The analysis of generalization thinking Skills on solving local super $H$-decomposition antimagic total coloring regarding the application of research based learning

R P Dini $^{12}$, Dafik$^{12}$, Slamin $^{13}$
$^1$CEREBEL University of Jember, Indonesia
$^2$ Depart. of Mathematics Edu. University of Jember, Indonesia
$^3$ Depart. of Informatics. University of Jember, Indonesia
Email: rimbipuspita3@gmail.com

Abstract. In this research, we aim to analyze students generalization thinking skills on solving super local $h$-decomposition antimagic total coloring under the application of research based learning. This research used a mixed method, namely combining a quantitative and qualitative methods. The subject of the research consisted of two classes, namely 42 students of control class and 44 students of experiment class. The research instruments were pre-test, post-test, observation form, questionare form and interview form. Prior to research activities, we tested the homogeneity of the two classes by using a pretest result. The result shows sig score is 0.059 $> 0.05$, thus the differences of mean of two classes are not significant. It implies the two classes are homogeneous. Furthermore, we also tested the normality, and finally we have the postest data analysis. It shows that the independent sample test on the post-test data of control class and experimental class was obtained that the score of sig value 0.00 $< 0.05$, thus it is significant. While the students generalization thinking skills indicates that 43% is categorised as very high level of GTS, 41% is categorised as GTS, 16% is categorised as fair level of GTS and 0% is categorised as low level of GTS. The result indicated that there impact the application of research based learning to improve students generalization thinking skills on solving super local $h$-decomposition antimagic total coloring.

1. Introduction
Science and technology are increasingly developing along with the progress of the times and human needs. One of the sciences that must be developed is Mathematics, because Mathematics also presents problems related to technology. The more often a person is trained in mathematics learning, the better thinking skills. Lince classifies thinking into three main components, namely (1) thinking is cognitive activity that occurs in the mental or mind of a person, is not visible, but can be concluded based on observed behavior, (2) thinking is a process that involves a lot of manipulation knowledge in the cognitive system. Knowledge is stored in memory along with current information, so changing one's knowledge about the situation faced, and (3) thinking activities directed to produce solutions to problems[5].

Thinking skills that can be trained are including the ability to think logically, analytically, systematically, critically, creatively and think generalizations. Generalization thinking is a thinking skill that is used to educate students so that reasoning emerges. This skill can help students in solving mathematical problems in discrete mathematics. The stages of mathematical generalization according
to Mason consist of four stages, namely: (a) perceptions of generality which at this stage students just arrived at the stage of introducing a rule or pattern. At this stage students have also been able to perceive or identify patterns. Besides that the students knew that the problem presented could be solved using attitudes or patterns, (b) expression of generality which at this stage students are able to use the results of pattern identification to determine the next structure/data. At this stage students have also been able to describe a rule or pattern, (c) symbolic expression of generality which at this stage students have been able to produce a general rule and pattern and are able to formulate numerically or verbally general, and (d) manipulation of generality which at this stage students have been able to use the results of generalizations to solve problems, and students have been able to apply the rules of the pattern of problems[6]. Based on the stages of generalization above, in this research, researchers developed the ability to think generalization on super local H-decomposition antimagic total coloring material with the indicators to be used as follows: the first indicator of generalization thinking ability is (1) Perception of generality, the succes of this indicator covers two sub indicators that are (a) Students are able to recognize a decomposition graph; and (b) Students are able to symbolize graphs, the second indicator is (2) Expression of generality the succes of this indicator covers two sub indicators that are (a) Students have been able to produce cardinality from graphs, and (b) students are able to formulate the general results of cardinality calculation of a graph, , the next is (3) Symbolic expression of generality the the succes of this indicator covers two sub indicators that are (a) Students have been able to label vertex of graph, and (b) Students have been able to label edge of graph, the fourth indicator is (4) Manipulation of generality the the succes of this indicator covers two sub indicators that are (a) Students have been able to find weight of graph, and (b) students have been able to find the number of chromatic in a graph.

