The profile of students’ creative thinking skills in solving local antimagic vertex coloring problem in research-based learning

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Abstract. This research aimed to know the profile of students’ creative thinking skills in solving the local antimagic vertex coloring in the implementation of Research Based Learning (RBL). This research used a mixed method, which was a combination of qualitative and quantitative methods. The research subjects were fifth semester students of mathematics education at University of Jember. Quantitative method was applied to analyze students' creative thinking skills, while qualitative method was done to see improvement in student learning outcomes. The results showed that students' creative thinking skills which were given treatment by RBL implementation increased from 26% of very well category to 43% of very well category. Based on the post-test value, the experimental class was superior to the control class. The results of the independent sample T-Test showed a significance value of 0.000 (p≤0.005) which indicated that there was a difference between the value of the experimental class and the control class.

1. Introduction

Facing future challenges in this era of globalization requires individuals to have various skills, one of which is creative thinking skills. As stated by Türkmen [14] that one of the important thinking skills to be developed in the field of education is creative thinking skills. In Law Number 20 of 2003 it was stated that national education has a function to develop the potential of students to be creative human beings. Creativity is a skill that must be fostered in all disciplines and in all intellectual and social fields [15]. Ersoy and Baser [6] revealed that the most important educational function is to train someone to be confident, curious, creative, innovative and also able to understand differences. Therefore, schools and higher education institutions as formal education institutions should carry out learning that can develop students’ creative thinking skills.

Developing creative thinking skills in learning can be implemented, one of which is by applying Research Based Learning (RBL). RBL can explore students’ creative thinking skills because one of the characteristics of RBL is creative, as expressed by Wardoyo [16]. RBL is learning that is based on a research approach as a step in implementing the process [16]. Sota said that research Based Learning (RBL) is a multi-aspect concept that refers to teaching and learning strategies that connect research and teaching [10].

In the Mathematics Education Program of Faculty of Education, University of Jember, students often conduct research on graphs. The results of the study were partly developed and used as final assignment material (thesis). Research about labeling graphs is often conducted. However, a labeling
which is still relatively new is Local Antimagic Vertex Coloring introduced by Arumugam et al. [2].
The purpose of this study was to find out the creative thinking skills of students to solve the Local
Antimagic Vertex Coloring problem in Research Based Learning.

Creative thinking can be defined as a whole set of cognitive activities which are used by
individuals according to objects, certain problems and conditions, or types of business against certain
events and problems based on individual capacity [3]. Silver [9] provided three components of
creative thinking, namely fluency, flexibility, and novelty. The three components review different
things and stand independently. Thus, it allows individuals to meet three components at once, or just
two components, or just one component.

| Component | Problem Solving |
|-----------|-----------------|
| Fluency   | Students are able to solve problems with various solution interpretation and answer |
| Flexibility | Students finish (or state or justify) in one way, then with another way. Students discuss various solving method. |
| Novelty   | Students check how solving method or answers (statement or justification), then make another different method. |

Table 1. Components of creative thinking skills in problem solving according silver [9].

Based on the above explanation, the researcher determined the indicators of creative thinking skills
in this research as follows.

Table 2. Indicators of creative thinking.

| Components | Indicators |
|------------|------------|
| Fluency    | a. Students are able to label Local Antimagic Vertex Coloring in graph correctly 
b. Students are able to determine chromatic number in Local Antimagic Vertex Coloring which has been made. |
| Flexibility | a. Students are able to compose notation in the graph and determine the cardinality 
b. Students are able to find coloring function based on the coloring and notation of dots given in the graph |
| Novelty    | a. Students are able to create new graph which has not been studied in the concept of Local Antimagic Vertex Coloring 
b. Students are able to make original statements based on their own thinking ability. |

Dafik [5] stated that RBL is a learning method that uses contextual learning, authentic learning,
problem solving, cooperative learning - hands on & minds on learning, and inquiry discovery
approach. Dafik [5] developed the stages of RBL implementation in lectures as follows:
a. Developing study groups or research groups consisting of at least three lecturers at the study program, department, faculty, or cross-faculty level.
b. Mapping a number of courses which are relevant to this research group, then developing syllabus,
   Course Outline, RTM, LKM, and Lecture Contracts together to apply RBL in learning.
c. Applying team teaching, contextual teaching, and cooperative learning through the following stages in classes: (1) provide basic information on the material being studied, (2) show the results of lecturer’s research in study groups or research groups relating to the material being discussed, (3) dividing students into discussion groups, (4) giving assignments to students in the form of discussions in groups about (a) the main content of the study, (b) the research process, (c) the method of analysis, (d) the formulation of conclusions, and (e) the values that emerge from the results of the research, (4) with the guidance of lecturer, the students conduct inter-group discussions, (5) together with the lecturer, students make conclusions. In this stage, students should be more involved in learning (student-centered learning). Lecturers act more as facilitators. If there are problems during the discussion which require literature, the lecturer can show it through online media (internet) so that the problems faced by students can be answered.

