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The Effectiveness of Discovery Based Learning Implementation through Improving Students' Innovative thinking Skills in solving Open-Ended Task of Pattern Generalization

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***Abstract*—** *The aim of this study is to know the result of Discovery Based Learning Implementation through Improving Students' innovative thinking skills in solving open-ended task of pattern generalization. The method used in the study is a combination between quantitative and qualitative method called mixed method. Learning model of discovery based learning in the research manages to improve students' innovative thinking skills in solving open-ended task of pattern generalization indicated by the insignificant difference t-test score between the pre-test score of control class and experiment class [t (48) = -6.897, p > 0.005]. It results post-test score of control class 71.88 (SD = 5.944) and experiment class 83.88 (SD = 6.110). Hence, it indicates that both of the average post-test score are significant [(48) = -12.00, p < 0.005]. Discovery Based Learning (DBL) model in this study may improve students' innovative thinking skills to solve open-ended task based on the result of questionnaire and interview. In addition, students are able to observe, to find new patterns and to present what they obtain.*

***Keywords*— Discovery Based Learning, Innovative Thinking Skills, Open-Ended, Pattern Generalization.**

I. INTRODUCTION

The development of education in current globalization and technology era demands the students to improve their innovative thinking ability. Innovative thinking ability is one of the demands of 21st century education implemented into curriculum of 2013. It is aimed to prepare youth generation to be able to deal with globalization era. It has four basic skills, namely (1) critical and problem solving skills, (2) collaboration skills, (3) communication skills, and (4) creativity and innovation skills commonly called as 4C's. This is part of developmental international movement focused on the skills needed by learners to get ready for the success in rapid transformation of digital society.

The concept of learning in this model leads students to have authorities to arrange and to run the learning program as well as carrying evaluation on the program independently. Therefore students do not only have skill, but also it is good way in solving a problem. One of the model which is going to be applied is Discovery Based Learning (DBL) learning model. It is a learning theory interpreted as a kind of learning process which happens if students are not delivered with a lesson in its final form, yet they are expected to organize it by themselves. "Discovery Learning is an inquiry-based approach in which students are given a question to answer, a problem to solve, or a set of observations to explain, and then work in a largely self-directed manner to complete their assigned task and draw appropriate inferences from the outcomes, discovering the desired factual and conceptual knowledge in the process" (Prince et al, 2006:123)

The discovery based learning model places more emphasis on previously unknown findings by providing problems engineered by the teachers, as it has similar principle with inquiry. The problem is not engineering result, therefore students have to exert their skills and thought to get findings in the problem through the research process.

Innovative thinking skills can be defined as students' skills in delivering several possibility answers and solving the problem. To find out the students innovative thinking process, lecturers may give an open-ended mathematic problem to the students. It is based on the Mihajlovic and Dejic statement that one of the advantages of using open-ended problems is to develop

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students' innovative creative thinking. Russeffendi also reveals that in order to encompass the creative people, it is better to use open questions (divergent) called as divergent questions. It demands the interviewees to presume, to hypothesize, to check hypothetically, to review the completion thoroughly and then make decisions.

Number pattern on discrete mathematics based on this image patternselected by a consideration of task which exist in this sub-subject is open-ended.Either mathematicopen-ended questions or problems can lead students to find different answers through different ways (discovery). Pattern generalization material can be used to measure the students' innovative thinking ability. Meanwhile, the research subject is students of Universitas Jember.

As formulation of the problem, the objective of this research is to describe discovery based learning model in solving an open-ended problem toward students' innovative thinking as well as to figure out the students' skills effectiveness which is based on each indicator criteria whether they are able to finish well and correctly or not.

In this research, the control group receives a traditional teaching model (lecture), while the experimental group receives discovery based learning model. Researcher uses pre-test and post-test design and mean scores comparison. Findings obtained by students reveal that discovery based learning model has significant effect on mathematic achievement. In their experimental study, researcher compares the effect of a discovery based learning model with a traditional teaching model (lecture). The aim of this study is to identify discovery based learning model effect in students' mathematic achievement explained as follows: (1) to examine the influence of discovery based learning model in improving students' innovative skills to solve pattern generalization problem, (2) to identify on discovery based learning model in improving innovative skills by performing an open-ended task.

