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The analysis of student's combinatorial thinking skill based on their cognitive style under the implementation of research based learning in the total rainbow connection study

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The analysis of student's combinatorial thinking skill based on their cognitive style under the implementation of research based learning in the total rainbow connection study

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Abstract. Combinatorial thinking skill is one of the skills that someone should have. Combinatorial thinking process provides the systematic steps in solving a problem. The purpose of this research was to analyze the level of the students' combinatorial thinking based on their cognitive styles. This research used a mixed method that combined qualitative method and quantitative method. The research subject consist of two classes, namely control class with 41 students and experimental class with 43 students. The data collection techniques in this research used GEFT (Group Embedded Figures Test), combinatorial thinking tests (pretest and posttest), and interview. After solving the problem, we analyzed the students' level of combinatorial thinking skill, namely low, good, and high while the cognitive style we categorize into Field Dependent and Field Independent and we applied research based learning to improve the level of combinatorial thinking skill. The research results showed that based on the results of the implementation of research based learning, 12% of students were categorized in the level of low combinatorial thinking skill, 53% were categorized in the level of good combinatorial thinking skill, and 35% in the level of high combinatorial thinking skill. The inferential statistical results of the independent sample t-test on the posttest results showed that the sig (2-tailed) value was 0.006 ($p \leq 0.05$) so that it was significant. This showed that there was a significant difference between the control class and the experimental class from the results of students' test after the implementation of research based learning. It can be concluded that the application of research based learning can improve the students' combinatorial thinking skills based on their cognitive styles in solving the total rainbow connection problem.

1. Introduction

Combinatorial thinking process is one of the thinking processes that must have by the students. According to [12] combinatorial thinking process is the essential part of mathematics thinking process. [6] states that combinatorial thinking process is different from other mathematics thinking process because this thinking process develops students' knowledge by using simple approach namely sign or semiotic approach. There are five indicators indicate that someone has combinatorial thinking ability which is understanding problem well, changing problem into mathematics symbol, creating strategy to solve problem, drawing conclusion, and explaining the obtained conclusion. The first step is the important process that is not only solving the combinatorial problem but also solving other mathematical problems. The second until fifth steps at glance are the same with the steps in other mathematics problem solving yet the processes are different [8]. Whereas, according to [7], there are five indicators which influence combinatorial thinking skill in which each indicator has some 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.

One of the learning models which lead to the ability of combinatorial thinking is Research Based Learning model. [11] 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)". 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 can improve academic achievement, promotes learning strategy and building new knowledge by itself [4]. This ability is essential in education especially on 21 century.

According to [17] 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. 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.

According to [7] he states that research based learning has feature for the students such as : Improving learning motivation, encouraging the ability to do the important work, improving the ability of problem solving especially on a complex problem. Making the students to be more active and successful in solving complex problem, generating fun learning atmosphere, increasing cooperation, interactivity, and feedback collaboration, developing and practicing communication skill, improving the students' source management, giving the experience of organizing project, time allocation, and other resources to finish the task, Providing the learning experience which involves the students in complex and designed to develop appropriately in the real world, involving the students to learn collecting information, processing information based on their own knowledge, then implementing it to the real world. In this learning process, the students are more involved in it and the lecturer is only being a facilitator.

The syntax of research based learning according to [2] 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.

Based on two syntaxes of RBL mentioned by [2] and [7], 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.

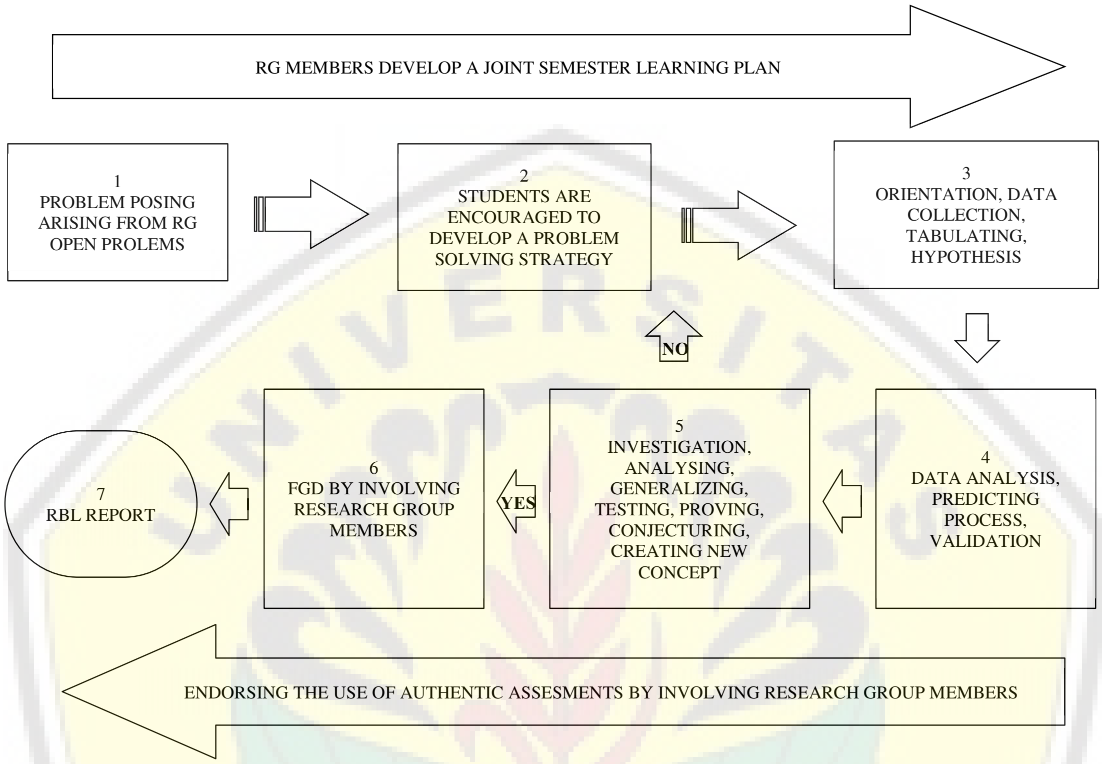


Figure 1. The Stages Chart of The research based learning Implementation[7]

