The analysis of the application of discovery learning in improving student’s combinatorial thinking skill to solve local super antimagic face coloring problem

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Abstract. This research aimed at discussing the analysis of the application of discovery learning in improving student’s combinatorial thinking skills to solve local super antimagic face coloring problem. The method used in this research was mixed method research which combined the quantitative and qualitative research methods. 42 students were chosen to be the control group, whereas 44 students were selected as the experimental group. In addition, this research was also intended to determine the portrait of the student’s thinking phase in solving the problem of local super antimagic face coloring which involved 3 students from experimental groups. The normality and homogeneity tests that were carried out on the results of pretest and posttest of the control and experimental groups showed that the data were normal and homogeneous as the sig value was > 0.005. Moreover, an independent sample t-test was performed on the results of the pretest and posttest. Independent sample t-test on the pretest of two groups brought up the result that sig value was 0.897. Since the sig value > 0.005, H₀ was accepted as there was no mean difference between the scores of pretest in control and experimental groups. Meanwhile, the result of the independent sample t-test on the posttest of two groups showed that sig = 0.000, which means that the sig value was < 0.005. It led to the rejection of H₀, so that there was no mean difference of the posttest scores in the control and experimental groups or it can be said that there was an effect on the implementation of discovery learning in improving student’s combinatorial thinking skills. While the students combinatorial thinking skills indicates that 43.18% is categorised as high level of combinatorial thinking, 50% is categorised as moderate level of combinatorial thinking, and 6.82% is categorised as low level of combinatorial thinking. Thus, it can be concluded that the application of discovery learning is able to improve student’s combinatorial thinking skill in solving local super antimagic face coloring problem.

1. Introduction
Until today, the learning method used in the learning process in higher education level is still using the traditional learning or known as conventional learning. The conventional learning used is lecture method, that is teacher-centered learning and the students only listen to it. This learning is considered to be less effective because the students as the learning participants will be passive, so that they don’t have skills needed nowadays. One of skills required today is combinatorial thinking skill. [5] claims that combinatorial thinking as a tool to solve a problem when he did the experiment with his students in doing geometry problems. He found that the students have to use combinatorial thinking skill they have. In his view, combinatorial thinking is the specific aspect of mathematical thinking. [6] develops the model of the students’ combinatorial thinking. In his opinion, this needs to be done to find out more about the students’ combinatorial thinking.

According to [5] there are five indicators of combinatorial thinking skill, in which each indicator has several different sub-indicators. The first indicator of combinatorial thinking ability is (1) identifying some
cases, the success of this indicator covers two sub-indicators that are (a) identifying the characteristic of a problem, and (b) implementing the characteristic into some cases, the second indicator is (2) recognizing the pattern of the case, the success of this indicator covers two sub-indicators that are (a) identifying the pattern of the problem solution, and (b) broadening the pattern of the obtained solution of the problem, the next is (3) implementing the pattern of mathematics symbol, the success of this indicator covers three sub-indicators that are (a) implementing the mathematics symbol, (b) calculating the cardinality, and (c) developing the algorithm, the fourth indicator is (4) proving mathematically, the success of this indicator covers five sub-indicators that are (a) doing the calculation of the argument, (b) testing the algorithm, (c) developing the bijection, (d) testing the bijection, and (e) implementing the inductive, deductive, and qualitative proves, then the indicator of the last combinatorial ability is (5) considering the another combinatorial problem with the sub-indicators (a) interpreting, (b) proposing the open problem, (c) knowing the new combinatorial problem, and (d) finding the potential application.

Discrete mathematics is one of mathematics branches that examines discrete objects (discontinuous). In the discrete mathematics, there are several topics discussed. One of them is graph theory that is an interesting material to be discussed because it relates to the problems found in several scientific disciplines, such as computer, physical, biological and social system sciences [4]. Besides that, graph is also used to ease various problems that are difficult to solve with ordinary calculation and consideration. Local super anti-magic face coloring is one of studies found in the graph theory that involves point and side labeling.