d. Each group developing reports, presentation slides and articles for possible publications on a local scale.

e. On a continuous basis, the lecturer bringing the results of PBR in this lecture in the study group, or the research group to be followed up more deeply by students who are taking undergraduate or master thesis.

Based on the flow chart, the RBL steps in this study were, (1) students gather information about the problem and finding the literature, (2) students were encouraged to identify problems to develop problem solving strategies based on experimental experience and literature studies, (3) students were encouraged to identify labeling Local Antimagic Vertex Coloring on the graph and started to make generalization based on each graph, (4) students complete the entire Local Antimagic Vertex Coloring
process to obtain chromatic numbers, and (5) students wrote RBL reports led by members of the research group.

**Definition 1.** $G = (V,E)$ is a graph connected with $|V| = n$ and $|E| = m$. The bijective function $f: E \to \{1,2,\ldots,m\}$ is called local antimagic labeling if for each $uv \in E$ is obtained $w(u) \neq w(v)$ where $w(u) = \sum_{e \in E(u)} f(e)$. A G graph is local antimagic if G has local antimagic labeling. Local antimagic chromatic number $\chi_{la}(G)$ is defined as the minimum number of colors used in G graph coloring due to local antimagic labeling.

From this definition, it can be understood that in labeling local antimagic vertex coloring (LAVC), a graph is labeled on its side so that the weight of the point (the number of all side labels connected with a point) is different for the two related points. Examples of LAVC labeling can be seen in Figure 2. From the picture it can be seen that each related point has different weights. Like the weight of $x_1$ is different from $x_2$, $x_2$ is different from $x_3$, and so on.

![Diagram of LAVC labeling](image)

**Figure 2. Examples of LAVC labeling in Cycle graph**

### 2. Research Method

This study used a mixed method. The mixed method is a research approach in which the researcher collects and analyzes both quantitative data and qualitative data in the same study [8]. Then to support the objectivity of research, triangulation models were used. The quantitative research used in this study was a quasi-experimental design (quasi-experimental design). The qualitative research was carried out by analyzing the results of the pre-test and post-test, and interviewing several experimental class students.

To find out the effect of RBL implementation, the design used was the quasi-experimental design of the non-equivalent control group with the pre-test and post-test. Before the study, the homogeneity test was carried out to determine the homogeneity of the two classes. If both classes were homogeneous, then the treatment was carried out in both classes, one experimental class ($x_1$) was taught using RBL and one control class ($x_2$) was taught using conventional learning models. After being given treatment, post-tests were carried out in both classes. The quasi-experimental design in this study is presented in Table 3.

| Group | Pre-test | Treatment               | Post-test |
|-------|----------|-------------------------|-----------|
| $x_1$ | $O_1$    | Research Based Learning | $O_2$     |
| $x_2$ | $O_1$    | Conventional Learning Model | $O_2$     |

To know the profile of students’ creative thinking skills in solving LAVC problem, interview was done with several students from experimental class ($x_1$) which had creative answers. Figure 3 shows triangulation where qualitative data were triangulated to determine the effect of RBL implementation in creative thinking skills of the students.
2.1. Population
Population of the study was the fifth semester students of the Mathematics Education Program, University of Jember, in the odd semester of the 2017/2018 academic year. The sampling technique used was cluster random sampling which was done by selecting two classes randomly. One class was used as an experimental class with 36 students given RBL and the other class as a control class with 36 students given conventional learning model. To support the objectivity of quantitative data, interviews were conducted with several students from the experimental class based on answers that reflected creative thinking skills.

2.2. Instrument
The instruments developed in this study were test, observation, and interview. Test of creative thinking skills included pre-test and post-test. Pre-test and post-test were used to determine the profile of students’ thinking skills in solving LAVC problems. In the experimental class, students were given RBL learning method which was supplemented by student worksheet (MFI), while the control class was taught by conventional learning where the teacher became the learning center.