II. METHOD

This research uses quantitative and qualitative research. Quantitative research used in this research is quasi-experimental design, while triangulation method comes from qualitative research. Triangulation method is multi-method conducted by a researcher when collecting and analysing data. It demands to examine and to analyse students' capability in solving an open-ended problems with qualitative approach, so the researcher tries to collecting the data from lecturers and students. The population in this study are 2 classes of PPG students who take discrete mathematics courses, which is totally 48 students. Sources of this research are discrete mathematics lecturer, validator, and questionnaires. The researcher uses observation, interview, test and documentation as method of data collection, while the research instruments are interview guide, validation sheet, questionnaires sheet, and test result.

There are three stages in this research namely preparation stage, implementation stage, final stage of the research. Preparation stage includes establishing research group and developing LKM, and then implementation stage covers learning process; Research Activity Test (RAT). In this stage, it includes (1) giving main information about materials, (2) showing results of lecturers' research in research group related to material which is going to be used, (3) giving assignments about (a) main research content, (b) research process, (c) analysing process, (d) drawing conclusion, (e) scores of research content (4) collectively drawing conclusions with the lecturer. In addition, researcher get more involved, so lecture becomes a facilitator in the stage. Last stage is to process the data and analyses the data as well as drawing a conclusion.

This research is used by measuring result data of students' innovative thinking ability test through research activity test. It shows students' ability in establishing new different pattern for each student, thus every single students has their own pattern. Meanwhile, the results of open-ended LKM afterward are collected and analysed since it is needed to find out the effectiveness of discovery based learning on students' innovative thinking skills based on three indicators as follows: (1) think creatively, (2) work creatively with others, and (3) implement innovation. Whereas analysing quantitative data is conducted by normality test with a technique of one-sample kolmogorov-smirnov. If normality test shows distributed test score is normal, then statistical analysis used is parametric statistical analysis, which uses independent sample t-test technique. Otherwise if it is concluded that the data is not normally distributed, then the statistical analysis used is nonparametric statistical analysis which uses mann-whitney test technique.

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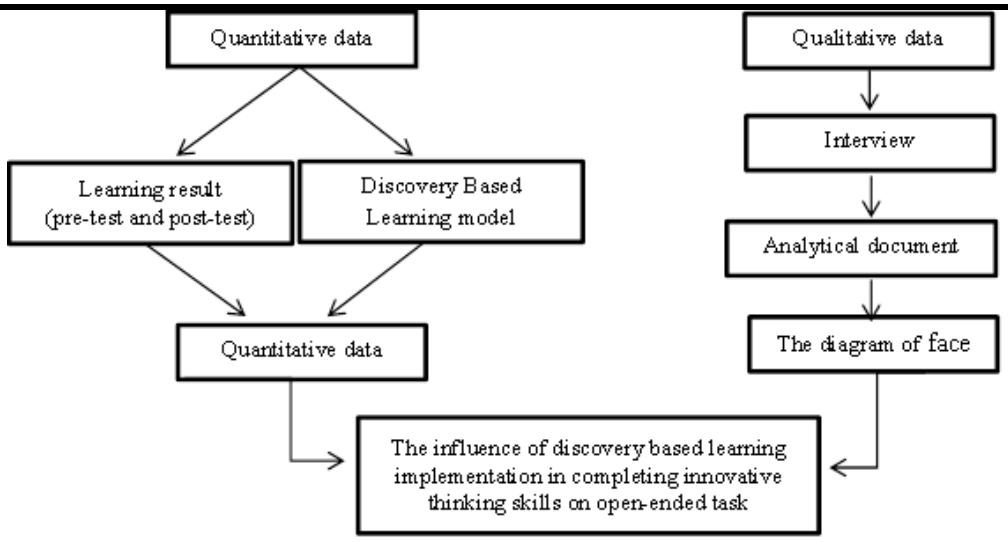