The affordability of thinking generalization of students must be conveyed to students with the help of learning. Learning used is to use Research Based Learning. Poonpan explains that: “Research based learning is a learning system that use authentic-learning (Learning by using real example), problem solving, cooperative learning, contextual (hand on and mind on) as well as inquiry approach (finding something) based on the philosophy of constructivism (students’ self-development which is continuous and sustainable)”[7]. In the level of higher education, the aim of Research based learning method is to help students to build strong intellectual ability and practical connection between the limitation of research and their own learning. Research based learning (RBL) is a concept that refers to teaching and learning strategies related to research and learning [8]. Research based learning can improve academic achievement, promotes learning strategy and building new knowledge[3]. This ability is essential in education especially on 21 century[4].

According to RBL is a learning method that use contextual learning, authentic learning, problem-solving, cooperative learning, hands on and minds on learning, and inquiry discovery approach[12]. The target of the implementation of RBL is encouraging the creation of higher level thinking skill in lecturers and students. The students are not only given the information and new knowledge but also should be taken into the higher level namely creating or communicating. The syntax of research based learning according to Arifin consists of three categorization of the main step that must be in the research based steps that are: (1) Exposure stage, collecting the information based on the inquiry and finding the literature in a particular topic (focused topic), (2) Experience stage, identifying and formulating the problem based on the literature study and experimental experience, (3) Capstone stage, delivering the plans or ideas in giving the solution of a problem or the method of measurement or computation[1].

Based on two syntaxes of RBL mentioned by Dafik and Arifin, I have combined it into: (1) collecting the information about the problem and finding its literature (2) the students are encouraged to identify and formulate the problem to develop the strategy in order to solve the problem based on the experimental experience and literature study (3) The analysis of the data by studying the pattern of total rainbow connection coloring to every different n.
Figure 1. The Stages Chart of The research based learning Implementation

Learning using research based learning is expected to increase the display of thinking generalizations of students. Learning will focus on discrete modeling with local material local super H-decomposition antimagic total coloring. This local learning of super H-decomposition antimagic total coloring is material from graph theory which will later become a parameter of student generalization thinking skills. Based on these explanations, the researchers wanted to analyze students' generalization thinking skills and apply research based learning to improve students' generalization thinking skills.

The purpose of this research was to investigate the effect of research-based learning compared to conventional learning on super local H-decomposition antimagic total coloring material, where local super H-decomposition antimagic total coloring was a problem. In presenting the visual of the graph, it can be expressed the objects with node, dot, circle, point or vertex, while the relationship between objects expressed by a line or edge.

Definition Let $G(V, E)$ be a connected graph of order $n$ and size $m$. A bijection $f:V(G) \cup E(G) \rightarrow \{1,2, ..., n + m\}$ is called a local super H-decomposition antimagic total coloring if there is bijective function $f:V(G) \rightarrow \{1,2, ..., n\}$ and bijective function $f^*:E(G) \rightarrow \{n + 1, n + 2, ..., n + m\}$ such that for any two adjacent subgraf $A_1$ and $A_2$, $\omega(A_1) \neq \omega(A_2)$, where $\omega(A) = \sum_{v \in V(A)} f(v) + \sum_{e \in E(A)} f(e)$.

Graph coloring is the cases of graph labeling. The labeling means giving colors on the points with certain boundaries. While, what is called as point coloring in which giving different color on the neighboring points so that there are no two neighboring points that have same colors. In the local super H-decomposition antimagic total coloring is giving colors on the points and sides, but for each neighboring H-decomposition must have no the same colors. The minimal number of the color that can be used for local super H-decomposition antimagic total coloring in a graph is called chromatic number. The first person who introduced local antimagic coloring is Arumugam et al [2]. The following are the examples of local super H-decomposition antimagic total coloring in the prism graph.
2. Research Methods
To analyze the results of the students’ learning outcomes and their generalization skills in the local super H-decomposition antimagic total coloring, the researchers used mixed-method. According to Sugiono, mixed-method is the research method that involves between qualitative and quantitative [11]. By mixing two methods, it can complete the weaknesses in the qualitative method and quantitative method. Quantitative method analyzes the students’ learning outcomes after the implementation of research based learning model. Then, in the qualitative research aims at analyzing the results of observation and interview of the students selected. The planning of this research was arranging two group of classes that were the control and experimental classes. The learning given to the control class was by using conventional learning while the experimental class was by using research based learning.