The following is the definition of local super anti-magic face coloring. Given $G(V,E)$ is a related graph that has $n$ vertex and $m$ edge. Mapping one by one (seeding) $f:V(G) \cup E(G) \rightarrow \{1, 2, \ldots, n+m\}$ called as local super anti-magic face coloring for every of two faces neighboring $A_1$ and $A_2$, $w(A_1) \neq w(A_2)$ in which $w(A) = \sum_{v \in V(A)} f(v) + \sum_{e \in E(A)} f(e)$. To understand more about local super anti-magic face coloring can be seen in the figure 1.

![Figure 1. One of examples of local super anti-magic face coloring on the planar graph](image)

Based on the indicator explanation concerning combinatorial thinking, it can be formulated the indicators used in this research. The indicator development according to [3] and adjusted with the material of local super anti-magic face coloring.

Combinatorial thinking skill will emerge if the learning model used is the student-centered learning. Discovery learning is one of learning models that is student-centered learning. [2] states that discovery learning is the learning in which the students organizing the material they learn with the final form. The basic of Bruner’s idea is the statement of Piaget that states that the students must be active in the learning activities in the classroom. In addition, [1] argues that discovery learning is a method that requires the students to draw a conclusion based on the activities and observations they have done independently.

There are several benefits in using discovery learning in the learning process, among of them are the students will be more active, the students will get accustomed to solve their problems by themselves, the students will have high social life because they are used to need friends to discuss and the students will remember the material in a longer time because in the learning process there are several processes done by them independently. In its implementation, there are 6 phases namely stimulation, problem statement, data collection, data processing, verification, and generalization to form what they know and understand in the final form.
Based on the previous explanation, this research was intended to find out the analysis result of discovery learning implementation to enrich the students’ combinatorial thinking skills in solving the problem of local super antimagic face coloring.

2. Methods

2.1. Research Scope

This research focused on the analysis of the ability of combinatorial thinking in solving the problem of local super antimagic face coloring. This research was intended to the students of Mathematic Education in the third semester in 2018/2019 academic year.

2.2. Sample

This research involved two groups namely the experimental and the control groups. The experimental group consisted of 44 students while the control one consisted of 42 students. All students were in Mathematics Undergraduate Program at Faculty of Teacher Training and Education at University of Jember. Both groups were administered a pretest before being given the treatment, in order to be able to see the initial abilities of both groups in combinatorial thinking skills. The experimental group was given the treatment through the use of discovery learning model while the control class used a conventional model (lecture).

2.3. Instrument and Procedure

The instruments used in this were test and interview. The tests were given twice, before treatment (pretest) and after treatment (posttest) to find out the ability of the beginning and the end of learning regarding the combinatorial thinking skills. Whereas, the interview was conducted to several students from the experimental group who were selected based on the level of combinatorial thinking skill.

This research referred to joint research (mix method). The design used was sequential explained the findings from quantitative data (e.g., after assessing pragmatic competence at group-level, following up on several participants to gain understanding about their characteristics) [10] also applied this model to their research. This type of quantitative research used quasi-experimental (quasi experimental design). The researcher used pretest-posttest control group design by using one type of treatment. The following was a research design table used in this research [9].

Table 1. Research Design

| Group | Pretest | Independent Variable (X) | Posttest |
|-------|---------|--------------------------|---------|
| KE    | $Y_1$   | $X$                      | $Y_2$   |
| KK    | $Y_1$   | $-$                       | $Y_2$   |

Notes:
- KE = Experimental group
- KK = Control Group
- $X$ = Treatment by using Discovery Learning Model
- $-$ = Treatment by using Conventional Model (Lecture)
- $Y_1$ = Pretest
- $Y_2$ = Posttest

2.4. Data Collection and Data Analysis

The data collection was carried out in October 2018. Quantitative data were obtained from the results of the pretest and posttest. Pre test was administered before the treatment. After giving the treatment, followed by posttest with the same questions. The results of the test were then analyzed by using the analysis of prerequisite test, which were homogeneity and normality tests through SPSS, then the independent sample t-test was performed.