However, it is not only the learning model, the students' unique characteristics also influence the learning process. Generally, the students showed different responses while facing the learning situation and condition, there are some who is enthusiastic and some who is less enthusiastic. According to [20], the different of the responses is emerged by someone regarding to the differentiation of their perception and intellectual characteristic approaches which take them to give response to a particular situation they faced, this difference is called as cognitive style differentiation. Some experts argue that cognitive style is a bridge between cognition and action that shows someone's personality [16]. [3] reveals that cognitive style is the process or control style which emerges on the students' self in which in a situation can determine the consciousness of activity of the students in organizing, regulating, accepting, and delivering information and deciding the students' attitude. Thus, cognitive style can be mentioned as the way students catch information, process it, and execute it in an action or attitude during the process of learning consistently.

Cognitive style can be differentiated into some ways of categorization, one of them is by [20] who identifies and categorizes someone based on the continuum characteristic of global analytic. Based on this way of categorization, Witkin divides cognitive style into two groups namely field dependent and field independent. Someone with field dependent cognitive style is a person who thinks globally; accept structure or the provided information, has social orientation, choose profession which is a social skill, tend to follow goals and the provided information, and tend to prioritize external motivation, while field independent cognitive style is a person who is able to analyze object separated from its environment, able to organize objects, has impersonal orientation, choose profession which is individual, and prioritize internal motivation.

The aim of this research was to analyze the ability of combinatorial thinking based on the students' cognitive style under the implementation of research based learning on the study of total rainbow connection.

Total rainbow connection has definition as follow.

Defines.

The total-colored graph of G is a total-connected rainbow of any two vertices which are connected by at least, one total rainbow path which is the edges and internal vertices which have distinct colors. The total rainbow coloring is a natural extension of edge rainbow coloring and vertex rainbow coloring. The total rainbow connection number of G, denoted by trc(G), is the smallest number of colors required to color the edges and vertices of G in order to make G total rainbow connected.

The Example of Total Rainbow Connection Coloring could be seen in Figure 2.

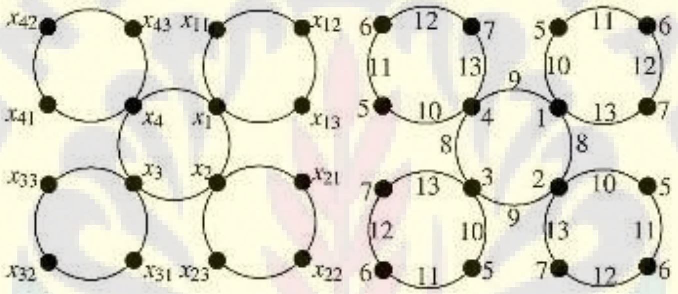


Figure 2. Example of Total Coloring Rainbow Connection

2. Methods

2.1. Research Scope

This research focused on the analysis of the ability of combinatorial thinking in solving the problem of total rainbow coloring based on the cognitive style. This research was intended to the students of Mathematic Education in the third semester in 2018/2019 academic year.

2.2. Sample

The subjects of the research were the third semester students of class A and B, mathematics study program of FKIP, University of Jember. Class A used as the experimental class, in which the number of the students in class A were 43 students, while the class B used as the control class with 41 students.

2.3. Instrument and Procedure

The instrument of collecting the qualitative data were GEFT test (Group Embedded Figure) to analyze the students' cognitive styles that then was continued by giving pre-test in the form of question test to analyze the combinatorial thinking skills. The collecting of qualitative data were in the form of interview to deepen the students' thinking skills used to create the potrait phase.

The method used in this research was the mixed-method, that is by using quantitative and qualitative approaches. The researchers collected the quantitative data as the main information, then the qualitative data were used as the supporting data. Research based learning was implemented in the experimental class while the conventional learning was implemented in the control class.

Table 1. Research Design

Group	Pre-test	Treatment	Post-test
Control Class	P_1	Conventional	P_2
Experiment Class	P_1	RBL	P_2

To know the students' combinatorial thinking skills level based on their cognitive style and to find out the improvement of the students' combinatorial thinking skills level, the researchers analyzed the results of the pre-test, post-test and interview guidance in two kinds of research and the learning process.

2.4. Data Collection and Data Analysis

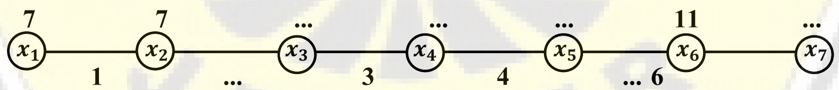
Both classes, experimental and control classes were given the same GEFT test, pre-test and post-test. The quantitative analysis used Independent Sample T-test. Qualitative data gained from the process of interview and was analyzed from the ordinal data.

Description and inferential statistics were implemented to analyze the quantitative and qualitative data. The data information, such as frequency, mean and standard deviation were used to describe the statistical data, especially inferential statistics to know the influence of RBL by using Independent Sample T-test in both experimental and control classes [9][13]. Independent Sample T-test used to compare the mean between two classes, by looking at the significant differences with 0.05 level. The data resulted were going to be analyzed by using SPSS 17.0. program.

The analysis of the students' answers in the scope of combinatorial thinking skills for each dimension consisted of (1) Identifying several cases, (2) Recognizing the pattern of all cases, (3) Generalizing all of the cases, (4) Proving mathematically, (5) Considering other combinatorial problems. The assessment of combinatorial thinking for each sub-indicator was scored as "good" with 3 points, "average" with 2 points and "poor" with 1 point. The points would be changed in the form of scale 1-96. The processing of the students' answers, as follows: The answer in the scope of combinatorial thinking skills for each dimension is categorized based on the assessment scale that consists of high combinatorial skills, good combinatorial skills, and low combinatorial skills [19]. In this research, the range scores of high combinatorial skills was $76 \leq x \leq 96$, good combinatorial skills was $54 \leq x < 76$, and low combinatorial skills was $32 \leq x < 54$. The analysis of the students' answers in the scope of cognitive style were divided into two categories that are (1) Field Dependent with the range score of $(0 \leq x \leq 9)$ and (2) Field Independent with the range score of $(10 \leq x \leq 18)$.