III. TASK

In this research, the researcher gives next task to the students related to discrete mathematics namely pattern generalization. Term of pattern in this case is colouring pattern on numerical pattern such as triangle, square, rectangular. The colouring pattern is based on numerical pattern which can be exploited until n-th and can be uncovered the formula, so that any n-th can be counted. A field is defined as exploited pattern among some required colours, but it forms colouring pattern in the field. If it is exploited, the colouring pattern automatically is exploited as well. n is term of -th or order of –th from a numerical pattern

Picture.1: Example of Pattern Generalization

x_{11}	x_{12}	x_{13}
x_{21}	$x2_{22}$	x_{23}
x_{31}	x_{32}	x_{33}

n=3

x_{11}	x_{12}	x_{13}	x_{14}
x_{21}	x_{22}	x_{23}	x_{24}
x_{31}	x_{32}	x_{33}	x_{34}
x_{41}	x_{42}	x_{43}	x_{44}

n=4

There is a colouring pattern (x_{ij}), so it is gained the yellow function pattern on

$$n = 3\ f_{(x_{ij})} = f(x_{11}, x_{13}, x_{23}, x_{31}, x_{32}, x_{33})$$

and white function on

$$n = 3\ f_{(x_{ij})} = f(x_{12}, x_{21}, x_{22},)$$

IV. RESULT AND DISCUSSION

The respondent in this research is PPG students of class A and B as many as 48 students, which are divided into 24 students on experimental group in class A and 24 students on control group in class B. This research runs for one month with 4 meetings. First meeting for experimental class, it focuses on observation about students' ability level in pattern generalization (pre-test). Second meeting is to distribute first students' worksheet, third meeting is to distribute second students' worksheet, and the last meeting is post-test. Meantime, to class control in the first meeting is also an observation toward student's ability level in pattern generalization (pre-test). Second meeting is continued with conventional teaching by delivering initial material such as colouring pattern along with the n-th formula. Third meeting talks about material to build function of colour variation, and the last meeting is post-test.

V. INSTRUMENT

Instruments used in this research are the test of student learning outcomes, students' worksheet, research activity test and interview.

VI. DATA COLLECTION AND DATA ANALYSIS

Control class and experimental class have completed pre-test and post-test, and resulted mathematics score as well as attitude value toward mathematics. The data of students' innovative thinking learning outcomes are analysed using kolmogorov-Smirnov with SPSS version 23 to know whether the data of students' innovative thinking learning outcomes are normal or not. Here are the outcomes of normality test by using kolmogorov- Smirnov test.

One-Sample Kolmogorov-Smirnov Test

		Kontrol
N		24
Normal Parameters [a,b]	Mean	71,88
	Std. Deviation	5,944
Most Extreme Differences	Absolute	,126
	Positive	,099
	Negative	-,126
Kolmogorov-Smirnov Z		,618
Asymp. Sig. (2-tailed)		,839

a. Test distribution is Normal.

b. Calculated from data.

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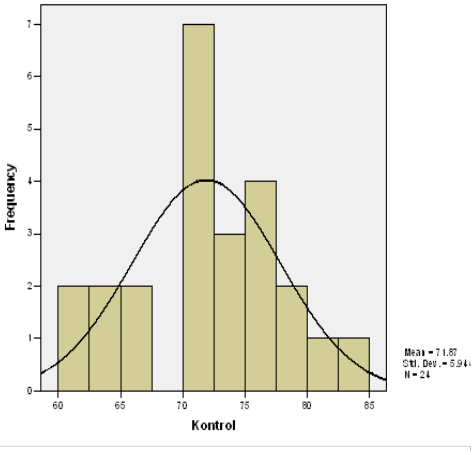
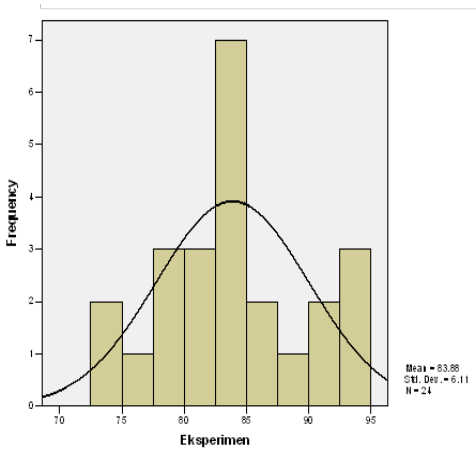
According to histogram image below, it appears the data (histogram) following normal curve pattern so that can be concluded the data distribution is normally distributed. It is similar with the kolmogorov- Smirnov statistical test outcome shown at the table 1 that score of sig. in Asymp. Sig. (2-tailed) is 0.839 for control class and 0.583 for experimental class. Sig. score on experimental class and control class are > 0.05 (level of significant). Therefore, it can be concluded that students' innovative creative thinking learning outcomes on the control and experimental class is normally distributed, so it can be conducted Independent Sample t-test.