Furthermore, the sources of qualitative data were obtained from the results of students’ works in which they were the results of the analyzed pretest, posttest, and interview. [13] also analyzed their qualitative data in their research. Next, each student was selected from 3 levels of combinatorial thinking skill, covering
high, medium, and low. Thus, the interviews were conducted with at least 3 students. In addition, the interviews were conducted with selected students to find out the portrait phase. In its implementation, this interview was conducted based on the posttest that the student had done.

2.5. Students’ Task

In improving the ability of students’ combinatorial thinking, the MFI used as a learning medium was developed based on the indicators of combinatorial thinking skill. In addition, the test was made based on combinatorial thinking indicators and also adapted from the material of local super antimagic face coloring. In labelling the graphs based on local super antimagic face coloring, there were 2 stages that the students needed to do. The first stage was labeling the point and side, then the second was labeling the face by adding the point and side labels on the face to produce the graph of local super antimagic face. The first, second, and final results can be seen in Figure 2.

![Figure 2](image)

**Figure 2.** (a) First Stage: Labelling; (b) Second Stage: Counting Face; (c) Final Results

3. Research Findings

This research was done first by developing the instrument, which was a test. After the development of the test, the next step was to test the validity and reliability of 38 students. This test used SPSS 16.0 and produced the following data.

| Correlations | q1 | q2 | q3 | q4 | q5 | q6 | total |
|--------------|----|----|----|----|----|----|-------|
| q1 Pearson Correlation | 1 | .260 | .314 | .114 | .448** | .356* | .677** |
| Sig. (2-tailed) | .115 | .055 | .497 | .005 | .028 | .000 |
As drawn in table 2, it can be seen that the value of questions 1-6 were 0.877; 0.489; 0.627; 0.422; 0.638; 0.668. Since all questions > 0.3, the test could be said to be valid. Then, the next test was the reliability test whose results can be seen on Table 3 as follows:

### Table 3. Reliability Test

#### Reliability Statistics

| Cronbach's Alpha | N of Items |
|------------------|------------|
| .619             | 6          |

According to Table 3, it is known that the value of Cronbach's Alpha from the developed instrument was 0.619. Thus, it can be said that the developed instrument was reliable as it had the value of Cronbach's Alpha > 0.6. Since the developed instrument had been valid and reliable, it can be concluded that the developed instrument could be used in this research.

This research involved 2 groups, they were control group which consisted of 42 students and experimental group that was covering 43 students. The control group used expository learning (lecture) while the experimental group used discovery learning. Before the learning was done, both groups did the pretest first.
Besides carried out the 3 tests above, the researcher also analyzed the value of the pretest based on the combinatorial thinking skills. In the following table 4 are three levels of combinatorial thinking capabilities in this research.

| Table 4. Level of Combinatorial Thinking Skill |
|-----------------------------------------------|
| Value          | Classification     |
| \( x \leq 55.56 \)  | Low combinatorial thinking skill |
| 55.56 < \( x \leq 77.79 \)  | Medium combinatorial thinking skill |
| 77.79 < \( x \leq 100 \)  | High combinatorial thinking skill |

Then, in the following figure 3 is a chart of combinatorial thinking skills obtained from the control class pretest results.

![Figure 3. Combinatorial Thinking Skills from the Control Class Pre Test Results](image)

From the figure, it can be seen that it was only in the first indicator which is Identifying Some Cases that achieved medium combinatorial thinking skill with the number of students as many as 26 students. Whereas the other 4 indicators only achieved low combinatorial thinking skills. In the following figure 5 is the result of the percentage of combinatorial thinking skills as a whole in the results of the control class pretest. It can be seen that all students in the control class produced a pre-test value which indicated that 92.86% of students in the control class had low combinatorial thinking skills and 7.14% of students in the control class had medium combinatorial thinking skills.