2.5. Students' Task

The purpose of this task was to enable the students to make the total coloring rainbow connection given the exercises in the Figure 4 and identify the correctness of the pattern of total coloring rainbow connection by using a table.



Initial Point	End Point	Rainbow Path	The Color of Rainbow Path
x_1	x_2		
x_1	x_3		
x_1	x_4		

Figure 3. One of the task for students

3. Research Findings

The initial research done the quantitative method that were validity and reliability tests in the post-test questions that were given to the students. The aim of validity and reliability was to know how far the validity of the assessment instrument to do its measurement function. The following were the results of validity and reliability tests had been conducted in the research subject. The samples used in the validity and reliability tests were as many as 45 students.

Table 2. The Results of Validity Test

		PROB_1	PROB_2	PROB_3	PROB_4	TOTAL_SCORE
PROB_1	Pearson Correlation	1	.072	.039	.201	.572
	Sig. (2-tailed)		.637	.802	.185	.000
	N	45	45	45	45	45
PROB_2	Pearson Correlation	.072	1	.131	.149	.557
	Sig. (2-tailed)	.637		.390	.329	.000
	N	45	45	45	45	45
PROB_3	Pearson Correlation	.039	.131	1	.149	.580
	Sig. (2-tailed)	.802	.390		.328	.000
	N	45	45	45	45	45
PROB_4	Pearson Correlation	.201	.149	.149	1	.625
	Sig. (2-tailed)	.185	.329	.328		.000
	N	45	45	45	45	45
TOTAL_SCORE	Pearson Correlation	.572	.557	.580	.625	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	45	.557	45	45	45

From the output in the table 2 the r_{count} value on the question 1 was 0,572; r_{count} on the question 2 was 0,557; r_{count} on the question 3 was 0,580; and r_{count} on the question 4 was 0.625, while r_{table} for $n = 45$ was 0,294. Therefore, it can be concluded that r_{count} on the questions 1-4 >r_{table} so that all of the questions were valid.

Table 3. The Results of Reliability Test
Reliability Statistics

Cronbach's Alpha	N of items
.357	4

Based on the table 3, the reliability value was 0.357 and r_{table} from the significant level was 0.05 with $df = N - 1 = 44$, $r_{table} = 0{,}297$. Thus, because $r_{count} > r_{table}$ therefore, the instrument was reliable.

Based on the results of GEFT test, in the control class with the research subjects as many as 41 students, 18 of them belonged to the category of field dependent and 23 others belonged to the category of field independent. Whereas, in the experimental class with the research subjects as many as 43 students, 17 students belonged to the field dependent category and 26 students belonged to the field independent category. The results of cognitive style distribution attached in the Figure 5 and the results of distribution of combinatorial thinking based on the cognitive style attached in the Figure 6.

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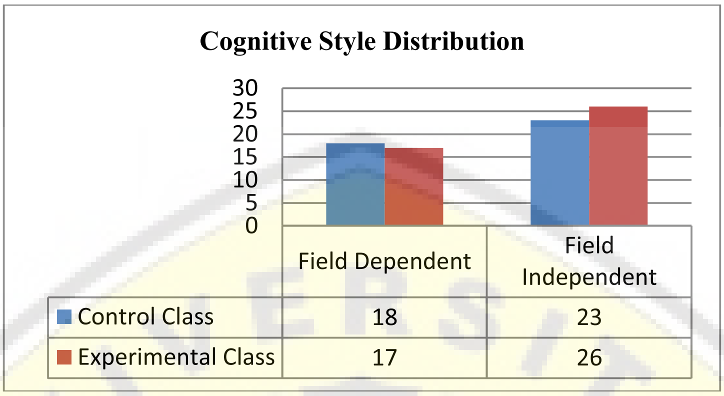


Figure 4. The Distribution of Cognitive Style in the Control and Experimental Classes

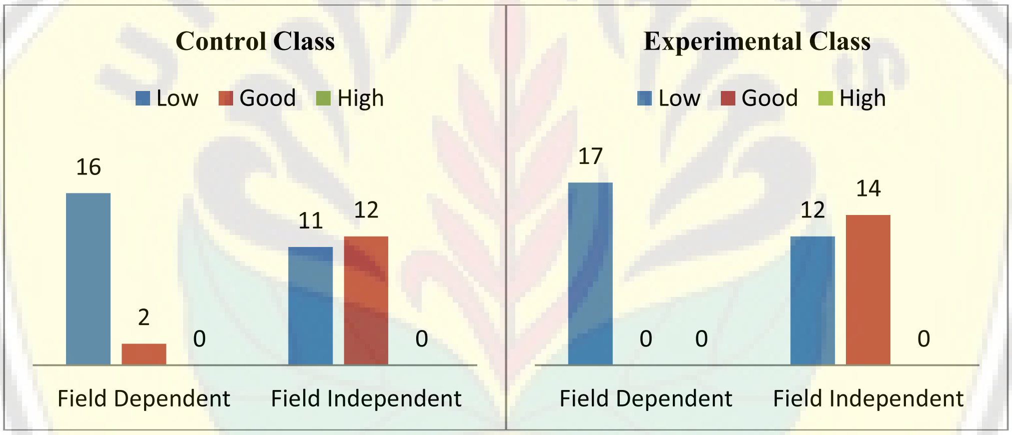
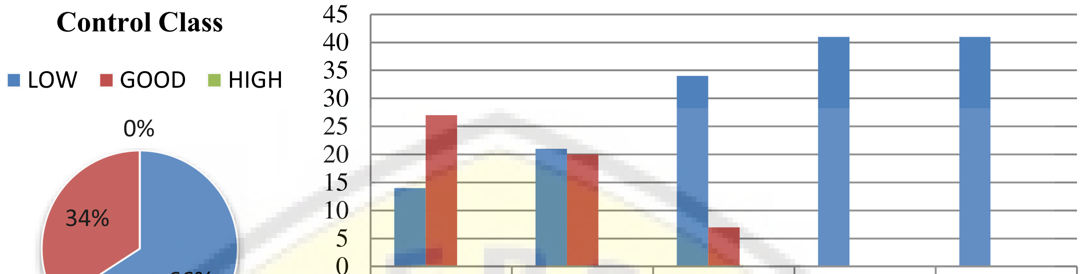


