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The Implementation of research based learning in developing the students mathematical generalization thinking skills in solving a paving blocks design problem

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Abstract: The mathematical generalization process is a powerful thinking skills that should be present in mathematical learning. Especially in the higher education students, the lecturer should maintain this process to sharp their deep understanding to form their mathematical generalization thinking skills. This paper aims to study the implementation of research based learning in developing students mathematical generalization thinking skills in solving a paving blocks design problems. The method used in this research is a mix method, which combines the qualitative and quantitative methods. The research subjects consisted of 40 students of experiment class and 35 students of control class. The pre test and post test were applied into two research classrooms to solve a square colored paving blocks design problem. Students are encourage to construct a design with two colors, namely blue and white and consider the beauty as a key factor too. The problem arising in the construction of a colorful paving design is how to develop a colored paving blocks decoration such that the number of colored paving respecting to several size of $n \times n$ form an arithmetic sequence, as well as the number of colored paving required can be determined easily. Once the problems done by the students, we analyze their level of three category of their mathematical generalization thinking skills, namely *low, medium, high* under the implementation of a research based learning. The results show, after the application of research based learning, 23% students are categorized in low level of mathematical generalization thinking skills, and 27% are categorized medium level of mathematical generalization thinking skills and 50% are categorized in high level of mathematical generalization thinking skills. The statistic analysis of students t-test score at level of confidence 5% is 0.041 (0.041< 0.05), which is significant. Thus, we conclude the implementation of research based learning can improve the students mathematical generalization thinking skills in solving a paving blocks design problem.

1. Introduction

Generalization and abstraction both play an important role in the minds of mathematics students as they are a good modality for studying a higher-level mathematical concepts. In the second chapter of the Springer book *Advanced Mathematical Thinking*, Dreyfus [1] defines generalization as the derivation or induction from something particular to something general by looking at the common things and expanding their patterns of validity. Dreyfus says that numerous mathematical objects such as equations, numbers, and functions can be expressed in the classroom in the context of generalization. But it can take more mental effort for students to generalize concepts, and according to my teaching experience, students tend not to try their best to generalize a mathematical concept if they do not receive good guidance from their teacher. There are several advantages to applying generalization, one of them the students can develop an advance thinking process of mathematical induction or deduction.

Another set of studies on generalization is researching ways to develop algebraic thinking at the school students. Kaput, *et al* [4] brought a comprehensive collection of research studies together that investigated the introduction of early algebra in elementary school in which generalization plays a crucial role. From outside of the mathematics education field, many educational psychologists researched how the thinking process manifests through the process of generalization. Vygotsky [9] considered that every concept is the result of a process of generalization.

The mathematical generalization of thinking skills is also very important especially in the advance of the P21 century era. These skills satisfy the needs of higher order thinking skills of students. In the future, students need a higher order thinking skills to survive in this century. With the ownership of higher order thinking skills, students will have the ability to solve some problems in their daily life. According to Sutarto, *et al* [7], there are five stages of the mathematical generalization process, namely (1) Developing basic ideas for solving mathematical problems, (2) Starting the development of mathematical patterns, (3) Expanding mathematical patterns, (4) Formalizing the obtained mathematical patterns, (5) Proving the truth of the pattern.

One of the mathematical objects that can train students related to the process of their mathematical generalization thinking skills is a paving blocks design problem. Construction of paving blocks in an open yard requires certain skills. Apart from requiring beautiness, also the most important thing is determining how many colored paving blocks are needed so that the construction process can be carried out effectively. With a good pattern and installation, including the color and the exact number paving block are needed, it will make easier for paving businessmen to decorate.

In this study, we applied a research based learning in accordance with the purpose of developing students mathematical generalization thinking skills in solving a paving blocks design problem. In the research based learning, students work individually or in groups to solve the paving blocks design problems to find new and unique decoration, continued by finding the general formula of the obtained pattern. Students are encourage to find a unique pattern which is different with other students. They then should generalize and develop the formula of the pattern. Their process of finding the pattern, generalisation and finding formula of the pattern become a main activity of students and it becomes a data source of the research activity apart from the data collected from students achievement test.