Then, the results of the pretest in the experimental class also showed results that were not much different from the control class. Figure 4 below is a bar chart of combinatorial thinking skills from the results of the experimental class pretest.
Figure 4. Combinatorial Thinking Skills of the Experimental Class Pre Test Results

In tables 5, 6, and 7 the following were the results of homogeneity, normality, and independent sample tests of the results of the pre-test in both control and experimental groups.

Table 5. The Pretest of Homogeneity Test

Test of Homogeneity of Variances

| VALUE | Levene Statistic | df1 | df2 | Sig. |
|-------|------------------|-----|-----|------|
|       | .003             | 1   | 83  | .954 |

The homogeneity test from the results of the pretest showed the sig value as much as 0.954 which means that two groups were homogeneous since the significant value produced was > 0.05.

Table 6. The Pretest of Normality Test

Tests of Normality

| CLASS       | Kolmogorov-Smirnova | Shapiro-Wilk |
|-------------|----------------------|---------------|
| VALUE       | Statistic | df | Sig. | Statistic | df | Sig. |
| Control Class | .114      | 42 | .200 | .971 | 42 | .362 |
| Experiment Class | .101      | 44 | .200* | .974 | 44 | .420 |

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

The normality test produced the sig value as much as 0.362 in the control group and sig value as much as 0.464 in the experimental group. The results of the normality test means that both groups were normally
distributed as the sig value > 0.05. Since the produced data were homogeneous and normally distributed, these data could be brought up to the next test, which was the independent sample test.

Table 7. The Test of Independent Sample Test

| Equal variances assumed | Equal variances not assumed |
|-------------------------|----------------------------|
| Levene's Test for Equality of Variances | F | .002 |
| Equal variances assumed | Equal variances not assumed |
| t-test for Equality of Means | Sig. | .962 |
| Df | .129 | 1.29 |
| Sig. (2-tailed) | 84 | 83.808 |
| Mean Difference | .897 | .897 |
| Std. Error Difference | .180 | .180 |
| 95% Confidence Interval of the Difference | Lower | -2.585 |
| Upper | 2.944 | 2.945 |

The independent sample test showed that the sig value = 0.897. Since the sig value > 0.05, then Ho was accepted and Ha was rejected which means that there was no difference in the average between the control class pretest value and the experimental class pretest value.

After the pre-test, the two classes followed learning with local super antimagic face coloring material. The control class used expository learning namely lectures while the experimental class used discovery learning which consists of 6 phases namely stimulation, problem statements, data collection, data processing, verification, and generalization. Learning in the experimental class used learning media in the form of MFIs (Student Worksheets) that had been validated by the validator. In the learning process, students worked in groups to complete the given MFI. There were 2 meetings in learning with local super antimagic face coloring material in this research.

After the learning was complete, then the post test was carried out in both classes. The posttest results from the experimental class and the control class were analyzed based on the combinatorial thinking skills. Combinatorial thinking skills of students in the post test can be seen in the bar diagram in figure 5.

From the figure, it can be seen that for every indicators that had increased after conventional learning (lecture) wasn’t significant. In figure 10, the following is the result of the percentage of combinatorial thinking skill as a whole in the results of the control class pretest. It can be seen that there were 2.38% of students from the control class who had high combinatorial thinking skills, the rest were 54.76% of students had medium thinking combinatorial skills and 42.86% of students from the control class who had low combinatorial thinking skills.

Furthermore, the results of the posttest in the experimental class showed a significant increase. In figure 6 the following is a bar diagram figure of combinatorial thinking skills obtained from the experimental class post test results.
Figure 5. Combinatorial Thinking Skill from Control Class Post Test Results

Based on figure 6, it can be seen that there were no indicators that had low combinatorial thinking skills. Students in the experimental class had medium and high combinatorial thinking skills on each indicator contained in combinatorial thinking. This shows that there was a significant increase in combinatorial thinking.
thinking skills in the experimental class. There were 43.18% of students had high combinatorial thinking skills. While the remaining 50% students had medium thinking combinatorial skills and 6.82% of students had low combinatorial thinking skills.

The homogeneity test, normality test, and independent sample test from the post test results on the control and experiment classes can be seen in Table 8, 9, and 10 below.