Figure 5. The distribution of combinatorial thinking based on the cognitive style

From the results of the pre-test work of students from the two cognitive style groups above, it can be concluded that, the field independent group students from the control class and the experimental class had better combinatorial thinking skills than the students in the field dependent group from the control class and experimental class. This can be seen from Figure 5 where there are very few students with good combinatorial thinking skills from the field dependent group and no students with good combinatorial thinking skills from the field dependent group in the control class. The situation is very different from the field independent group where students with good combinatorial thinking skills are more than students with low combinatorial thinking skills.

The results of the pre-test among two classes showed that both classes had the same variant. The results of the research showed that the combinatorial thinking ability skills in the control class that there was no student who had high combinatorial thinking skills, 34 % or as many as 14 students had good combinatorial thinking skills, and 66% or as many as 27 students had low combinatorial thinking skills while in the experimental class, 33% or as many as 14 students had good combinatorial thinking skills, and 67% students or 29 students had low combinatorial thinking skills, similar with the control class, in the experimental class there was no student who had high combinatorial thinking skills. The results of the control class can be seen in the Figures 7, while for the experimental class can be seen in the Figures 8.



	Identifying Some Cases	Recognizing the Pattern of All Cases	Generalizing All Cases	Proving Mathematically	Considering Other Combinatorial Problems
Low Combinatorial Thinking Skill	14	21	34	41	41
Medium Combinatorial Thinking Skill	27	20	7	0	0
High Combinatorial Thinking Skill	0	0	0	0	0

Figure 6. The Distribution of Combinatorial Thinking in the Control Class before the Implementation of RBL

	Identifying Some Cases	Recognizing the Pattern of All Cases	Generalizing All Cases	Proving Mathematically	Considering Other Combinatorial Problems
Low Combinatorial Thinking Skill	13	21	38	43	43
Medium Combinatorial Thinking Skill	30	22	5	0	0
High Combinatorial Thinking Skill	0	0	0	0	0

Figure 7. Distribution of Combinatorial Thinking Skill in Experimental Class before the Implementation of RBL

From the research results, it was found effective findings from the use of independent sample t-test in research based learning using t-test analysis obtained through the average score of the pre-test and post-test in the experimental class and control class, and the normality test performed. The number of respondent was 84 students.

Table 4. The Homogeneity Test of Pre Test

Test of Homogeneity of Variances			
Class			
Levene Statistic	df1	df2	Sig.
.139	1	82	.710

Table 4. The homogeneity test results from the pre-test, the value (Sig.) On the Homogeneity Variances Table Test was 0.710 so it can be concluded that the assumption of homogeneity of variance was fulfilled. Since the significance value obtained was more than 0.05, the data had the same or homogeneous variance value.

Table 5. Pre-test result and mean scores between control class and experimental class

Report				
Group	N	Mean	Std. Deviation	Std. Error Mean
The Pre-test Score of Control Class	41	48.0000	10.10940	1.57882
The Pre-test Score of Experimental Class	43	44.9767	10.09830	1.23998

The reliability of the pre-test results distribution was 0.05. The average score in the control class was 48.0000 (SD = 10.10940) while in the experimental class was 44.9767 (SD = 10.09830). The difference between the pre-test achievement in the control class and the experimental class score of 2 groups was [t (84) = 0.213, p> 0.05], which means that the average difference between the two classes was not significant.

Table 6. The data below presents the comparison of pre-test score of experiment class and control class score using independent sample t-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidences Interval of the Difference	
		F	Sig	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Score	Equal variances assumed	.139	.710	1.371	82	.174	3.02326	2.20544	-1.36406	7.41057
	Equal variances not assumed			1.371	81.801	.174	3.02326	2.220550	-1.36434	7.411085

Table 6 also shows that the results of the t-test indicated that the sig value. (2-tailed) from the independent sample the pre-test t-test was 0.710 (p> 0.05), so it was not significant. This implies both classes were homogeneous on the results of the students' pretest.

Table 7. Test the normality of both class from the post test

Test of Normality							
Group		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Score	The Post-test Score of Control Class	.113	41	.200*	.972	41	.398

The Post-test Score of Experimental Class	.093	43	.200	.957	43	.112
a. Lilliefors Significance Correction						
*. This is a lower bound of the true significance.						

The results of the normality test of each class obtained a significance value of each, namely post-test in the control class of 0.398, and post-test in the experimental class of 0.112. The significance of the values of the two classes was greater than the value of α (0.05), which means that the two classes of research samples were normally distributed.

Table 8. Results of the post-test and the average score between the control class and the experimental class

Report				
Group	N	Mean	Std. Deviation	Std. Error Mean
The Post-test Score of Control Class	41	62.1951	9.90762	1.54731
The Post-test Score of Experimental Class	43	68.5116	10.52971	1.60577

Table 8. Presents the results of the control class post-test, marked at 61.9429 (SD = 10.06433), while the experimental class obtained 66.9000 (SD = 10.52421). Table 7. Shows there were significant differences between the two classes as indicated by [t (75) = -2,077, p <0.05].