2.3. Task
To measure students’ creative thinking skills, researchers made a test instrument that could measure indicators. The test instrument used was in the form of an students’ worksheet which started with a discussion of LAVC labeling on the Cycle graph.
By considering the connected points, we started to label the graph’s sides. In the cycle graph, the minimum color used was three. The objective of this test was to ask the students to find the label of the graph that had been never labeled by LAVC.

3. Research Result
Prior to show our results, we need to test a validity of our instrument. The following table shows the validity result.

| No. | Observed aspects                                                        | Assessment | Validator 1 | Validator 2 | $I_t$ | $V_a$ |
|-----|------------------------------------------------------------------------|------------|-------------|-------------|-------|-------|
| 1.  | Content validity                                                       |            |             |             |       |       |
|     | a. Test 1 can assess fluency aspect                                    |            | 5           | 4           | 4,5   |       |
|     | b. Test 2 can assess flexibility aspect                                |            | 4           | 5           | 4,5   |       |
|     | c. Test 1 and Test 2 can assess novelty aspect                         |            | 5           | 5           | 5     |       |
| 2.  | The accuracy of the question in measuring indicators of creative thinking skills |            | 5           | 5           | 5     | 4,5   |
| 3.  | The clarity of instruction                                             |            | 4           | 4           |       | 4     |
| 4.  | The suitability of language use                                        |            | 4           | 4           |       | 4     |
| 5.  | The suitability of time allocation                                     |            | 5           | 4           |       | 4,5   |

Based on Table 4, it could be seen that the average value of the two validators $V_a$ was 4.5. Based on the validity criteria stated by Hobri [7] instruments with a value of $V_a = 4.5$ is classified as valid. The pre-test results conducted in both classes showed creative thinking skills in the control class was 24% students were very good, 33% were good, and 43% were in poor category. While, the result in the experimental class showed 26% students were very good, 31% were good, and 43% were poor. The results of both classes can be seen in the following figures (Figure 5 and Figure 6).
To see the effect of RBL implementation, a free sample of T-test was conducted on the pre-test and post-test score of the control class and the experimental class. Previously, a homogeneity test of the score of the pre-test between the control class and the experimental class was conducted. The homogeneity test result is shown in Table 5.

**Table 5. Homogeneity of pre-test result between experimental class (x₁) and control class (x₂)**

| Pre-Test | Test of Homogeneity of Variances |
|----------|---------------------------------|
| Levene Statistic | df1 | df2 | Sig. |
| 1.040     | 1   | 70  | .311 |

**Figure 5.** Distribution of Creative Thinking Skills in Control Class

**Figure 6.** Distribution of Creative Thinking Skills in Experimental Class
The results of the homogeneity test using the statistical Levene method showed a significance value (0.311). This value was higher than the significant level (0.05). Therefore, it could be concluded that the initial ability of the experimental class ($x_1$) and the control class ($x_2$) were homogeneous. Because of the initial ability of two homogeneous classes, research could be carried out to determine the effect of RBL implementation.

**Table 6.** Results of the pre-test and the average score of the control class and the experimental class

| Group Statistics | Control | N | Mean | Std. Deviation | Std. Error Mean |
|------------------|---------|---|------|----------------|-----------------|
| Pre-Test         | 36      | 59.75 | 10.766 | 1.794 |
| Experiment       | 36      | 60.39 | 9.613  | 1.602 |

Based on table 6, the average score in control class was 59.75 (SD=10.766), while in experimental class was 60.39 (SD=9.613).

**Table 7.** The comparison of pre-test score of control and experimental class by using *independent sample t-test*

| Independent Samples Test | Levene’s Test for Equality of Variances | t-test for Equality of Means |
|--------------------------|----------------------------------------|------------------------------|
| F                        | Sig. (.311)                            | t (6.266) df (70)            |
| Pre-test                 |                                        | Mean Difference (2-tailed)   |
| Equal variances assumed  | 1,040                                  | -.369                       |
|                          |                                        | Std. Error Difference       |
|                          |                                        | 2,406                       |
|                          |                                        | 95% Confidence Interval of the Difference |
|                          |                                        | Lower (5.437) Upper (4.159)  |
| Equal variances not assumed | -.266                                | 69.121                      |
|                          |                                        | Mean Difference (2-tailed)   |
|                          |                                        | -.369                       |
|                          |                                        | Std. Error Difference       |
|                          |                                        | 2,406                       |
|                          |                                        | 95% Confidence Interval of the Difference |
|                          |                                        | Lower (5.438) Upper (4.160)  |

Table 7 shows the results of the T-test between the control group and the experimental group on the pre-test which showed that t-count value was 0.266 with a significance value of 0.791, while the negative sign in the t-count value showed an increase in the value from the pre-test to post-test. Significance value of 0.791 was greater than 0.05 which indicated that there was no difference in the score of the control class and the experimental class in the pre-test.