A research based learning (RBL) is a concept referring to teach and learn strategy relating to research and learning Sota, *et al* [5]. According to Tohir, *et al* [8], RBL is a learning method which involves contextual learning, authentic learning, problem-solving, cooperative learning, hands-on & minds on learning, and inquiry discovery approach. The RBL implementation aims to encourage the development of higher-order thinking skills on the part of both lecturers and students. Yudha, *et al* [2] explains that Research Based Learning has advantages for learners, encompassing increased motivation to learn, improved ability to do important work, and improved problem solving skills, especially when dealing with complex problems. Furthermore, it offers the benefits in developing and practicing

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communication skills, improving learners' skills in managing resources, providing experience in organizing projects, assisting in the allocation of time and resources, other sources to accomplish the task, and providing a learning experience that involves learners. At this stage, students are more likely to be involved in learning (student-centred learning) [3]. Therefore, lecturers play more role as facilitator during discussion, when possible to help students dealing with any problems. The main characteristic of the implementation Research Based Learning is the existence of Research Group (RG). RG is a group of researchers who work on teaching, research, community services activities, and supervising on specific research of interest to solve a fundamental problem from a simple to complex problem, from new theory to new application.

Based on suntusia, *et al*'s research model [6], the syntax of RBL especially dealing with solving paving blocks design problems are: *First, the students are asked to understand the proposed problems of paving blocks design problems, student are encouraged to develop a problem solving strategy to the given problem, setudents gather information and locate some relevant literatures. Second, the students are encouraged to identify partial solution and start to generalize locally based on the pattern recognition. Third, the students conduct an analysis on the global pattern to generate two-dimensional arithmetic sequence problem. Fourth, the students complete the whole process generalization to produce an algorithm of desired decoration of paving blocks design problems. Fifth, the students write an RBL report supervised by the research group members.*

The purpose of this research was to investigate the effectiveness of Research-Based Learning compared with conventional model in solving paving blocks design problems. By paving blocks design problems, we mean the problem in the following. This concept was introduced in Sutarto, *et al* [7].

Definition 1*. Let n be natural numbers. The construction of nxn colored paving blocks design will satisfy the effectiveness of decoration if its ordered pair of color forms an arithmetic sequence and the obtained color pattern meet a beauty feature as possible.*

In this study, the students were asked to find a paving design with two colors, namely blue and white and the beauty as a key factor. The principle of construction of the colorful paving blocks design is how to determine the pattern uniquely and the number of colored paving needed. Below are the example of students potential decoration. The two paving colors are decorated such that the ordered pair of the number of color required form an arithmetic sequence as as follows.

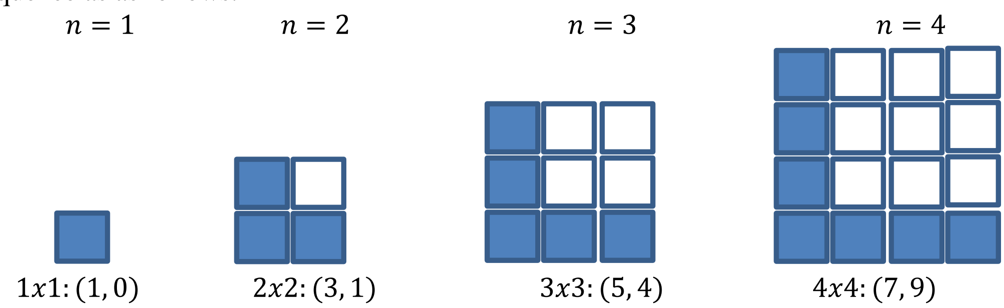


Figure 1. The example of potential paving blocks design

2. Methods

2.1. Reseacrh Focus

The research focuses on analyzing students mathematical generalization thinking skills in solving paving design problems. This research is intended for students of mathematics education in the semester IV of the academic year 2017/2018.

2.2. Sample

The subjects of this study were fourth-semester students of class A and B of mathematics education department of FKIP Jember University. Class A is used as an experimental class with 40 students, while class B is used as a control class with 35 students.

2.3. Procedure and Instruments

The method used in this study is a mixed method, which is a combination of quantitative approaches and qualitative approaches. The researcher collects quantitative data as main information, then qualitative data is used as supplementary data. Quantitative data collection instruments in the form of test questions respecting to paving blocks design problems of the mathematical generalization thinking skills and student worksheets that contain essay questions. The worksheet result will be assessed based on the assessment rubric of the students generalization skills. For qualitative data collection in the form of interviews and observations on the implementation of research-based learning in the classes, namely control or experiment classes. Research-based learning is applied to the experimental class while conventional learning method is applied to the control class.

Table 1 showed the triangulation method in which the qualitative data were triangulated with the quantitative data to identify the effect of the research-based learning on the material of dominating set

Table 1. Quasy Experiment design

Group	Pre-test	Treatment	Post-test
Control Class	P_1	Convensional	P_2
Experiment Class	P_3	RBL	P_4

Note that P_1 and P_3 are the score of the students pre-test while P_2 and P_4 are thescore of students post-test.