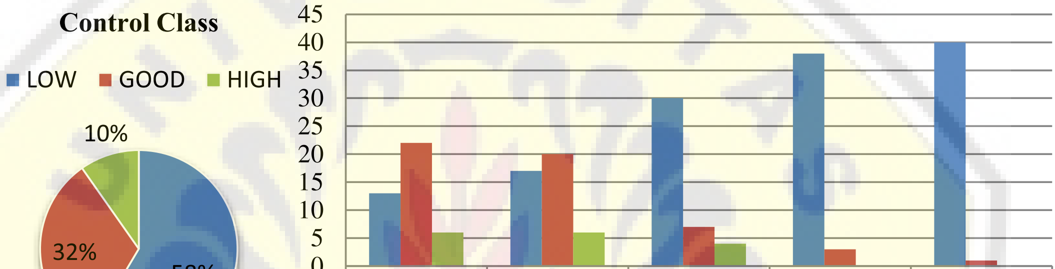
Table 9. This was the comparison between post-test scores between experimental class and control class by using an independent t-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidences Interval of the Difference	
		F	Sig	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Score	Equal variances assumed	.107	.745	-2.828	82	.006	-6.31651	2.23322	-10.75908	-1.87393
	Equal variances not assumed			-2.833	81.987	.006	-6.31651	2.22995	-10.75259	-1.88042

Table 9 shows that the results of the t-test indicated the sig. value (2-tailed) from the independent sample post-test t-test was 0.006 ($p \leq 0.05$), so it was significant. This implies that the two classes were having differences in terms of students' achievement tests after the implementation of research based learning.

According to these results we can conclude that there is a significant impact from the application of research based learning to the students' combinatorial thinking skills in solving total rainbow connection problems.

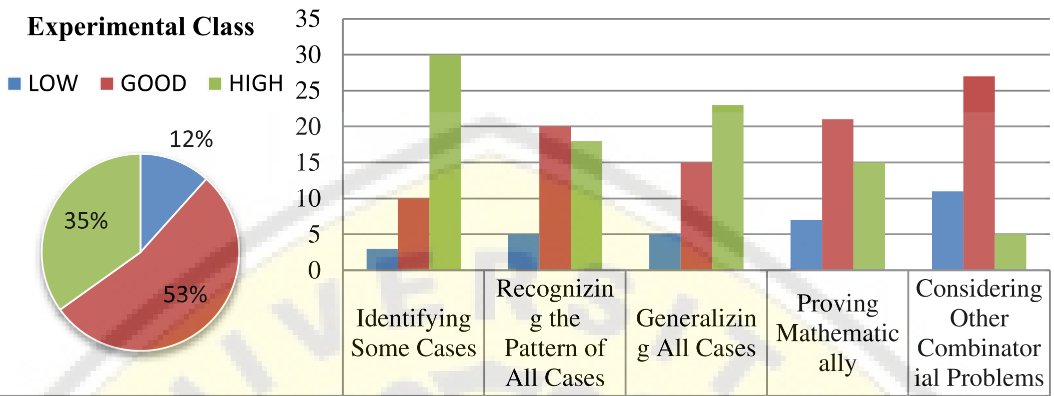
Based on the results of the post-test analysis between the two classes, it could be seen that the experimental class was superior to the control class. The result showed combinatorial thinking skills in the control class, the students who had low combinatorial thinking skills were from 66% to58 %, while students who had good combinatorial thinking skills were from 34% to 32%, and students who had high combinatorial thinking skills were from 0% to10%. The change in the results of students' combinatorial thinking skills in the experimental class was very significant, students who had low combinatorial thinking skills which were from 67% decrease to 12%, while students who had good combinatorial thinking skills which were from 33% to 53%, and students who had combinatorial thinking skills was very good which were from only 0% increased to 35%. The results of the two classes can be seen in Figure 8 and Figure 9 below:



	Identifying Some Cases	Recognizing the Pattern of All Cases	Generalizing All Cases	Proving Mathematically	Considering Other Combinatorial Problems
Low Combinatorial Thinking Skill	13	17	30	38	40
Medium Combinatorial Thinking Skill	22	20	7	3	1
High Combinatorial Thinking Skill	6	6	4	0	0

Figure 8. Distribution of Combinatorial Thinking Skill in Control Class after the RBL Implementation

Furthermore, from the observations result, it shows that students combinatorial thinking skills of the control class and experiment class are as follows. The student's works are showed when the research-based learning was applied. The researcher takes three student's works as illustrations of the student's activities under the research based learning. The first work shows the students with low combinatorial thinking skill level, second work shows the students with good combinatorial thinking skill level, and the last work shows the students with high combinatorial thinking skill level.



	Identifying Some Cases	Recognizing the Pattern of All Cases	Generalizing All Cases	Proving Mathematically	Considering Other Combinatorial Problems
Low Combinatorial Thinking Skill	3	5	5	7	11
Medium Combinatorial Thinking Skill	10	20	15	21	27
High Combinatorial Thinking Skill	30	18	23	15	5

Figure 9. Distribution of Combinatorial Thinking Skill in Experimental Class after the RBL Implementation

The first work shows how students begin to set colors for each road as a edge and home as a vertex . Many of the colors given by these students are minimum, while that these students cannot generalize the housing plan and cannot make the coloring function in general for a wider housing plan.

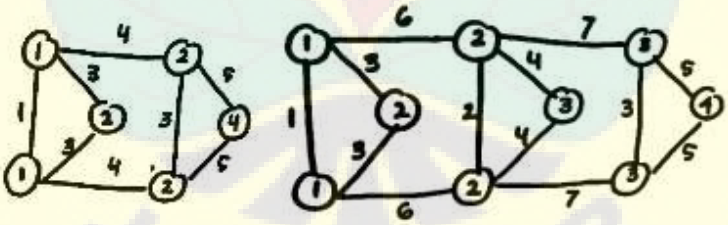


Figure 10. The students work on low combinatorial thinking skill level (S1)

To know deeply the student activities of their combinatorial thinking process, we use a potrait phase. The portrait phases are taken to draw the graph of their combinatorial thinking proces under 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. We finally can depict the graph representation of their combinatorial thinking process in the following portrait phase, see Figure 11. Figure 10 shows the process of combinatorial thinking the skill of subject 1 in solving total rainbow connection problem. In step 1a to stage 1b, subject 1 identifies the characteristic of total rainbow connection, can identify the minimum color of the graph and applies some case. S1 goes ahead to the step 2a and stop, this mean S1 cannot generalize the pattern.