VII. FINDINGS

The aim of this study as previously explained is to test the effectiveness of discovery based learning model in completing open ended task based on students' innovative skills. Independent Sample T-test is used to analyse pre-test and average score of students' post-test on control and experimental class. It is determined through examining of data normality. The students' learning outcome comes from pre-test and post-test score for each 48 students. Pre-test has a limitation of 0.05 and it indicates 0.3 for pre-test score. Since the limitation is between -1 and +1, the distribution is normal (Morgan et al, 2001). Second test for normality is divided by standard slope error which must be in negative two and positive two (SPSS, 1999). As it is shown on the table 1, pre-test mean score for control class is 71.88 (Std Deviation = 5.944) and experimental class is 83.88 (Std Deviation = 6.110).

Group Statistics

	Kelas	N	Mean	Std. Deviation	Std. Error Mean
Nilai	Kontrol	24	71,88	5,944	1,213
	Eksperimen	24	83,88	6,110	1,247

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Nilai	Equal variances assumed	,001	,977	-6,897	46	,000
	Equal variances not assumed			-6,897	45,965	,000

Independent Samples Test

		t-test for Equality of Means			
		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
				Lower	Upper
Nilai	Equal variances assumed	-12,000	1,740	-15,502	-8,498
	Equal variances not assumed	-12,000	1,740	-15,503	-8,497

Based on the table 4 above, it is clarified that Sig. score is 0.977 > 0.05 on Levene's test for equality of variances, thus the examination result of students innovative thinking skills is accepted as homogeneous. It means that to make a decision, it is used equal variencies assumed method. In this method, Sig. score (2-tailed) reaches 0.000 < (0.05). Hence, since the significance score is less than 0.05, it means H0 is rejected and Ha is

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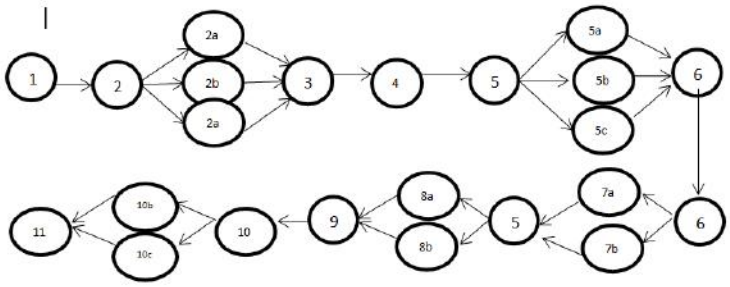
received. If it is connected with decision-making method, the examination result of students innovative thinking skills on experiment class is better than control class. Above quantitative analysis can be concluded that students innovative thinking skills on experiment class is better than control class. This happens because in the experiment class, it is used LKM which is included open-ended method with discovery based learning model, whereas in the control class, it applies LKM which has been prepared by the lecturer.

The data analysis from some sources helps the researcher to comprehend deeply the discovery based learning model. In this study, the researcher identifies some levels of understanding on discovery based learning model which emphasizes on task to find new ideas or concepts and to discover new patterns in a square.

Initial Point	Ending Point	Color
x_{11}	x_{14}	Yellow
x_{21}	x_{23}	White
x_{31}	x_{33}	White
x_{24}	x_{24}	Yellow
x_{34}	x_{34}	Yellow

Initial Point	Ending Point	Color
x_{11}	x_{11}	Yellow
x_{12}	x_{12}	White
x_{21}	x_{22}	White
x_{13}	x_{13}	Yellow
x_{23}	x_{23}	Yellow
x_{31}	x_{33}	Yellow

According to the data taken from discovery based learning model, estimation process of students in solving the problems is started from some steps such as, stimulation, problems statement, data processing, generalization, and then students internalizing the actions to be a process of finding, predicting the patterns, and discovering formula of function from specific coloring pattern determined. Research structure is served in phase diagram as follows.