**Table 8.** Result of normality test from both classes from post-test score

| One-Sample Kolmogorov-Smirnov Test | Control | Experiment |
|-----------------------------------|---------|------------|
| N                                 | 36      | 36         |
| Normal Parameters                 | Mean    | 69.56      |
|                                   | Std. Deviation | 10.429     | 11.197  |
| Most Extreme Differences          | Absolute| .109       |
|                                   | Positive | .096       |
|                                   | Negative | -.109      | -.095   |
Based on Table 8, the results of the Kolmogorov-Smirnov test normality in the control class showed a significance value of 0.782 and 0.878 for the experimental class. The significance value of the two classes were higher than \( \alpha \) (0.05), so that it could be concluded that the data was normally distributed.

Table 9. Result of post-test and average score between control class and experimental class

| Group Statistics |
|------------------|
| Class            | N   | Mean | Std. Deviation | Std. Error Mean |
| Post-test Control| 36  | 69.56| 10.429         | 1.738           |
| Experiment       | 36  | 79.64| 11.197         | 1.866           |

Based on Table 9, it showed the post-test results of the control class was 69.56 (SD = 10.429), while the experimental class was 79.64 (SD = 11.197).

Table 10. Comparison of the post-test score from control class and the experimental class using independent sample t-test

| Independent Samples Test |
|--------------------------|
| Levene’s Test for Equality of Variances | t-test for Equality of Means |
| F   | Sig. | t    | df  | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference |
| Lower | Upper |
|------|------|-----|-----|------------------|-----------------|----------------------|----------------------------------------|
| Post-test Equal variances assumed | .005 | .944| -3.954| .000             | -10.083          | 2.550                | -15.170 -4.997                       |
| Equal variances not assumed     |      |     |      |                  |                 |                      |                                         |

Based on Table 10, the t-test between the control class and the experimental class on the post-test showed a t-count score of 3.954 with a significance value of 0.000, while the negative sign on the t-count value showed an increase in the score from the pre-test to post-test. Significance value of 0.000 was smaller than \( \alpha \) 0.05 which indicated that there were differences in the value of the post-test between the control class and the experimental class after the implementation of the RBL.

From the results described above, it could be concluded that the experimental class \( (x_1) \) was affected by RBL. Based on the results of the post-test, it was found that the experimental class \( (x_1) \) was superior to the control class \( (x_2) \). The results showed that thinking skills in the control class were 31% of students were very good, 36% were good, and 33% were poor. While in the experimental
class, 43% of students were very good, 33% were good, and 24% were poor. The results of both classes can be seen in the following figures (Figure 7 and Figure 8).

![Pie chart of Creative Thinking Skills in Control Class]

**Figure 7.** Distribution of Creative Thinking Skills in Control Class

| Percentage of Creative Thinking Skills in Control Class |
|--------------------------------------------------------|
| **Fluency** | **Flexibility** | **Novelty** |
| Excellent   | 12              | 12          | 10          |
| Good        | 14              | 12          | 12          |
| Fair        | 10              | 12          | 14          |

![Bar chart of Creative Thinking Skills in Experimental Class]

**Figure 8.** Distribution of Creative Thinking Skills in Experimental Class

| Percentage Creative Thinking Skills in Experimental Class |
|----------------------------------------------------------|
| **Fluency** | **Flexibility** | **Novelty** |
| Excellent   | 18              | 14          | 14          |
| Good        | 12              | 12          | 12          |
| Fair        | 6               | 10          | 10          |
Figure 9. Distribution of observation result from all subjects in experimental class

Figure 9 showed student’s involvement during the implementation of RBL. Based on Figure 9, it could be seen that 45% of students were very actively involved in learning, 32% were active, 12% were hesitant, 8% were passive, and 3% were very passive. Thus, it could be concluded that RBL worked well in the learning process to solve LAVC problems.

Following figures shows students’ works.