Table 1. Design of grouping the pre-test and post-test

| Class             | Pre-Test | Treatment   | Post-Test |
|-------------------|----------|-------------|-----------|
| Control (n=42)    | R1       | conventional | R2        |
| Experimental (n=44)| R1       | X           | R2        |

This research done with 86 students consisted of 42 students in the control class and 44 students in the experimental class. In the control class, the conventional learning was conducted and in the experimental class, research based learning model was used. The results of the research obtained from the test results and observation. The instruments in this research used test, observation and interview. This research was given to the students in the experimental class with the assessment that is accordance with the generalization thinking criteria.

The tasks used in this research were based on the generalization thinking criteria that has been developed. The following was the task based on the generalization thinking criteria that is the students are able to find out the minimum labeling or chromatic value on the graph. The task given to the students namely LKM which was adjusted with the learning based on the generalization thinking indicators. The task given also according with the the material of local super H-decomposition antimagic total coloring as follow:

\[
\begin{align*}
W_1 &= x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 = \cdots \\
W_2 &= x_1 + x_4 + x_5 + x_6 + x_7 = \cdots \\
W_3 &= x_1 + x_4 + x_5 + x_6 + x_7 = \cdots \\
W_4 &= x_1 + x_4 + x_5 + x_6 + x_7 = \cdots
\end{align*}
\]

Figure 3. One of the task for students

The initial research done was by using qualitative method done in the 86 students to find out the students’ generalization thinking level. Before looking at the results of the research conducted by us, we conducted reliability and validity test of the post-test instrument.
Then, we implemented the pre-test in the control and experimental classes. After carrying out the pre-test in both classes, then the learning process was done in the experimental class by using research based learning model and in the control class by using conventional learning, next the data obtained were going to be tested by using SPSS and analyzed.

3. Research Findings

The researcher conducted reliability and validity tests for the instruments before showing the results. The following table showed the results of reliability and validity tests:

| Table 2. The result of validity question |
|-----------------------------------------|
| **Correlations**                        |
|                                        |
|                                          |
| No_1 Pearson Correlation                |
| Sig. (2-tailed)                         |
| N                                       |
| TOTAL                                   |
|                                          |
| No_2 Pearson Correlation                |
| Sig. (2-tailed)                         |
| N                                       |
| TOTAL                                   |
|                                          |
| No_3 Pearson Correlation                |
| Sig. (2-tailed)                         |
| N                                       |
| TOTAL                                   |
|                                          |
| No_4 Pearson Correlation                |
| Sig. (2-tailed)                         |
| N                                       |
| TOTAL                                   |
|                                          |
| TOTAL Pearson Correlation                |
| Sig. (2-tailed)                         |
| N                                       |

Based on Table 2, it was obtained that the value of $r_{count}$ for question 1 was 0.567, question 2 was 0.582, question 3 was 0.577, question 4 was 0.639, and all values were valid as they fulfilled $r_{count} > r_{table}$ with $N=44$.

**Correlation is significant at the 0.01 level (2-tailed)**

| Table 3. The test result of the reliability question |
|----------------------------------------------------|
| **Reability Statistics**                           |
| Cronbach's Alpha                                   |
| N of Items                                         |
| .375                                               |
| 4                                                  |

Based on Table 3, it was obtained that the value of reliability was 0.375 and $r_{count}$ of 5% significance level with $r_{table} = 0.297$, therefore $r_{count} > r_{table}$. It could be concluded that the instruments were reliable.