1	**Doing observation**	7	**Understanding provided patterns**
2	Comprehending several generalization toward provided patterns.	7a	How many similar patterns obtained in the area
2a	Understanding the definition	7b	Restrictiveness of expansion in the patterns
2b	Knowing characteristics	8	Searching new coloring patterns from the surroundings
2c	Comprehending the function	8a	Appropriate with numerical pattern
3	Completing coloring pattern	8b	Inappropriate with numerical pattern
4	Observing coloring pattern from some provided patterns	9	Making one specific pattern
5	Finding out coloring pattern as well as numerical pattern shaped from several provided patterns	10	Considering nth-formula and function formula
5a	Determining nth-term	10a	Odd and even formula
5b	Deciding nth-formula	10b	Proving the formula
5c	Considering function formula	10c	Proving through coloring
6	Completing provided patterns	11	Expanding the patterns

1st Subject (High-score students)

According to innovative indicator (anonymous, 2015:3), students use wide range thinking to create ideas such as, debating, creating something new either good concept or extraordinary concept which is beneficial, colaborating their ideas, completing their ideas, analyzing their ideas, and evaluating their ideas in order to enhance innovative results. In addition, it also improves, implements, and communicates new ideas to others open-endedly as a response toward something new and different as well as working intensively in a group can give input and feedback as the result. To demonstrate a

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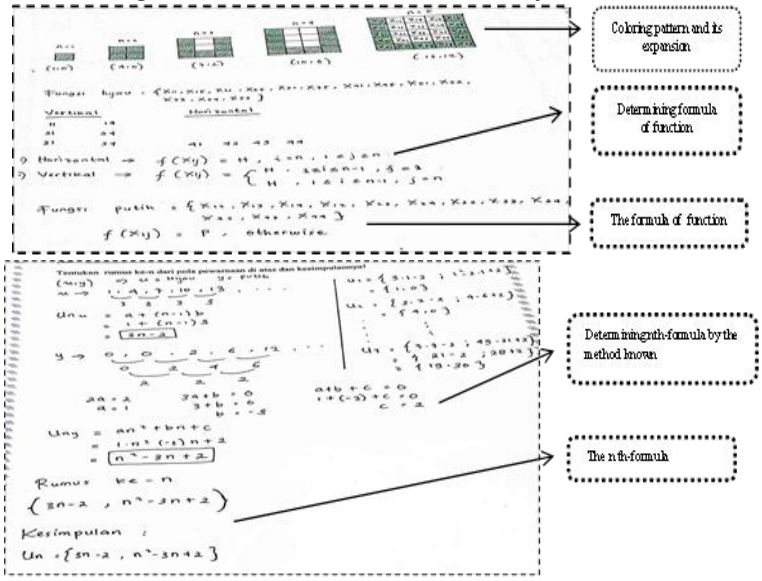
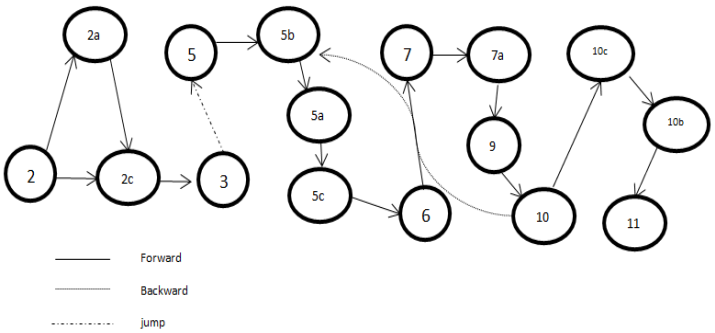
newness is included as a sophisticated work in which it must know the boundaries of its application in adapting new ideas. They can see a failure as an opportunity to learn more and understand that a long-period innovation is cycle process begun from a little success and fault. Working in creative thought to produce obvious and useful creation in a study can make the innovative work happened. By understanding problems to convey the relation among mathematics ideas perceived is to solve 1st and 2nd problem which has used problem-solving strategy. In this stage, students work with some concepts, for instance progression and numerical pattern. The students connect progression and numerical pattern concepts to discover coloring patterns that has not been known in the problems. Next, students are able to operate nth-formula that has been obtained from the patterns. The students succeed to employ the connection among mathematics ideas involving the concept, nth-formula, and also the formula of function. In the step of making a plan, students apply concept of ordinary numerical pattern to illustrate coloring pattern detected in 1st problem. Besides, high-ability students utilize nth-formula which the operation uses progression to seek the expansion. The relation of mathematical ability that connects to material and everyday life can be identified from 1st problem. High-ability students link problems with everyday life such as aesthethics and patternly uniqueness. Students are able to connect the result with the problems given. High-ability students succeed in solving open-ended problems on generalized pattern material well and using formula and possible changes in the issues.

