On the implementation of project-based learning to improve the students creative thinking skills in solving rainbow antimagic coloring problems

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Abstract. This study was intended to know the implementation of project-based learning to improve creative thinking skills of students in solving rainbow anti-magic coloring problems. The methods used in this study were a combination of quantitative and qualitative methods. The quantitative method was used for the statistical analysis of test, while the qualitative method was used to analyse data that are related to the results of the test on each indicator and the results of phase portraits. This research used two classes, experimental and control, in which each class consisted of 26 students as respondents. Both classes were given treatments with different type of learning model. In the experimental class, the learning instruments that have been developed was applied along with a project-based learning method, while in the control class only used project based learning. The results of creative thinking skills of the students for control class indicated that 53% of students were categorized as low, 37% of students were categorized as medium, and 10% of students were high-level creative thinking skill while in the experimental class 34% of students were low, 44% of students were medium, and 22% of students were high-level creative thinking skill. The homogeneity test result of two classes, using a pre-test result, showed \( p \) – value of 0.701 > 0.05; therefore, the mean difference between classes was not significant. The inferential statistical result of the independent sample t-test on the post-test showed \( p \) – value 0.0053 (\( p < 0.05 \)), which was significant. It can be concluded that project-based learning has a significant effect for improving creative thinking skills of the students in solving rainbow anti-magic coloring.

1. Introduction
Education is the basic for modernizing an people mindset, which closely related to culture and makes it essential to developing a country. Mathematic is one of the compulsory subject that exist at every level of education. Mathematic provides the students with some skills such as logical, systematic, critical, and analytic thinking. Critical thinking skill can be an alternative to problem-solving and decision-making [1]. Students, in the learning process, are required to able to think and solve a problem. There are four levels of thinking in learning process are categorized according to higher-order thinking as follows: retention, fundamental, critical, and creative [2]. In developing creative thinking, it is necessary to create a learning environment that involves students' authentic experiences [3].
Table 1. Indicators of creative thinking levels.

| No | Aspects | Indicators |
|----|---------|------------|
| 1  | Fluency | a) Students are able to continue the rainbow anti-magic coloring  |
|    |         | b) Students are able to give the new rainbow anti-magic coloring  |
|    |         | c) Students are able to determine the number of rainbow anti-magic coloring  |
|    |         | a) Students are able to find the cardinality of graph to n-th |
| 2  | Flexibility | b) Students are able to give the notation and function  |
|    |         | c) Students are able to prove the n-th function |
|    |         | a) Students are able to create a new coloring |
| 3  | Novelty | b) Students are able to determine the cardinality, RAC, notation and n-th function |
|    |         | c) Students are able to prove the results |

Students who study mathematics, especially at the tertiary education level, are expected to adapt well with the times. In tertiary level education, there are many topics studied in mathematics; one of them is graph theory. This material is a part of combinatorial mathematics. Combinatorial knowledge is the knowledge that needs higher-order thinking abilities that are critical and creative. There are some topics discussed in graph theory. The topic of rainbow anti-magic coloring is attractive due to the result of Sulistyono et al. [4]. Appropriate learning design is needed to shape students’ creative thinking; therefore, along with the development of the era, education quality must be improved.

There are many learning models, one of them is project based learning (PjBL). The PjBL model focuses on the students to understand a concept through some investigations of a problem and find a solution by doing a project. This research implements PjBL model to the students in solving of rainbow anti-magic coloring problems. The research activities in project based learning (PjBL) cover three stages: preparation, learning, and evaluation; all of them are described into six stages [5]. The PjBL model has been implemented in some researches and studies [5-9]. From those researches, it is known that the PjBL models improved the creative thinking skill of the students.

Based on the problems, there will be a development of learning instruments that uses PjBL model, which aims to improve the creative thinking skill of the students in combinatorial problems. The problem focuses on discrete mathematics with the study on rainbow anti-magic coloring. Therefore, we select the topic Rainbow Antimagic Coloring.