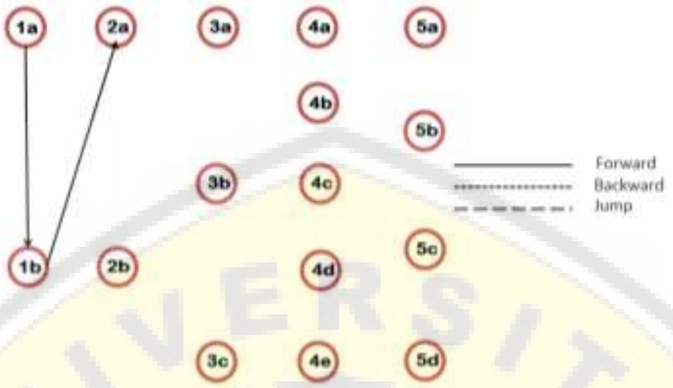


Figure 11. The students work on low combinatorial thinking skill level (S1)

The second work shows how students begin to set minimum colors on each road as a edge and house as a vertex and can be used for a wider housing plan or can find a more general coloring pattern for total rainbow connections, but students cannot determine the function coloring for the broader pattern.

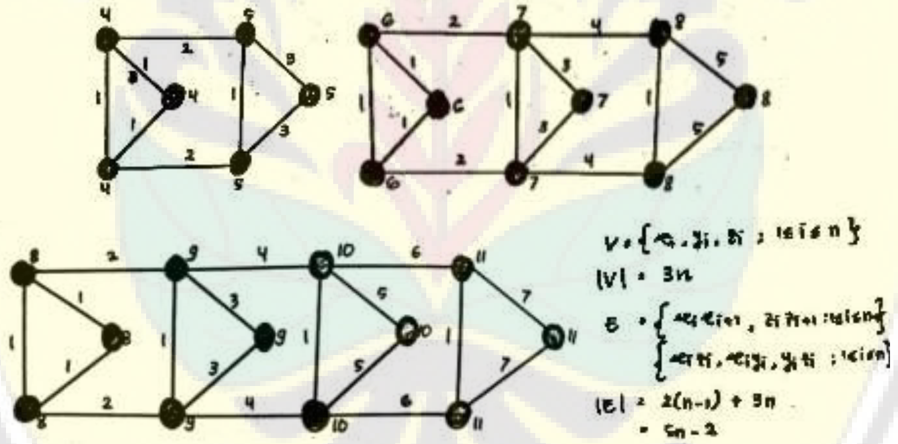


Figure 12. The students work on good combinatorial thinking skill level (S2)

To know deeply the student activities of their combinatorial thinking process, we use a potrait phase. The portrait phases are taken to draw the graph of their combinatorial thinking proces under the implementation of research based learning. By interviewing the student S2, 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. We finally can depict the graph representation of their combinatorial thinking process in the following portrait phase, see Figure 13. Figure 12 shows the process of combinatorial thinking the skill of subject 2 in solving total rainbow connection problem. S2 starts from 1a jump to 2a, and continue to 2b. However S2 goes back to 1b and jump to 3b and stop. S2 identifies the characteristic of total rainbow connection, can identify the minimum color of the graph and applies some case, 2b means S2 can genelize the pattern. S2 didn’t sign the symbol but can find the cardinality. S2 also cannot find the bijection function of total rainbow connection for the expansion of housing plan.

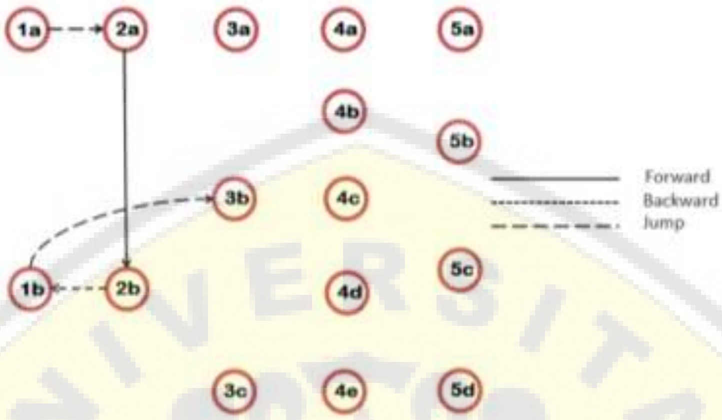


Figure 13. The students work on good combinatorial thinking skill level (S2)

The third work shows how students begin to set minimum colors on each road as a edge and each house as a vertex. These students can expand the coloring of the housing plan and can determine the bijective function of the coloring for the total rainbow connection on the housing plan or the results of its expansion.