2.4. Data analysis

The two classes of the experimental class, and control class were both given a pre-test and post-test. Quantitative analysis using the Independent Sample T-test, but before data analysis was carried out, we did the homogeneity and normality test. Descriptions and inferential statistics were applied to analyze qualitative data. Information from the data, namely frequency, average, and the standard deviation is used to describe statistical data about the application of RBL in the experimental class. The Independent Sample T-test was used to compare the mean of the two groups of classes, considering a significant difference at the 0.05 level. Qualitative analysis is related to student activities mainly in (1) Developing basic ideas for solving mathematical problems, (2) Starting the development of mathematical patterns, (3) Expanding mathematical patterns, (4) Formalizing the obtained mathematical patterns, (5) Proving the truth of the pattern. Each indicator will be assesed on every sub-indicator with involve four indicators, namely (1) Poor, (2) Fair, (3) Good, and (4) Very Good. The total of sub-indicators are seventeen items. Thus the maximam score is 68. Finally, the category of mathematics generalization thinking skills will be classified into three categories, namely low ($17 \leq x \leq 33$), medium ($34 \leq x \leq 50$), and high ($51 \leq x \leq 68$).

3. Research Findings

The following we give the research results. The findings concerned with the analysis of the student's mathematical generalization thinking skills in solving paving blocks design problems under the implementation of research-based learning. We circulate pre-test and post-test to both classes, either experiment class or control class. We also distribute a student worksheet to the research respondents. By using a student t-test, we analyzed the obtained data initiated by homogeneity and normality analysis. Based on the results of the pre-test analysis between the two classes it can be seen that the two classes have the same variant. It implies that they are homogenous. The results of the pre-test of 75 students showed that the students mathematical generalization thinking skills of 35 students in control class were 8% or as many as 3 students have high level of thinking skills, 29% or as many as 10 students have medium level of thinking skills, and 63% or 22 students have low level of thinking skills, while for 40 students in experimental class 10% or as many as 4 students have high level of thinking skills, 30% or as many as 12 students have medium level of thinking skills, and 60% or as many as 24 students have low level of thinking skills. The results of the two classes can be depicted in Figure 2.

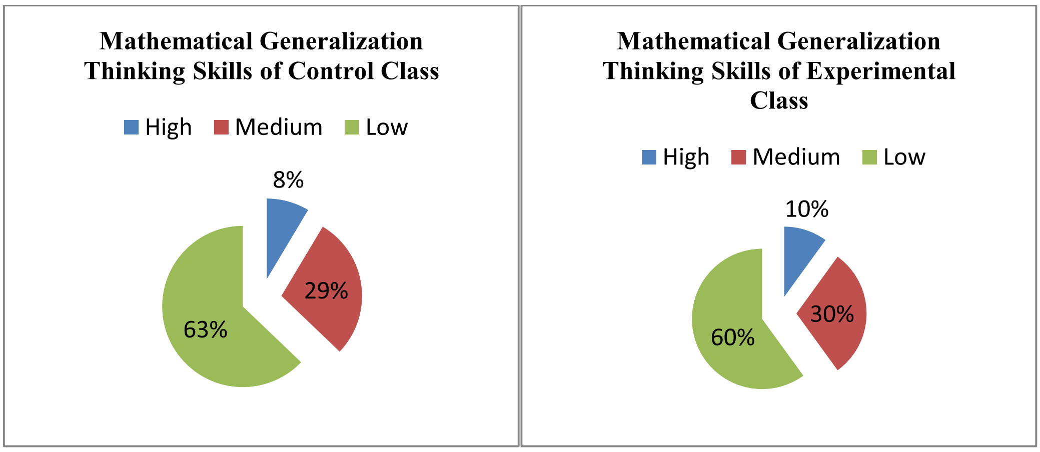


Figure 2. The Distribution of students mathematical generalization thinking skills of pre-test

Prior to implement the research based learning, the homogeneity analysis were implemented to both classes of 75 students all together by using a student t-test. In Table 2 and Table 3, the homogeneity test results from the pre-test, the value (Sig.) of the homogeneity variances regarded to the t-test table is 0.686. Thus it concludes that the assumption of variance homogeneity is fulfilled since the obtained significance value is more than 0.05. It implies that the mean of students mathematical generalizations thinking skills score of the two classes are not significantly different or homogeneous.