The initial research used qualitative method to the subjects of 42 students in the control class and 44 students in the experimental class. The results of pre-test of both groups showed the percentage that could be seen in the following Figure 4 and Figure 5:
Figure 4. The percentage result of pre-test on generalization thinking skill of the control class

| Perception of generality | Expression of generality | Symbolic expression of generality | Manipulation of generality |
|--------------------------|--------------------------|----------------------------------|---------------------------|
| p1                       | p2                       | e1                               | e2                        |
| very good                | 25                       | 13                               | 7                         | 1                         |
| good                     | 11                       | 15                               | 17                        | 9                         |
| quite good               | 6                        | 11                               | 10                        | 18                        |
| low good                 | 0                        | 3                                | 8                         | 14                        |

Figure 5. The percentage result of pre-test on generalization thinking skill of the experimental class

| Perception of generality | Expression of generality | Symbolic expression of generality | Manipulation of generality |
|--------------------------|--------------------------|----------------------------------|---------------------------|
| p1                       | p2                       | e1                               | e2                        |
| very good                | 24                       | 12                               | 7                         | 5                         |
| good                     | 14                       | 18                               | 17                        | 13                        |
| quite good               | 5                        | 12                               | 12                        | 15                        |
| low good                 | 1                        | 2                                | 8                         | 11                        |

Figure 4 is the result of the percentage with the indicators of generalizing thinking skill of the control class in which 57% was less good, 41% was quite good, 2% was good, and 0% was very good; and Figure 5 is the percentage result based on the indicators of generalizing thinking skill of the experimental class in which 36% was less good, 48% was quite good, 16% was good, and 0% was very good. The total students who categorized based on the sub-indicators on the level of generalization thinking skill in the control and experimental classes. The researcher would count by using spss program of the quantitative method for each data of pre-test and post-test.
The data of pre-test was then tested by using homogeneity test, homogeneity test is a test to know whether the variance of some population is the same or not. The following was the result of homogeneity test of the pre-test data of the control and experimental classes:

**Table 4. Test the homogeneity of pre test**

| Test of Homogeneity of Variances |
|----------------------------------|
| Levene Statistic | df1 | df2 | Sig |
|--------------------|-----|-----|-----|
| .174               | 1   | 86  | .677 |

In Table 4, the result of homogeneity test was the value of sig 0.582. Based on the calculation of spss, it was known that the significance value was 0.582 > 0.05 which meant that both classes has the same variance or homogeneous.

After the homogeneity test was finished, the data was tested by using normality test. Normality test was used to test whether the data of the research has normal distribution or not. The following was the results of normality test of pre-test data from the control and experimental classes:

**Table 5. Test the normality of both class from the pre test**

| Test of Normality |
|-------------------|
| Kolmogorov -- Smirnov\(^a\) | Shapiro-Wilk |
| Statistic | df | Sig | Statistic | df | Sig |
| CONTROL | .095 | 42 | .200* | .972 | 42 | .373 |
| EXPERIMENTAL | .093 | 42 | .200* | .977 | 42 | .534 |

\(^a\). Lilliefors Significance Correction  
\(^*\). This is a lower bound of the true significance

In Table 5, normality test obtained the value of 0.200 in the control class and 0.200 in the experimental class. Based on the result of spss, it was known that the significance value was 0.200 > 0.05 in the control class and 0.200 > 0.05 in the experimental class which means that both classes were normally distributed.

Next, independent sample test was conducted. Independent sample test was used to test whether the data of the research was independent.

**Table 6. Test the independent of pre-test in the control and experimental classes**

| Independent Sample Test |
|-------------------------|
| 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 |
|---|-----|---|-----|----------------|----------------|-------------------|------|------|
| Equal variances assumed | .624 | .432 | - | 84 | .059 | - | .63831 | - | .04533 |
| NILAI | 1.918 | 1.22403 | 2.49338 |
| Equal variances not assumed | - | 81.198 | .059 | - | .64041 | - | .5014 |
| NILAI | 1.911 | 1.22403 | 2.49819 |

Table 6 was the results of independent test of pre-test in the control and experimental classes. The test obtained the value of sig (2-tailed) 0.059. Based on the result of spss, it was known that the significance value was 0.059 > 0.05 which means that it was not significant or pre-test of the control and experimental classes has no different.