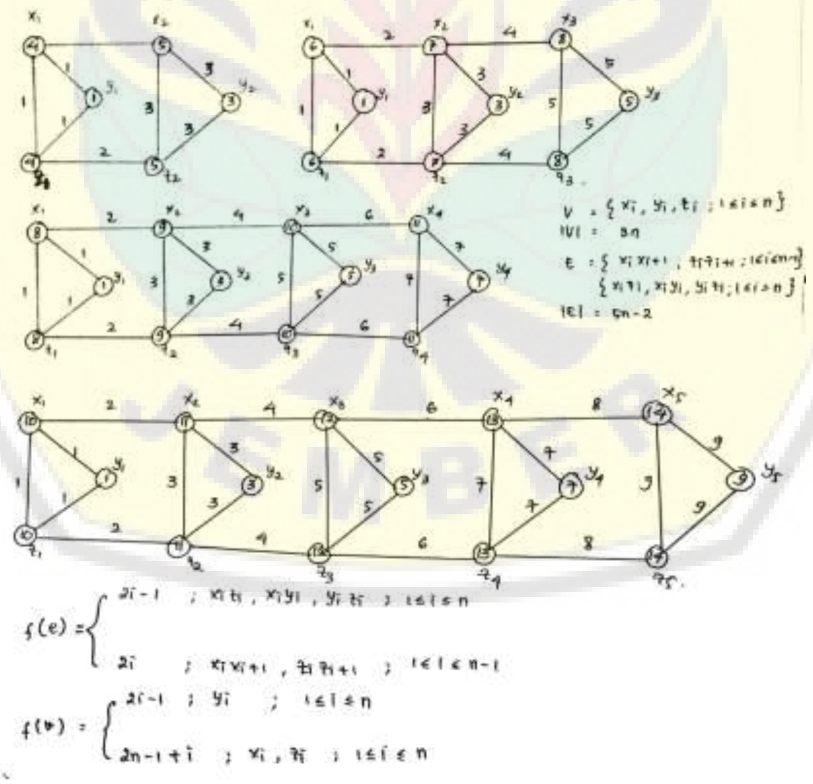


Figure 14. The students work on high combinatorial thinking skill level (S3)

To know deeply the student activities of their combinatorial thinking process, we use a potrait phase. The portrait phases are taken to draw the graph of their combinatorial thinking proces under the implementation of research based learning. By interviewing the student S3, 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. We finally can depict the graph representation of their combinatorial thinking process in the following portrait phase, see Figure 15. Figure 14 shows the process of combinatorial thinking the skill of subject 3 in solving total rainbow connection problem. S3 starts from 1a, he goes to 1b, jump to 2b and go ahead to 3a, 3b, 3c and jump two steps to 4c, goes to 4d. S3 has higher combinatorial thinking than S1 and S2 because S3 can find the bijection function of total rainbow connection and while interview S3 knows the aplication of total rainbow connection and find a new problem, that means S3 jump to 5d and goes back to 5c .

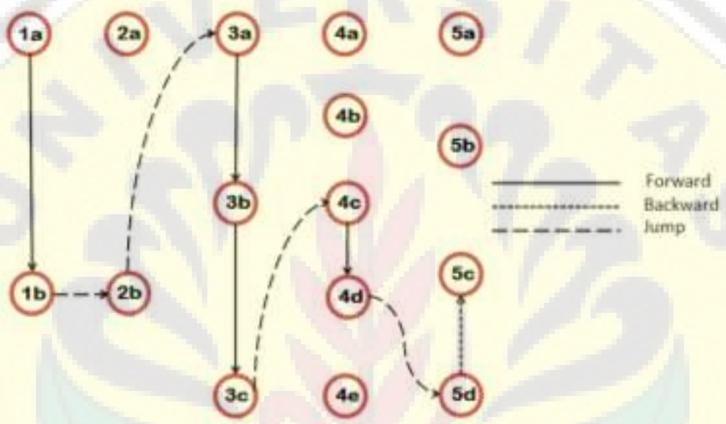
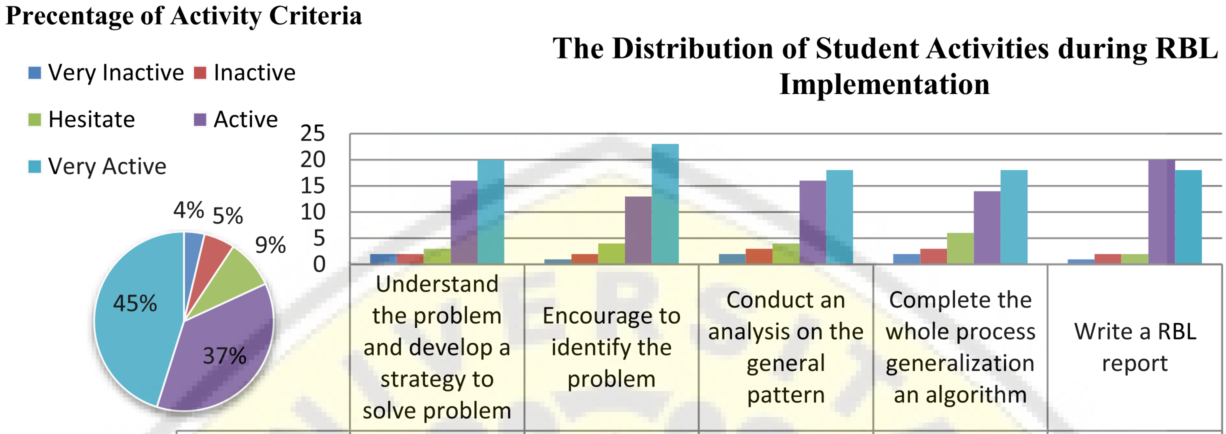


Figure 15. The students work on high combinatorial thinking skill level (S3)

Finally, we understand how easy to have a best total rainbow connection solution through the implementation of the research based learning. We also notice that there is a significant impact of the implementation of research-based learning in improving the student's combinatorial thinking skills in solving a total rainbow connection problem. It is in line with [10] and [17], they found that there is a significant influence of the research-based learning implementation to the student's achievement.

Student's activities show a positive trend. The distribution of students activities during the implementation of research based learning in the experimental class shows 4% of students are very inactive, 5% of students is inactive, 9% of students hesitates, 37% of students are active, 45% of students are very active. The fact shows the linearity this research with other research about the implementation or research-based learning holds, see [15]

Based on Figure 16 it reveals that students became competent in manipulating the color such that they can get a best total rainbow connection. This competence developed during the implementation of research based learning. It indicates the research based learning can be used as an alternative model for having a good combinatorial thinking skills of the students in such a way the students can contribute a novelty of knowledge during the class process. This also meet with the reseach carried out by [18] stated that the reserach based learning can enhance the research skill of the students. Finally we recommend the use of research based learning in every advance subject courses.