Table 2. The homogenity test of pre-test

Test of Homogeneity of Variances			
Class			
Levene Statistic	df1	df2	Sig.
.164	1	73	.686

Table 3. The mean score of pre-test result of control class and experimental class

Report				
Group	N	Mean	Std. Deviation	Std. Error Mean
The Pre-test Score of Control Class	35	48.7429	10.38195	1.75487
The Pre-test Score of Experimental Class	40	45.3000	8.82363	1.39514

The pre-test results distribution is confirmed on 0.05. The average score of pre-test results of the control class is 48.7429 (SD = 10.38195) while in the experimental class is 45.3000 (SD = 8.82363). The difference between the mean score of pre-test of the control class and the experimental class is [t (75) = 0.223, p> 0.05], which means that the mean difference between the two classes is not significant.

Table 4. The levene's test for equality of variances 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
Sc	Equal	1.51	.22	1.55	73	.125	3.44286	2.21757	-.97676	7.862

ore	variances assumed	3	3	3						47
	Equal variances not assumed			1.536	67.169	.129	3.44286	2.24187	-1.03173	7.91744

Table 4 also shows that the results of the t-test indicate the sig value. (2-tailed) from the independent sample t-test of the pre-test distribution was 0.125 (p> 0.05), thus it is not significant. This implies both classes are homogeneous.

We are now describing the research result of after the implementation of research based learning. Prior to show the result we need to explain the result of normality test of data generated from the post-test result as follows.

Table 5. 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	.114	35	.200*	.972	35	.508
	The Post-test Score of Experimental Class	.119	40	.160	.948	40	.064

The normality test of each research group generated from post-test showed that the significance value of each control class indicates a value of 0.508, and the experimental class indicates a value of 0.71. The significance values of the two classes are greater than the value of α (0.05), which means that the two classes of research samples are normally distributed.

Tabel 6. The standard deviation of post-test results

Report				
Group	N	Mean	Std. Deviation	Std. Error Mean
The Post-test Score of Control Class	35	61.9429	10.06433	1.70118
The Post-test Score of Experimental Class	40	66.9000	10.52421	1.66402

Table 6 presents the average post-test results of the control class and the experimental class. For the control class, its average is 61.9429 (SD = 10.06433), while the experimental class is 66.9000 (SD = 10.52421). Thus, it can be concluded that the average of the experimental class is better than the control class, after the implementation of research-based learning. Furthermore, the question is whether the mean difference is due to the implementation of research-based learning or not. Table 7 shows that the value of sig. (2-

tailed) of the independent t-test is [t (75) = 0.041, p <0,05]. It implies that difference shows a significant difference between the two classes. Finally we can conlude that the is a significant impact of the implementation of research based learning in improving the students mathematical generalization thinking skills in solving a paving blocks design problem.

Table 7. The independent t-test of the experimental class and control class

		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	.64	.686	-2.077	73	0.041	-4.95714	2.38690	-9.71422	-.20007
	Equal variances not assumed			-2.083	72.403	0.041	-4.95714	2.37971	-9.70055	-.21374

Students who have low mathematical generalization thinking skills in control class change from 63% to 52%, while students who have medium mathematical generalization thinking skills change from 29% to 37%, and students who have high mathematical generalization thinking skills change from 8% to 11 %. The change of the students mathematical generalization thinking skills in the experimental class is more significant, students who have low mathematical generalization thinking skills change from 60% to 23%, while students who have medium mathematical generalization thinking skills change from 30% to 27%, students who have high mathematical generalization thinking skills change from 10% to 50%. The results of the observation of the two classes can be seen in Figure 3 below.

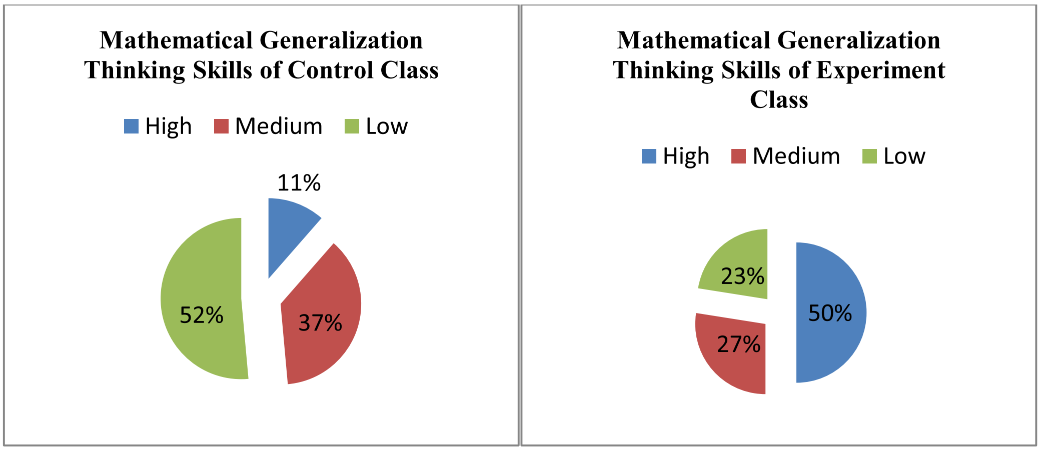


Figure 3. The Distribution of students mathematical generalization thinking skills of post-test