Let \( G = (V, E) \) is a simple graph. Graph \( G \) is called anti-magic if \( G \) has a label of anti-magic. A bijective function \( f: E \to \{1, 2, \ldots, |E|\} \) is called as anti-magic label if, for \( u \in V(G) \) and weight \( w(u) = \sum_{e \in E(u)} f(e) \) where \( E(u) \) is an edge set that is incident to \( u \) fulfilled by \( w(u) \neq w(v) \) for two different vertices of \( u \) and \( v \) [10].

Let \( G \) as a simple graph. For a bijective function \( f: V(G) \to \{1, 2, \ldots, |V(G)|\} \), the weight resulted from edge \( uv \in E(G) \) of \( f \) is \( w_f(uv) = f(u) + f(v) \). A path \( P \) of graph \( G \) which its vertex is labeled called as rainbow path if, for each two edges \( uv, u'v' \in E(P) \), there is \( w_f(uv) \neq w_f(u'v') \). If for each two edges of \( u \) and \( v \) from \( G \), there is a rainbow path \( u - v \), then \( f \) is called as rainbow anti-magic labeling of graph \( G \).

The aim of this research is to identify the creative thinking of the students and the implementation on mathematics learning instrument with PjBL model in solving problem of rainbow anti-magic coloring.
2. Research Methods
In this research, we use quasi-experimental design. We apply a pre-test and post-test in the control class and experiment class. The pre-test is carried out at the beginning of the lesson and the post-test is carried out at the end of the lesson. For the experimental research design, we adopt the design used in [11-13], as follows.

Table 2. Experimental Research Design.

| Group    | Pre-Test | Independent Variable (X) | Post-Test |
|----------|----------|---------------------------|-----------|
| Experimental | $O_1$    | $X_1$                     | $O_2$     |
| Control  | $O_3$    | $X_2$                     | $O_4$     |

Note:
- $O_1$ & $O_3$: the two groups were observed by using pre-test to know the initial work ability. It is expected that the groups has equal initial work ability.
- $X_1$: learning using project based learning.
- $X_2$: learning using group discussion
- $O_2$ & $O_4$: classroom post-test result.

There are two classes involved in this research, namely, experimental class and control class. Both classes have been tested for their homogeneity by using the result of test. Before giving the treatment, both classes were given a pre-test to know their creative thinking skills. And then, the experimental class was given a treatment with PjBL model, while the control class was given a group discussion model. After giving the treatment, a post-test was given to the students in both classes. All of the test results were analyzed to conclude the effect of PjBL model.

2.1. Population
This research was taken place in Mathematics Education study program, Faculty of Teacher Training and Education, University of Jember, with the undergraduate students as the subjects.

2.2. Research Procedure
This research employed instruments in form of tests, observation, and interviews. The combination of the research design along with the research procedure is illustrated in Figure 1.

The creative thinking skill of the students was measured using the indicator converted into an assessment instrument. In this research, we employed a quantitative method to analyze the creative thinking skill after the implementation of PjBL model. In addition, a qualitative method was also used to analyze the data collected from the class observations and selected interviews with the students. We investigated two variables, which are the implementation of PjBL as independent variable and creative thinking skill of students as the dependent variable.

We had a criteria of testing, if $p$ value $>0.05$, then $H_0$ is accepted, while if the significance value $<0.05$, then $H_0$ is rejected. The hypotheses that were tested in this research, is described as follows.

$H_0$: There is no effect of learning instruments based on PjBL model to the creative thinking skill of the students.
$H_1$: There is a significant effect of learning instruments based on PjBL model to the creative thinking skill of the students.
2.3. Task
In this research, the creative thinking skills of the students were measured by test instrument based on the indicators in Table 1. The topic in the instrument was rainbow anti-magic coloring [14].

For the example is path graph. Path graph is simple graph, this graph is denoted by $P_n$, and has set of vertices and edges, respectively, $V = n$ and $E = n - 1$. Figure 2 illustrates the path graph.

![Flowchart of the mixed method model](image)

**Figure 1.** Research procedure of the mixed method model.
According to [4,14], the rainbow anti-magic connection number of path graph is \( r_{ac}(P_n) = n - 1 \). Figure 3 represents the rainbow anti-magic coloring on windmill graph with \( n = 3 \). The vertex labelling function \( f : V(P_n) \to \{1, 2, ..., n\} \) is defined as follows \( f(x_i) = i \) and from that function the edge weight function as follows \( w(x_i x_{i+1}) = 2i + 1; \ 1 \leq i \leq n - 1 \).