	Understand the problem and develop a strategy to solve problem	Encourage to identify the problem	Conduct an analysis on the general pattern	Complete the whole process generalization an algorithm	Write a RBL report
Very Inactive	2	1	2	2	1
Inactive	2	2	3	3	2
Hasitate	3	4	4	6	2
Active	16	13	16	14	20
Very Active	20	23	18	18	18

Figure 16. The Observation results distribution of all subjects in the experimental class

4. Discussion

This research was conducted to analyze the effect of research based learning on the students' combinatorial thinking skills based on their cognitive style. The findings of this study indicated that the implementation of research-based learning had a significant effect on the students’ combinatorial thinking skills in the experimental class.

The students in the experimental class showed that their combinatorial thinking skills were higher compared to the control class. The results showed that the improvement on the learning outcomes and students' combinatorial thinking skills were seen in the post-test. Experimental class scores were significantly better as Research Based Learning was implemented in the experimental class to improve combinatorial thinking skills. The students in the experimental class were taught by using Research Based Learning, in which they had an understanding of the concepts to help each other, therefore, Research Based Learning was great in improving the students' combinatorial thinking skills

The results of this study are in line with the research carried out by [1], she pointed out that the achievement of the average cognitive results from a class in which Research Based Learning technique was used, was found to be significantly higher rather that the average scores in control class. Based on these findings, it can be confirmed that the project technique was effective in achieving the targets in cognitive outcomes. The results of this study are also in accordance with the research done by [5], who mentioned that Research Based Learning Method was very helpful for the students to pass the determined standard. These results showed us that the learning objectives also played an important role in solving the students’ problems. This learning objective could also be stated as the objectives of mastery and achievement [14]. According to the learning objective, the students focused on learning, mastery, appropriate with the standards, improving new skills, improving or developing competencies, trying to solve something challenging and trying to increase the understanding and the knowledge [15]. Research Based Learning must be applied in many departments to expand the researches in all institutions, and to apply the researches in education, the relationship between the research and teaching.

5. Conclusion

Based on the research that was conducted, it shows that the application of Research Based Learning had a significant effect on the students' combinatorial thinking skills in the experimental class. The students' combinatorial thinking skills in the experimental class were compared to the control class. The results showed that the improvement on the learning outcomes and students' thinking combinatorial skills were seen from the post-test. The experimental class scores were better since it is supported by Research Based Learning in improving combinatorial thinking skills. Hence, Research Based Learning was great to improve the students' combinatorial thinking skills.

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References

[1] Alacapinar F. 2008. *Effectiveness of Project Based Learning*. Eurasian Journal of Educational Research (EJER) **32** 17-34.
[2] Arifin, P. 2010. *National Confference of Research Based Learning*. Bandung: Institut Teknologi Bandung.
[3] Bassey S W & Umoren G. 2009. *Cognitive Styles, Secondary School Students' Attitude And Academic Performance In Chemistry*. Akwa Ibom State . Nigeria.
[4] Blackmore P, Fraser M. 2007. *Researching and teaching*: Making the link. In P. Blackmore & R. Blackwell (Eds.), towards strategic staff development in higher education. Maidenhead, UK: McGraw-Hill International. pp. 131-141.
[5] Fatimah, Is dan Anas, A Khoirul. 2018.*Incorporating Research in Chemistry Courses: Research Data-Based Learning.* International Journal of Engineering & Technology **7**476-479
[6] Godino J D, Batanero C, and Font V. 2007. *The onto-semiotic approach to research in mathematics education.* The International Journal on Mathematics Education **39** 127-135
[7] Hobri, Dafik, & Hossain, A. 2018.*The Implementation of Learning Together in Improving Students' Mathematical Performance*. International Journal of Instruction 11**2** 483-496.
[8] Guilford, J. P. 1972. *Intelect and the gifted*. Gifted Child Quarterly **16**175-184, 239-243.
[9] Hilton, P.R., Brown, C., Mc Murray, I&Cozens, B. 2004.*SPSS explained. Routledge*. Inc New York.
[10]Kotzer, S., & Elran, Y. 2012. *Learning adn teaching with Moodle-based E-learning environments*, combining learning skills and content in the field of Math and Science & Technology. *1st Moodle Research Conference* . Israel. 122-131.
[11]Poonpan S and Siriphan S. 2001. *Indicators of Research-Based Learning Instructional Prosess* : ACase Study of Best Practice in a Primary School. Disertasi. Faculty of Education, ChulalongkornUniversity Phaya Thai. Bangkok. Thailland
[12]Rezaie M, Gooya Z. 2007. *What do I mean by combinatorial thinking?* Procedia Social and Behavioral Sciences **11** (2011) 122-126.
[13]Sarwono, Jonathan. 2006. *Quantitative and Qualitative Research Methods.* Yogyakarta: Graha Ilmu
[14]Schapper, J., & Mayson, S. E. 2010.*Research-led Teaching: Moving from a Fractured Engagement to a Marriage of Convenience*. Higher Education Research & Development **29** 641-651.
[15]Schunk, DH. 2012. *Learning Theories and Educational Perspective Sixth Edition.*Yogyakarta: Student Literature.
[16]Sternberg R & Grigorenko E. 2001. *Practical Intelligence and the Principal*. Yale University. Yale

IOP Conf. Series: Journal of Physics: Conf. Series **1211** (2019) 012088 doi:10.1088/1742-6596/1211/1/012088

[17]Suntusia, Dafik, Hobri. 2019. *The Effectiveness of Research Based Learning in Improving Studenst' Achievement in Sloving Two-Diimensional Artithmetic Sequence Problem*. International Journal of Instrucyion**12** 17-32.

[18]Syaibani, Hassan A. 2016. *Research Based Learning In Increase The Ability Of Student's Creative Thinking*. In: Sunardi dkk, editor. Opportunities of Mathematics and Learning in Facing Masyarakat Ekonomi ASEAN (MEA); 2016 October; Jember, Indonesia. Jember: Jember University. 209-213.

[19]Widiyastuti E and Utami S. 2017. Math. *Combinatorial Thinking Skill Description*. Journal of Mathematics Education. Alpha Math Vol **3**

[20]Witkin, H.A., et.al. (1997). *A.Field-Dependent and Field-Independent Cognitive Style and Their Educational Implications.* Journal Review of Educational Research **47.**