Furthermore, from the observations result, it shows that students mathematical generalization 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 mathematical generalization thinking skill level, second work shows the students with medium mathematical generalization thinking skill level, and the last work shows the students with high mathematical generalization thinking skill level.

The first work shows how the students start to assign the color consisting of two colors combination of blue and white on the paving blocks design of nxn. The pattern obtained by these students is quite simple, they just start with the simple color combination, even in this decoration they just display the paving blocks coloring horizontally by skipping one row alternately, namely blue-white-blue-white. Furthermore, students are asked to count the number of required blue and white paving, but they are only able to count for the paving blocks up to 6x6, otherwise, they can not generalize the ordered pair of the blue-white colors.

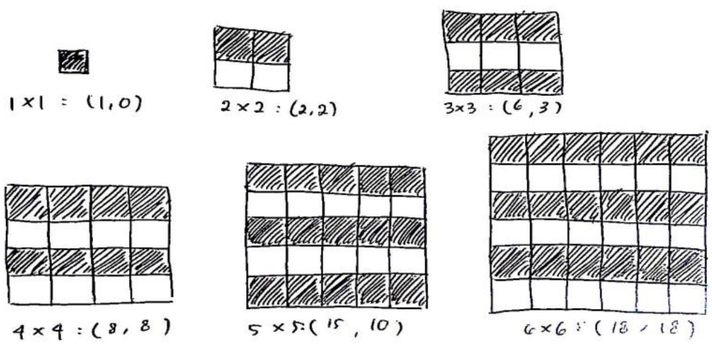


Figure 4. The students work on low mathematical generalization thinking skill level (S1)

In order to know deeply the student activities of their mathematical generalization process, we use a potrait phase. The portrait phases are taken to draw the graph of their mathematical generalization thinking proces under the implementation of research based larning. 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 mathematical generalization thinking process in the following portrait phase, see Figure 5. Figure 5 shows the process of mathematical generalization thinking the skill of subject 1 in solving paving blocks design problem. Subject 1 starts from 1a to stage 1b, subject 1 identifies the characteristic of paving blocks coloring and applies some case. then S1 goes ahead to the step 2a to 2b and to 3a, this shows that S1 can identify the pattern of paving blocks coloring. However, S1 goes back to 1a, it indicate s1 is not convinced his work.

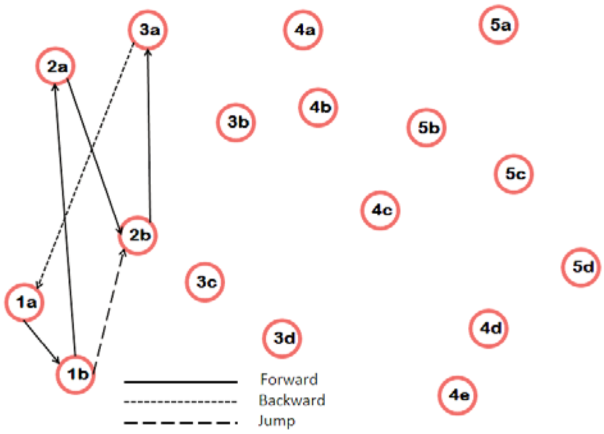


Figure 5. The students work on low mathematical generalization thinking skill level (S1)

The second work shows how the students start to assign the color consisting of two colors combination of blue and white on the paving blocks design of nxn. The pattern obtained by these students is quite complex. They start assigning color diagonally continued by right diagonal coloring. The obtained decoration is very nice as the number of blue required and white requred are not the same. It adds the beauty of color decoration of paving blocks design. Furthermore, students can count easily the paving blocks up to 6x6, even they can generalize the ordered pair of the blue-white colors up to n-size of the square paving. However, students can not develope the bijective function of the color on the n x n paving blocks. They fail to locate the matrix representation of the paving square and converting into mathematical expression.