3. Results
In this section, we divided our results into three sub-sections: instrument validity, main results, and phase portrait.

3.1. Instruments Validity
Before showing the main results of this research, we have done a test for the reliability and validity of the instrument we made. We was involving three validators for the test, and the results are described as follows. The instruments that need to be tested for the reliability and validity, are pre-test and post-test assessments. After the test, we analyse the results of validity using Pearson Correlation as can be seen in Table 3 and analyse the results of reliability as can be seen in Table 4.

| Item | Pearson Correlation | Item_1 | Item_2 | Item_3 | Item_4 | Item_5 | Total |
|------|---------------------|--------|--------|--------|--------|--------|-------|
| Item_1 | Pearson Correlation | 1      | .169   | .228   | .460*  | .215   | .573** |
|       | Sig. (2-tailed)     |        | .409   | .262   | .018   | .292   | .002  |
|       | N                   | 26     | 26     | 26     | 26     | 26     | 26    |
| Item_2 | Pearson Correlation | .169   | 1      | .043   | .223   | -.026  | .415* |
|       | Sig. (2-tailed)     | .409   | 1      | .833   | .273   | .900   | .035  |
|       | N                   | 26     | 26     | 26     | 26     | 26     | 26    |
| Item_3 | Pearson Correlation | .228   | .043   | 1      | .479*  | .388   | .684** |
|       | Sig. (2-tailed)     | .262   | .833   | .013   | .050   | .000   |       |
|       | N                   | 26     | 26     | 26     | 26     | 26     | 26    |
| Item_4 | Pearson Correlation | .460*  | .223   | .479*  | 1      | .595** | .866** |
|       | Sig. (2-tailed)     | .018   | .273   | .013   | .001   | .000   |       |
|       | N                   | 26     | 26     | 26     | 26     | 26     | 26    |
| Item_5 | Pearson Correlation | .215   | -.026  | .388   | .595** | 1      | .698** |
|       | Sig. (2-tailed)     | .292   | .900   | .050   | .001   | .000   |       |
|       | N                   | 26     | 26     | 26     | 26     | 26     | 26    |
| Total | Pearson Correlation | .573** | .415*  | .684** | .866** | .698** | 1     |
|       | Sig. (2-tailed)     | .002   | .035   | .000   | .000   | .000   |       |
|       | N                   | 26     | 26     | 26     | 26     | 26     | 26    |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).
Based on the instrument validity results, it is known that the values of \( r_{count} \) are 0.573 (number 1), 0.415 (number 2), 0.684 (number 3), 0.866 (number 4), and 0.698 (number 5). All items resulted \( r_{count} > r_{table} \) with \( N = 26 \). Therefore, all items is valid. Then, based on the instrument reliability results, it is known that the value of reliability was 0.644 and \( r_{table} \) from the significance level of 5% with \( df = N - 1 = 25 \), \( r_{table} = 0.396 \). Therefore, \( r_{count} > r_{table} \), so this means that the instrument is reliable.

### 3.2. Main Results

The first result of this research is the level of the creative thinking skill before treatment by PjBL model. This result is obtained from the pre-test given to control class and experimental class. Each class involved in this research consists of 26 students. The result of each class can be seen in Figure 4 and Figure 5.

| Table 4. The test result of the realibility question. |
|-----------------------------------------------------|
| Reliability Statistics                              |
| Cronbach’s Alpha                                    | N of items |
| .664                                                | 4          |

![Figure 4. The distribution of pre-test of students’ creative thinking skill in the control class.](image)

![Figure 5. The distribution of pre-test of students’ creative thinking skill in the experimental class.](image)
As we can see in Figure 4 and Figure 5, it is known that most of the students are in uncreative and quite creative levels. The sum percentage of uncreative and quite creative levels is above 60% in both classes. In average, the creative thinking level of experimental class is lower that the control class.