After that, the data of post-test obtained from homogeneity test which was the test to know whether the variance of some population was the same or not.
Table 7. Test the homogeneity of post test

Test of Homogeneity of Variances

| Levene Statistic | df1 | df2 | Sig |
|------------------|-----|-----|-----|
| .024             | 1   | 84  | 0.878 |

In Table 7, the result of homogeneity test obtained sig value of 0.921, based on the result of spss, it was known that the significance value was 0.921 > 0.05 which means that the control and experimental classes has the same variance or homogeneous.

After homogeneity test was done, the data was tested by using normality test. Normality test was used to test whether the data of the research had normal distribution or not.

Table 8. Test the normality of both class from the post test

Tests of Normality

| Kolmogorov – Smirnov | Shapiro-Wilk |
|----------------------|--------------|
| Statistic df Sig     | Statistic df Sig |
| CONTROL .097 42 .200* | .985 42 .845 |
| EXPERIMENTAL .0094 42 .200* | .969 42 .298 |

a. Lilliefors Significance Correction
*This is a lower bound of the true significance

In Table 8, normality test obtained the value of 0.200 in the control class and 0.200 in the experimental class, based on the result of spss, it was known that the significance value was 0.200 >0.005 in the control class and 0.200 > 0.05 in the experimental class which means both classes have normal distribution.

After normality test was done, the data was tested by using independent test. Independent test was used to test whether the data of the research were independent.

Table 9. The result of independent test of post-test in the control and experimental classes

Independent Sample Test

| Levene's Test for Equality of Variances | t-test for Equality of Means | 95% Confidence Interval of the Difference |
|----------------------------------------|-----------------------------|-----------------------------------------|
|                                        | Sig. (2-tailed) Mean Difference Std. Error Difference Lower Upper |
| RESULT Equal variances assumed .024 .878 - 84 .000 - .68926 .608712 3.34578 |
|                                        | 6.843                       |
| RESULT Equal variances not assumed - 83.988 .000 - .68869 - - |
|                                        | 6.848                       |

In Table 9, independent test obtained sig (2-tailed) 0.000, based on the result of spss the value was 0.000 < 0.05 which means that it was significant. Therefore, there was different of both classes’ score after the implementation of RBL.

Based on the result of the research, the following was the figure of the percentage result of post-test from the result of all students from each control and experimental classes:
Figure 6. The percentage result of posttest of generalist thinking skill in the control group. There was the percentage result of 42 students on figure 6. It was found that 7% of the research subjects were in very good criteria, 29% of those were in good criteria, 52% belonged to quite good criteria and 12% for the poor one.

Figure 7. The results of generalization thinking skill of posttest in the experimental group. Figure 7 described the percentage result of 44 students. It was obtained that the highest score was 43% for the research subjects who were in very good criteria, 41% were included in good criteria, 16% were in quite good criteria and 0% for the poor. Based on the implementation of RBL learning greatly helped the students develop the ability to think of generalizations on local super H-decomposition antimagic total coloring material.

After learning with research based learning model, students were capable to understand the material provided so that they could label a graph based on local super H-decomposition antimagic total coloring. There were two stages of labeling graphs based on local super H-decomposition antimagic total coloring; the first was labeling points and sides. The next stage was sum up the points and sides whose results were the sub-graph decomposition. To know deeply the student activities of their generalization thinking process, we use a potrait phase. The portrait phases are taken to draw the graph of their mathematical generalization thinking process regarding the implementation of research.
based learning. By interviewing the student S1, we can explore their thinking from the first step, following the step and the last step that the student has done. We draw a directed line to go from the previous step to the next step. The results of student's works can be seen on this below:

![Diagram](a)

**Figure 8.** (a) The result of students work on low good level (b) potrait phase of a student work on low good level

Figure 8(b) shows the process of generalization thinking the skill of subject 1. In step 1a to stage 1b, subject 1 are able to recognize a decomposition graph and then subject 1 are able to symbolize graphs, and subject goes ahead to the step 2a been able to produce cardinality from graphs and stop, this mean Subject 1 cannot find chromatic number of graph.