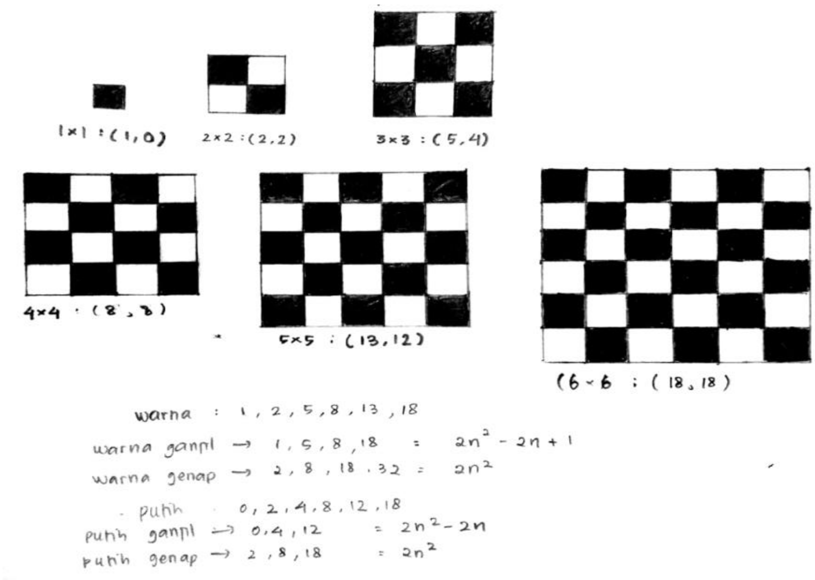


Figure 6. The students work on moderate mathematical generalization thinking skill level (S2)

To know deeply the student activities of their mathematical generalization process, we use a potrait phase. The portrait phases are taken to draw the graph of their mathematical generalization thinking proces under the implementation of research based larning. 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 mathematical generalization thinking process in the following portrait phase, see Figure 7. Figure 7 shows the process of mathematical generalization thinking the skill of subject 1 in solving paving blocks design problem. S2 starts from 1a jump to 2a, and continue to 2b and to 3a. However S2 goes back to 1b and jump to 3b, next go to 3c, jump to 4a and goes to 4b. S2 goes back to 1b as S1 can not expand the mathematical pattern.

The third work shows how the students start to assign the color the paving blocks design of nxn with complex color combination. The number of blue required and white requred are not the same, thus it also adds the beauty of desired color decoration. Furthermore, students can count easily the paving blocks up to 6x6, even they can generalize the ordered pair of the blue-white colors up to n-size of the square paving and surprisingly they can develop the bijective function of the color on the n x n paving blocks.

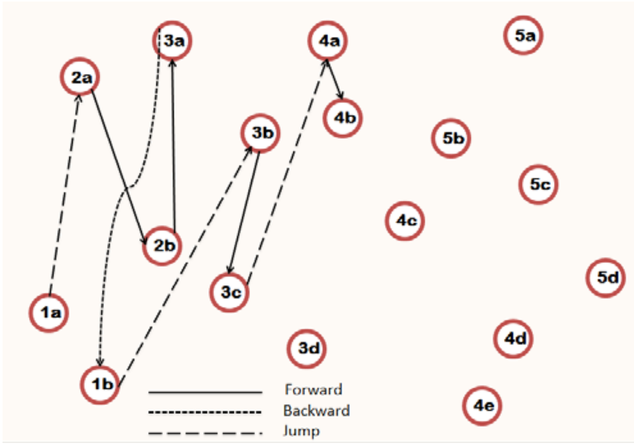


Figure 7. The students work on medium mathematical generalization thinking skill level (S2)

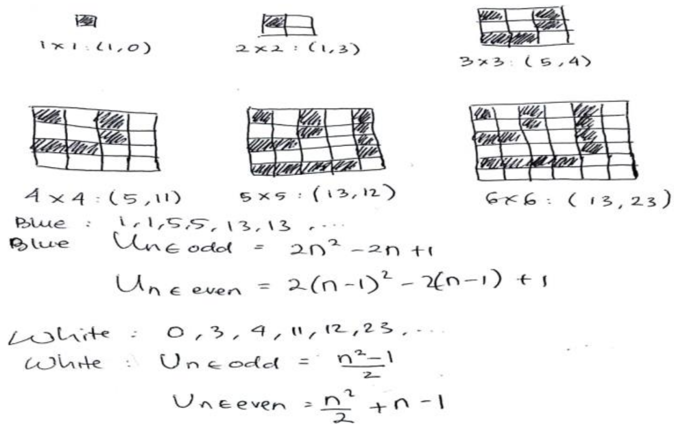


Figure 8. The students work on high mathematical generalization thinking skill level (S3)

To know deeply the student activities of their mathematical generalization process, we use a potrait phase. The portrait phases are taken to draw the graph of their mathematical generalization thinking proces under the implementation of research based larning. 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 mathematical generalization thinking process in the following portrait phase, see Figure 9. Figure 9 shows the process of mathematical generalization thinking the skill of subject 1 in solving paving blocks design problem. S3 starts from 1a, he goes to 1b, 2a, 2b, 3a. S3 jump to 3c and goes to 3d, 4a, 4b, 4c, 4d and jump to 5a, and jump again to 5d. S3 is a subject research who can work well up to the last step. S3 is quite convident to his work, and able to expand the pattern and develop the bijection.