The pre-test data results were analysed by using quantitative statistics of variance to find the differences between both classes in the initial creative thinking skill before the implementation of treatment. For the analysis process, we used R-shiny [15] to test the normality and homogeneous of the data distribution. The result of the test is shown in Figure 6 and Figure 7. According to it, the significant value obtained was $0.09724 \geq 0.05$. It revealed that the data of both classes were in Normal distribution.

![Figure 6](image1.png) The result of normality test of pre-test data by R-shiny.

![Figure 7](image2.png) The result of homogeneous test of pre-test data by R-shiny.

Based on the pre-test implementation data in both classes, it showed that the data variance was normally distributed and homogeneous. And then, we performed the independent t-test to the data (See Figure 8). According to the results, Sig value (2-tailed) was based on mean $= 0.711 > 0.05$. Therefore, $H_0$ was accepted since there were no differences in the mean scores of pre-test in the control and experimental classes.

![Figure 8](image3.png) The result of independent t-test of pre-test data by R-shiny.

After the pre-test, we continue the research by implementing the PjBL model to the control class and implementing the PjBL model with instrument developing to the experimental class. This is the main step of our research. We use the same topic for the learning which is rainbow anti-magic coloring. After the learning was done, we gave the students a post-test to find out the improvement levels of creative thinking skill. The results that we got from the post-test are given in Figure 9 and Figure 10.
As we can see in Figure 9 and Figure 10, the creative thinking levels of the students are significantly increasing. There are a lot of improvement in students’ creative thinking skill in solving rainbow anti-magic coloring. Besides, as we can also see, the creative thinking skill levels of students in experimental class increase more significant than the control class. Before the learning, control class is in a higher levels compared to experimental class. But, after the learning, experimental class is in the higher levels.

In this research, we also analyse the post-test data using quantitative statistics of variance with R-shiny. We apply this analysis to find out the effect of the PjBL model for learning. But, first we had to take a normality and a homogeneous test to the data. The results of the tests are shown in Figure 11 and Figure 12 as follows.
The result of normality test of post-test data by R-shiny.

Figure 1. The result of normality test of post-test data by R-shiny.

The result of homogeneous test of post-test data by R-shiny.

Figure 2. The result of homogeneous test of post-test data by R-shiny.

After the normality and homogeneous test, we implement the independent test, and the result is presented in Figure 15. Based on the result, there is a difference found in the mean scores of post-test in both classes since $H_0$ was rejected.

![Figure 13](image.png)

Figure 13. The result of independent t-test of post-test data by R-shiny.

The results of the independent t-test, as presented in the figure above, showed that variance was obtained with $p$-value (2-tailed) was 0.0053 < 0.05. Thus, it can be concluded that the results of the post-test gained from experimental and control classes had significant differences after being taught by realistic mathematical learning tools. The mean score of the control class is 22.88462, while the experimental class is 25.15385. It is known that the average of creative thinking skills of the students in the experimental class is higher than the control class, and it proves that learning by using the PjBL model affects the students’ creative thinking skills significantly.

![Figure 14](image.png)

Figure 14. The graphic of the students activities during project based learning (PjBL) implementation.
Observation of student activities during project-based learning in the experimental class is shown in Figure 14 with the results that 40% of students are very active, 28% of students are active, 20% of students are less active, and 12% of students are inactive. So it can be concluded that the learning carried out has positive results.

This research used the PjBL model to improve the creative thinking skills of students and it had been proved that this model affected the student's learning process. Before using PjBL, students had difficulty in finding ideas and class lectures. But, now after the PjBL, students were active to find the patterns of rainbow anti-magic coloring. Creativity, in mathematics, is often associated with submission and problem solving. [16] also assessed creative thinking skills in their research. This research was done to analyze creative thinking skills and the PjBL model implementation. The PjBL model provided an opportunity for the students to be more active in the process of learning. Besides, the implementation of PjBL improved the skills of creative thinking.

3.3. Phase Portrait
The phase portrait referred to an illustration of how the students thought while solving a problem. In this research, the phase portrait of each student was based on his creative thinking skill by solving the rainbow anti-magic coloring. Nine objects of control and experimental classes were selected to represent the level of creative thinking skill, but only four subjects were described as the illustrations. The interviews were done with the selected subjects to find out their thoughts while solving rainbow anti-magic coloring.