The second work shows how students begin to find minimum colors on graph, but students cannot determine the minimum coloring for the graph. The results of student's works can be seen on this below:

![Diagram](a)

**Figure 9.** (a) The result of students work on quite good level (b) potrait phase of a student work on quite good level

Figure 9(b) shows the process of generalization thinking the skill of subject 2. In step 1a jumped to 2a and then returned to 1b, he jumped to 2b and stop, this mean Subject 2 cannot find chromatic number of graph.
The third work shows how students begin to find minimum colors on graph, but students cannot determine the minimum coloring for the graph. The results of student’s works can be seen on this below:

![Figure 10](image)

**Figure 10.** (a) The result of students work on good level  
(b) Portrait phase of a student work on good level

Figure 10(b) shows the process of generalization thinking the skill of subject 3. In step 1a to stage 1b, 1b continued 2a, 2b, 3a, 3b, 4a and stop. This mean Subject 3 can find weight number of graph but nor chromatic number.

The fourth work shows how students begin to find minimum colors on graph, and in subject 4 determine the minimum coloring or chromatic number for the graph. The results of student’s works can be seen on this below:
Figure 11. (a) The students work on very good level (b) portrait phase of a student work on very good level

Figure 11(b) shows the process of generalization thinking the skill of subject 4. In step 1a jumped to 2a to stage 2b, for 2b returned to 1b, and then jumped to 3a, continued 3b, 4a, and stop. This mean Subject 4 can find weight number of graph and find chromatic number of graf.

4. Discussion

This research was intended to analyze the generalization thinking skill and the implementation of research based learning. This research found that the implementation of research based learning had a significant effect on the generalization thinking skill on the students in the experimental group. The students in the experimental group showed the generalization thinking skills compared to the ones in the control group. The results showed that the improvement of learning outcomes and the students’ generalization thinking skills were seen in the posttest results. The scores in the experimental group were significantly better as it was supported by RBL. The experimental group had understood the concepts to help each other, therefore RBL was very good in improving the students’ generalization thinking skills.

The result of this research is in line with the one conducted by [13], which showed that generalization process is very important to solve the pattern of numbers. Sota[10] report that the application of RBL among master-degree students when dealing reading, analysing, synthesis, and presentation as well as discussion can improve cognitive skill, knowledge, ethics, competence, social skills, communication, arithmetic and information technology skills, and satisfaction in finding information, which are all found at high extent. RBL can be fully recommended for engineering education so as to produce higher students’ motivation and improve learning outcomes and more well-developed life aspects[7]. Furthermore, RBL should be applied in many departements to expand research in studies across all institution, apply research in education, and strengthen the relationship between research and teaching[9]. If RBL is applied in classroom, students will be more active and creative and think more critically than students taught using conventional learning. The result of this research show that learning objectives also played a vital role in solving students’ problems.

The data produced in this research showed that 19 students belonged to very good level with 43% as its percentage, 18 students were grouped into good level with 41% as its percentage, 7 students were at quite good level with 16% as its percentage, and no students were at a less good level with 0% as its percentage, while in the control group, there were 3 students who were placed at very good level with the percentage of 7%, 12 students were at good level with the percentage of 29%, 22 students were at quite good level with the percentage of 52%, and 5 students were at a less good level with the percentage of 12%. Based on these results, it can be concluded that RBL is considered helpful in improving students’ generalization thinking skills.

Moreover, the data obtained through interview explained that the students gave a positive response through the comments about the implementation of research-based learning. Through research-based learning, the students were able to master the material and find new ideas and be able to make a conclusion of the material that had been studied.
5. Conclusion
Basically, this research aimed at finding out that RBL had a significant effect in the experimental group. In the experimental group, the students were able to bring up the generalization thinking skills compared to the control group. The results showed an increase and can be seen in the results of the post-test. In the experimental group, the students were capable to get better grades due to the use of RBL to improve generalization thinking skills, so it can be concluded that RBL was an excellent learning to improve students’ generalization thinking skills.

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