Dafik and Tirta I M 2019 The analysis of research based learning implementation in improving students conjecturing skills in solving local antimagic vertex dynamic coloring Journal of Physics: Conference Series 1211(1) p 012090 IOP Publishing.
[13] Yudha F, Dafik and Yuliati N 2018 The Analysis of Creative and Innovative Thinking Skills of the 21st Century Students in Solving the Problems of “Locating Dominating Set” in Research Based Learning International Journal of Advanced Engineering Research and Science 5(3)
[14] Rotherham A J and Willingham D 2009 21st century skills: The challenges ahead Educational Leadership 67 16–21
[15] P21 2007 The intellectual and Policy Foundations of the 21st Century Skills Framework (Partnership for 21st Century Skills)