The analysis of subject 1 in Figure 15 while solving rainbow anti-magic coloring of the tadpole graph showed how the students labeled each vertex and edge weight (edge coloring) on the graph and determined the edge coloring as rainbow coloring. Then, the students gave notation on the graph and made the vertex and edge functions, and determined the cardinality of the vertices and edges in the graph.

![Graph](image)

**Figure 15.** The Result of Work done by Subject 1 of uncreative category.

Phase portrait was done to find out more about the students’ activities concerning the creative thinking process. The phase portrait was to draw a graph that resulted from their creative thinking process while being taught by project-based learning. The interview was conducted with Subject 1; the lines and directions were obtained from one step to another from the beginning of his work to the completion. After that, we drew a graphic representation of his process of creative thinking in a phase portrait. Figure 16 showed the process of creative thinking of subject 1 in solving the rainbow antimagic coloring problem. Concerning the steps, Subject 1 began from 1a, then went to 2a, returned to 1b, and stopped; subject 1 could not determine the number of rainbow anti-magic coloring; it led to the uncreative level he possessed.
Figure 16. The Phase portrait of subject 1 of uncreative category.

The analysis of subject 2, as drawn in Figure 17 of the rainbow anti-magic coloring of the tadpole graph, revealed how the students made notations on the graph, vertex and edge functions, and they were capable of determining the cardinality of the graph vertices and edges. Then the students labeled each vertex in the graph, calculated the edge weights (edge coloring), and determined the edge coloring as rainbow coloring and the number of rainbow anti-magic coloring. The students were also able to make the vertex labeling and edge weight functions.

Figure 17. The Result of Work done by Subject 2 of Quite creative Category

The interview was conducted with Subject 2; the lines and directions were obtained from one step to another from the beginning of his work to the completion. After that, we drew a graphic representation of his process of creative thinking in a phase portrait. Figure 18 showed the process of creative thinking of subject 2 in solving the rainbow anti-magic coloring problem. Subject 2 began from 2a, then returned to 1a, went to 1b, went to 1c, jumped to 2b, and stopped; subject 2 was not able to provide proof on his result, it means that he was categorized into quite creative.
The analysis of subject 3, as drawn in Figure 19 of the rainbow anti-magic coloring of the tadpole graph, revealed how the students made notations on the graph, and also vertex and edge functions. They were able to determine the cardinality of vertices and edges of the graph. Then the students labeled each vertex in the graph, calculated the edge weights (edge coloring) and made vertex labeling and edge weight functions as well as determined the edge coloring as rainbow coloring and the number of rainbow anti-magic coloring; he was also able to give proof in is expanded result.

The interview was conducted on subject 3. Based on the steps taken from the beginning of the work until the finish, a line and direction were generated from one step to the next. After that, we drew a graphic representation of their process of creative thinking in a phase portrait. Figure 20 show the process of creative thinking of subject 3’s skills in solving the rainbow anti-magic coloring problem. Subject 3 started to step from 2a, returned to 1a, went to 1b, jumped to 2b, returned to 1c, jumped to...
2c, and stopped. Subject 3 did not find a result on the new graph; this means that Subject 3 was in the creative category.

![Figure 20. Phase portrait of subject 3 at the creative category.](image)

The analysis of subject 4 in Figure 21 shows that the rainbow anti-magic coloring of the tadpole graph shows how the students made notations on the graph and made vertex and edge functions, and determined the cardinality of the vertices and edges of the graph. Then the students provided labeling at each vertex on the graph, calculated the edge weights (edge coloring), and determined the edge coloring as rainbow coloring and the number of rainbow anti-magic coloring; they also made vertex labeling functions and edge weights and proved the results of their findings to be expanded. Students made coloring on a new graph and were able to determine the cardinality, RAC, notation, and function formulas up to the-n on the new graph, and they were able to prove the formula on the new graph they found.