For Amal graph \((C_4, v, n)\) with \(n \geq 2\),
\[
\chi_{la}(\text{Amal}(C_4, v, n)) = 3.
\]

\[
v = \{P\} \cup \{x_i, y_i, z_i; 1 \leq i \leq n\}\n|v| = 3n + 1
\]
\[
E = \{Px_i, Py_i, x_i, y_i, z_i; 1 \leq i \leq n\}\n|E| = 4n
\]

Figure 10. Example of student’s work

In Figure 10, students determined a graph to be identified and labeled with LAVC labeling. The student gave notation, then wrote the cardinality of the graph. The graph used by the student was the result of amalgamation point from \(C_4\), which was given the name Amal \((C_4, v, n)\). In Figure 11, after the student labeled the graph, the student determined the side function formula and the point weight function of the graph, and the result was the chromatic number of the graph was 3 \((\chi_{la} = 3)\).
To know about student responses regarding the implementation of RBL, interviews were conducted with students. The results of the interview were as follows.

Researcher: What did you do after reading the problem?
Student: looking for the literature about the problems, which was LAVC.

Researcher: Then what did you do?
Student: Choosing a graph to be labeled with LAVC.

Researcher: Do you understand about LAVC?
Student: Yes. A graph is given side label, so that the neighboring point weights can differ and the weight of the resulting point can be minimal.

Researcher: How many point weight or color found in the graph you labeled?
Student: I found three chromatic numbers.

Researcher: How could you be sure that it is the least?
Student: Because the graph that I labeled is the result of an amalgamation operation the point of the cycle, where the chromatic number of the cycle is 3, then the graph must be the chromatic number $\geq 3$. But because it can already be found 3, then it must be chromatic number 3.

Researcher: Besides labeling and determining chromatic numbers, what else did you do?
Student: I gave a notation to the graph, determine its cardinality, and formed its function formula.

Researcher: Have you worked on LAVC labeling before?
Student: Yes, but the graph labeled was just an ordinary graph, it was not expanded.

Researcher: How do you think about the learning process?
Student: I think learning is fun because with my group I have a partner for discussion. Besides that, we understand it better because we found the result by ourselves.
Figure 12. Portrait of Creative Thinking Phase of S1

Figure 13. Portrait of Creative Thinking Phase of S2

Figure 14. Portrait of creative thinking phase of S3

Figure 12, Figure 13, and Figure 14, show the portrait of creative thinking phase of three research subjects.

4. Discussion
This study was conducted to determine the profile of students' creative thinking skills in solving vertex coloring local antimagic problems by applying research based learning. From the results of the study, it was found that the application implementation of RBL proved to have an influence in improving students' creative thinking skills in the experimental class. Before the implementation of RBL, the percentage of students' creative thinking skills was very good for 26%, good for 31%, and poor for 43%. Whereas, after the RBL implementation, students' creative thinking skills increased to 43% for very good, 33% for good, and 24% for not good category.

Students in the experimental class showed higher skills than the control class. The results showed an increase in learning outcomes and creative thinking skills which was seen from the results of the post-test. The average value of the experimental class was higher than the control class because of the effect of RBL. In the experimental class, the average post-test score was 79.64, while the control class was 69.56. In the experimental class, 43% of students had good creative thinking skills, while in the control class were only 31% of students. Students in the experimental class were encouraged to
find and understand problems, and solve them themselves through discussion with their friends so that they could really understand the material. Therefore, RBL was very good for improving student learning outcomes and thinking skills.

The result of this study is in line with the research results by Yudha et al [17], Tohir et al [13], and Susiani et al [12] which showed that RBL has an influence in improving students' creative thinking skills. In addition, this research is also in line with the results of research from Anwar et al [1] and Surapuramath [11] which stated that there is indeed a positive relationship between creative thinking and student learning outcomes.

From the data based on the interview, it was found that students gave a positive response to the application of Research Based Learning. Students felt that learning was more fun and they could better understand the material being studied. In addition, the results of the observation showed that there were more active students than passive students, which proved that the implementation of RBL was attractive to students; thus triggering students to be active in learning process. This is in accordance with Dafik's statement [4] that one of the benefits of RBL is to encourage the role of learners to be more active in the learning process.

5. Conclusion
Based on the results of the study, it was found that the implementation of RBL had a positive influence in improving students' creative thinking skills in solving local antimagic vertex coloring problem. Students in the experimental class showed better creative thinking skills than the control class. The results showed an increase in learning outcomes and creative thinking skills which can be seen from the post-test scores. The experimental class showed better results because it was supported by the implementation of RBL. Therefore, RBL is a good learning method to improve students' creative thinking skills.

However, RBL does not give effect only on students’ creative thinking skills. The other thinking skills, such as critical thinking, may be affected as well. It’s good for the future researcher to conduct a study about the effect of implementing RBL to the other students’ thinking skills in solving local antimagic vertex coloring problem.

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