**Table 8. Homogeneity Test of Post Test Homogeneity**

| Test of Homogeneity of Variances | value |
|----------------------------------|-------|
| Levene Statistic                | .985  |
| df1                              | 1     |
| df2                              | 84    |
| Sig.                             | .324  |

The homogeneity test from the results of the two Post Test classes showed that the sig value = 0.324. It can be said that the data from the test results of the two classes were homogeneous because the sig value > 0.05.

**Table 9. Normality test of Post Test**

| Tests of Normality |
|-------------------|
| Kolmogorov-Smirnov* | Shapiro-Wilk |
| class              | Statistic | df | Sig. | Statistic | df | Sig. |
| Control class      | .169     | 42 | .004 | .949      | 42 | .061 |
| Experiment class   | .099     | 44 | .200*| .976      | 44 | .480 |

*a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

The normality test performed resulted in the sig value = 0.061 in the control class and sig = 0.480 in the experimental class. The results of the normality test means that both classes were normally distributed because the sig value > 0.05. Since the data generated was homogeneous and normally distributed, this data could be tested to the next test, namely the independent sample test.

**Table 10. The Test of Independent Sample Test**

| Independent Samples Test |
|---------------------------|
| VALUE                     |
|                            | Equal variances assumed | Equal variances not assumed |
| Levene's Test for F        | .985                    |                            |
| Equality of Variances Sig. | .324                    |                            |
| t-test for Equality of Means T Df | -20.424 84 | -20.323 78.843 |
### Independent Samples Test

|              | Equal variances assumed | Equal variances not assumed |
|--------------|-------------------------|----------------------------|
| Sig. (2-tailed) | .000                    | .000                       |
| Mean Difference | -31.179                 | -31.179                    |
| Std. Error Difference | 1.527                  | 1.534                      |
| 95% Confidence Interval of the Difference |                      |                            |
| Lower         | -34.214                 | -34.232                    |
| Upper         | -28.143                 | -28.125                    |

The test of independent sample test resulted sig value = 0.000. Since the sig value <0.05, thus Ho was rejected and Ha was accepted which means that there was a difference in the mean between the control class post test scores and the experimental class pre test scores. This showed that there were differences in the values of the control class and the experimental class. The value of the experimental class was higher than the value of the control class, which means that the use of discovery learning had an effect in improving students’ skills.

The following is a bar diagram that presents the mean of value of the results of the pre test and post test in the control class and experiment. From the picture, it can be seen that the results of the pre test in the control and experimental classes have differences that are not much different, namely the mean of value in the control class is 34.45 and 34.27 for the experimental class. While the differences can be seen clearly in the average value of the post test results, namely 53.57 in the control class and 84.75 in the experimental class. This shows that the combinatorial thinking ability in the experimental class is better than the control class. Experimental classes use discovery learning models while the control class uses expository learning models so that it can be said that discovery learning learning models are more effective than expository learning models in improving students’ combinatorial thinking skills.

![Mean of Value Pre Test dan Post Test](image)

**Figure 7. Mean of Value Pre Test dan Post Test**

There are three enhancing abilities in combinatorial thinking abilities, namely low, medium, and high. The following are the results of the work and a portrait of the phases of each of these abilities. The results of the work are the post test results that have been done by students, while the phase portrait is the representation of students thinking plot in solving a problem. In this research, students’ phase portrait was based on the skill of combinatorial thinking in solving the study about local super antimagic face coloring based on discovery learning.
First, low combinatorial thinking capabilities. Students who have low combinatorial thinking skills can only do tests until the graph panes and give label for them. However, in labeling, students who are capable of low combinatorial thinking cannot yet produce minimal colors. The results of the work of low-ability students can be seen in Figure 8.

![Figure 8](image)

**Figure 8.** The students work of low combinatorial thinking skill

The portrait phase of low combinatorial thinking students is in Figure 9. Students' thinking flow only reaches indicator 2b.