![Figure 21. The work of subject 4 at a very creative category.](image)

The interview was done on subject 4. Based on students’ steps from the beginning of the work until the finish, a line and direction were generated from one step to the next. After that, we drew a graphic
representation of their process of creative thinking in a phase portrait. Figure 22 showed the process of creative thinking of subject 4’s skills in solving the rainbow anti-magic coloring problem. Subject 4 started to step from 2a, returned to 1a, went to 1b, went to 1b, went to 1c, jumped to 2b, went to 2c, went to 3a, went to 3b, went to 3c, and stopped. Subject 4 found a result in a new graph, which means Subject 4 was in the very creative category.

Interview Subject 4:
Researcher : Do you understand about Rainbow Anti-magic Coloring?
Student : Yes, I do understand about Rainbow Anti-magic Coloring.
Researcher : Could you continue the Rainbow Anti-magic Coloring?
Student : Of course, I could continue it.
Researcher : Could you find the cardinality and the function for the n-th Rainbow Anti-magic Coloring?
Student : Yes, I could find the cardinality and the function.
Researcher : Are you able to give a new Rainbow Anti-magic Coloring?
Student : Yes, I am. I can give a new Rainbow Anti-magic Coloring.
Researcher : Could you determine the number of Rainbow Anti-magic Coloring?
Student : Sure, I could do it.
Researcher : Are you able to give the notation and function?
Student : Definitely.
Researcher : Would you able to prove the n-th function?
Student : Of course. I can prove it.
Researcher : Do you know how to make a new Coloring?
Student : I guess so.
Researcher : Could you determine the cardinality, RAC, notation, and the n-th function for your new coloring?
Student : Definitely. It’s not a problem.
Researcher : Are you able to prove your new n-th function?
Student : Sure, I’m able to prove it.

![Figure 22. Phase portrait of subject 4 at the very creative category.](image-url)
4. Discussion
This research was done to analyze the creative thinking skills in the implementation of PjBL. Creative thinking skills fulfill several indicators; they are fluent thinking, flexible thinking, and original thinking. The subjects used were 26 students in the control class and 26 students in the experimental class. Project-based learning was conducted in the experimental class. In the experimental class, it was found that there was an effect of PjBL on creative thinking skills. The results of the independent sample t-test on the pre-test questions of the control and the experimental class obtained $p$ - value of 0.711 and 0.711 > 0.05 in the condition if $p$ - value > 0.05, then there was no significant difference between the learning outcomes of the control class and the experimental class. Whereas in the posttest results, the independent sample t-test conducted in the experimental control class obtained $p$ - value of 0.0053. This proves that the two classes represent differences in terms of students’ learning outcomes after the implementation PjBL. This research used a PjBL model to improve students' creative thinking skills and it had been proved that the model affected the student's learning process. Before using PjBL, students had difficulty in finding ideas and class lectures. After conducted PjBL, students they were active in finding the patterns of rainbow anti-magic coloring. In mathematics, creativity is often associated with problem solving and submission. [12] Also assessed creative thinking skills in their research. This research was done to analyze creative thinking skills and the application of PjBL. The PjBL model provided opportunities for students to be more active in the learning process; beside that, the implementation of project based learning (PjBL) improved creative thinking skills. The results of this research indicated that 9 students were at a very creative level, 10 students were at a creative level, 5 students were at quite creative level, and 2 students were at uncreative level.

5. Conclusion
Based on the results, this research concluded that the implementation of project based learning (PjBL) had a significant effect on creative thinking skills of the students in the experimental class. Students in the experimental class had higher levels of creative thinking skills than the control class. The results show that there were improvements on students’ learning outcomes and skills of creative thinking that depicted from the post-test. The phase portrait of students is a picture the flow that explains steps of students’ creative thinking in completing the Rainbow Antimagic Coloring. There was a difference in the flow of thoughts in the both class, control and experimental. The control class had a relatively low flow, while the experimental class had a relatively high flow of thoughts. The study can be developed further researcher in the other topic or the other mathematics problem.

Acknowledgement
We thank a lot to the post-graduate department of Mathematics Education, Faculty of Teacher Training and Education, University of Jember, CEREBEL and CGANT research groups, as well as the reviewers who provided suggestions on this paper.

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