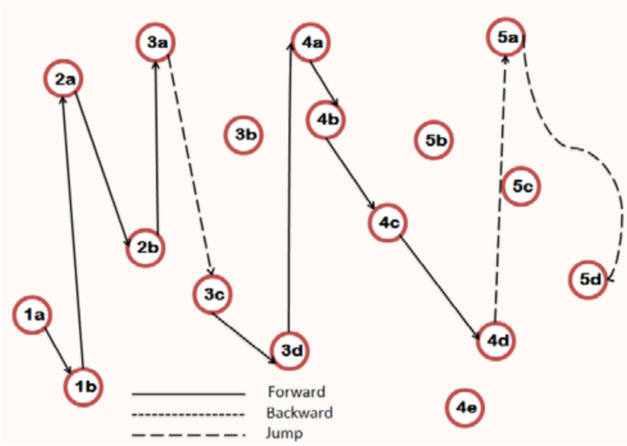
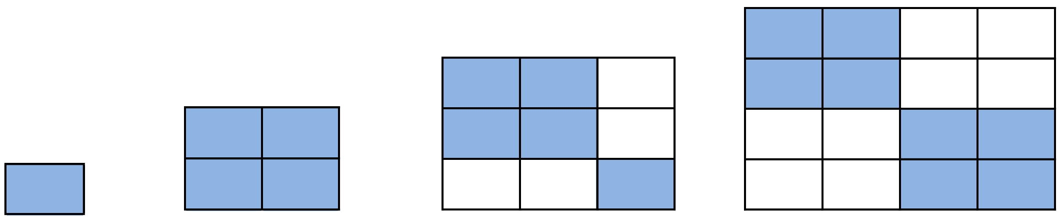


Figure 9. The students work on high mathematical generalization thinking skill level (S3)

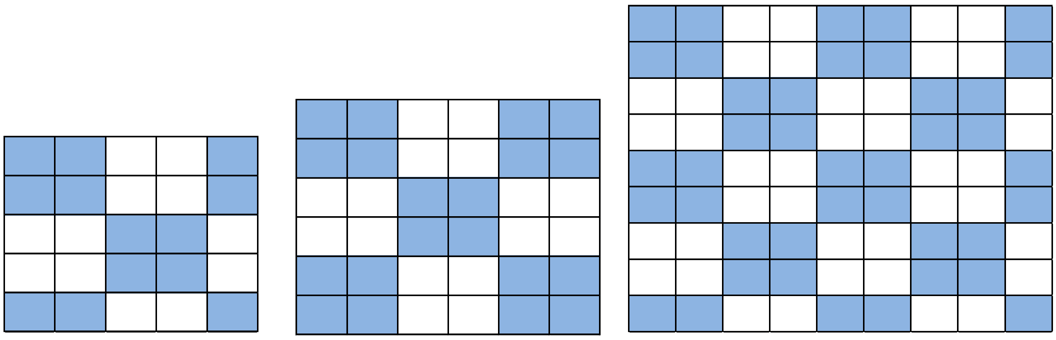
4. Generalization Process and Discussion

From the student's work above under the research-based learning, the third work shows the suitable and very complex paving blocks design. It also fulfills the principle of the beauty of decoration. This design can be used in daily life and can be recommended to paving blocks designer to be implemented to the customer order. To complete the suggestion to the supplier we need to develop the complete mathematical generalization such that it is not only knowing the number of required paving blocks of either blue and white color but we need also to show the injective function of the blue and white color on the (n x n)-matrix representation of the paving blocks design.