![Figure 9](image)

**Figure 9.** The Phase Portrait of low combinatorial thinking skill

The second combinatorial thinking ability is medium thinking combinatorial ability. From the tests that have been done, it can be seen that students in this ability can label the given graph, exposing the graph which is then labeled as well, then giving the symbol on the vertex and edge of the graph and calculating the cardinality. The work of students is being seen in Figure 10.

![Figure 10](image)

**Figure 10.** The students work of medium combinatorial thinking skill

The portrait phase of medium combinatorial thinking students is in Figure 11. Students' thinking flow only reaches indicator 3b.
Figure 11. The Phase Portrait of medium combinatorial thinking skill

The third thinking combinatorial capability is high combinatorial thinking capabilities. In this ability, students are able to work on all the tests given so that all the indicators given are able to be done by students with high combinatorial thinking skills. The work of these capable students can be seen in Figure 12.

Figure 12. The students work of medium combinatorial thinking skill

Student who are capable of high combinatorial thinking can work on all the questions given so that in the phase portrait, all the indicators contained in combinatorial thinking can be done. The portrait phase of medium combinatorial thinking students is in Figure 13.

4. Discussion

The result of independent sample test on the pretest of the experimental and control classes that had been done obtained the value of sig=0.915. Because the value of sig > 0.05, H0 was accepted and Ha was rejected, it means that there was no different between the average of pre-test from the control class and the experimental class. Whereas, independent sample test done in the post-test of the experimental and control classes obtained the value of sig= 0.000. Because the value of sig < 0.05, H0 was rejected and Ha was accepted, it means that there was a different between the average of post-test score of the control and experimental classes. The score of the experimental class was higher than in the control class which means that the use of discovery learning had influence toward the ability of students’ combinatorial thinking.

According to [3], there are five indicators in combinatorial thinking. In each indicator, there are some different sub-indicator as much as 16 sub indicators in combinatorial thinking ability. Pre-test and Post-test that had been developed were based on the indicator of combinatorial thinking and it had been matched with the material of local super antimagic face coloring.
The result of pre-test from both classes revealed the similar combinatorial thinking ability of the students that, in both classes, was slow. After conducting pre-test, both classes were given a treatment. The control class used conventional learning model (lecturing), while the experimental class used discovery learning. After that, post-test was given to both classes. The results of post-test showed the improvement of students’ combinatorial thinking ability in the experimental and control classes. However, the improvement in the control class was not significant and it was only 2.38% students had moderate combinatorial thinking ability and 97.62% students still had low combinatorial thinking ability. Besides, the improvement in the experimental class was quite significant, it was 88.3% students had high combinatorial thinking ability and 11.63% students had moderate combinatorial thinking ability.

Based on the result of the interview, it was known that the students were more understand the learning material by using discovery learning model. This is in line with [7], [8], and [9] who states that discovery learning can help students to understand material. By implementing discovery learning, it could also improve the students’ combinatorial thinking ability; it was shown from the test done by the students. The students could done the test after finishing the given LKM because the test was made based on the indicators of students’ combinatorial thinking ability, so if the students could do the test, it means that the students’ combinatorial thinking improved.

5. Conclusion
This research revealed that there was an influence of the use of discovery learning in improving the students’ combinatorial thinking ability. This was known from the analysis of the quantitative and qualitative data. The analysis of the quantitative data that was independent sample t-test showed that there was an average different between the control and the experimental classes. The score of the experimental class was higher than one in the control class which means that the use of discovery learning had influence toward the students’ combinatorial thinking ability. The analysis of qualitative data showed the similar results of 88.3% students had high combinatorial thinking ability and 11.63% students had moderate combinatorial thinking ability in the experimental class. Moreover, the results of the interview also showed that the students were more understand the material by using discovery learning model, especially on the material of local super antimagic face coloring. Suggestions for future researchers to measure students’ combinatorial thinking skills using other learning models.
Acknowledgement
We would like to say thanks to mathematics postgraduate education of The Faculty of Teacher Training and Education, University of Jember, Indonesia. We would like to say thanks to the support from CEREBEL and the research group.

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