1×1: (1,0) 2×2: (4,0) 3×3: (5,4) 4×4: (8,8)

Figure 10. The students work on high mathematical generalization thinking skill level



5×5: (13,12) 6×6: (20,16) 9×9, (41, 40)

Figure 11. The students work on high mathematical generalization thinking skill level

The required number of paving blocks of blue color of *nxn* squre form an arithmetics sequence as follows: 1,4,5,8,13,20,25,32,41,52. Thus, the n^{th} term of this sequence gives $U\,n\,\epsilon\,odd = 2\left(\frac{n+1}{2}\right)^2 + 2\left(\frac{n+1}{2}\right) + 1$, and $U\,n\,\epsilon\,even = 4\left(\frac{n}{2}\right)^1 - 8\left(\frac{n}{2}\right) + 8$. The required number of paving blocks of white color of $n \times n$ square form an arithmetic sequence as follows: 0, 0, 4, 8 , 12, 16, 24, 32, 40, 48. Thus, the n^{th} term of this sequence gives $U\,n\,\epsilon\,odd = 2\left(\frac{n-1}{2}\right)^2 - 2\left(\frac{n-1}{2}\right)$ and $U\,n\,\epsilon\,even = 4\left(\frac{n}{2}\right)^2 - 4\left(\frac{n}{2}\right)$. Furthermore, the injection function of the paving blocks design decoration of two colors blue (B) and white (W) is $f(x_{i,j}) = B \longrightarrow$ 2i = 2j, $f(x_{i,j}) = W \longrightarrow otherwise$

Finally, we understand how easy to have a best paving blocks design decoration of two colors 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 mathematical generalization thinking skills in solving a paving blocks design problem. It is in line with Tunisia et.al research (2018), 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 3% of students are very inactive, 4% of students is inactive, 8% of students hesitates, 39% of students are active, 46% of students are very active. The fact shows the linearity this research with other research abotu the implementation or research-based learning holds, see Shunk (2017), Chartrand et.at (2009).

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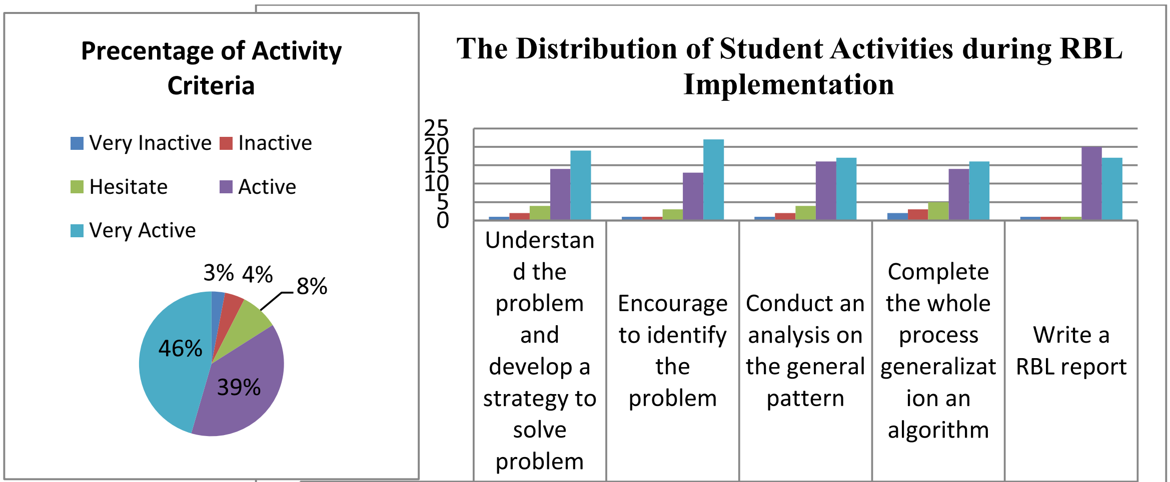

	Understand the problem and develop a strategy to solve problem	Encourage to identify the problem	Conduct an analysis on the general pattern	Complete the whole process generalization an algorithm	Write a RBL report
Very Inactive	1	1	1	2	1
Inactive	2	1	2	3	1
Hasitate	4	3	4	5	1
Active	14	13	16	14	20
Very Active	19	22	17	16	17

Figure 12. The Observation results distribution of all subjects in the experimental class

Based on Figure 11 it reveals that students became competent in manipulating the color such that they can get a best paving blocks design decoration of two colors of blue and white. 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 mathematical generalization 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 otu by Salman et. al. (2009) stated taht 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.

5. Conclusion

We have finished presented the result finding of the implementation of research based learning in developing the students mathematical generalization thinking skills in solving a paving blocks design problem. The results show, after the implementation of research based learning, 23% students are categorized in low level of mathematical generalization thinking skills, and 27% are categorized good level of mathematical generalization thinking skills and 50% are categorized in high level of mathematical generalization thinking skills. the statistic analysis of students t-test score at level of confidence 5% is 0.041 (0.041< 0.05), which is significant. thus, we conclude the implementation of research based learning can improve the students mathematical generalization thinking skills in solving a paving blocks design problem.

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