The result of sustainable LKM 1 and LKM 2 starts from coloring pattern determination to formula of function. Subject of TBK 5, Yuli Fajar Wati N.T.



The diagram of 1st subject phase (high-score students)



2nd Subject (Medium-score students)

Medium-score students that use the concept of numerical pattern in solving LKM 1 as the step to figure out the problems are considered as the appropriate strategy for problem solving. Students can pour the ideas owned in accordance with problem solving provided in the stage of preparing the plan. However, the medium-ability students tend to calculate numerical patterns at their first step, and then it is applied to coloring patterns. Thus, students are less accurate in recognizing and applying that have been owned to finalize problems delivered on LKM 1 in the stage of doing students' plan. In this stage, the medium-ability students do not understand the concept of material and cannot link the

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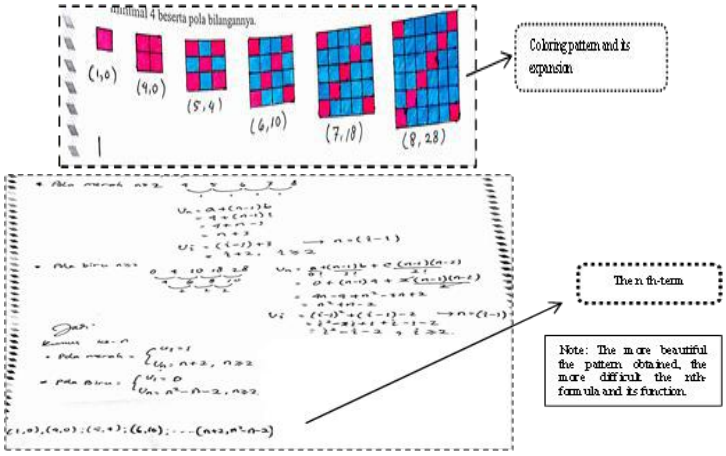
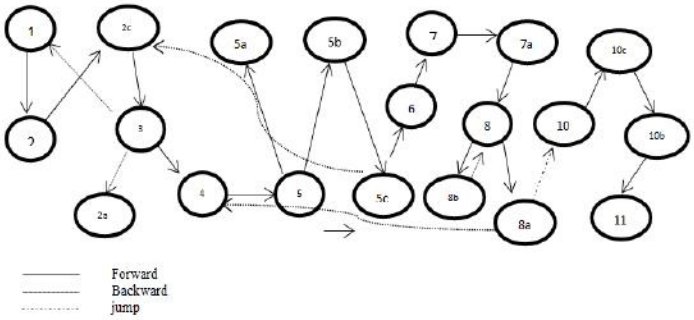
concept contained in LKM 1, so as in finishing LKM 2, they cannot achieved it. The mathematical ability connected between material and everyday life can be known from solving LKM 1. On LKM 2, students seem incapable to complete the problems with right answer and to associate with some problems known previously. Students are good enough in understanding the problems and making plans, but it still needs to increase thouroughness in implementing the plan.

The result of LKM 1 has apparently developed better, but it has no continuation in LKM 2 as the so-called formula of function. Subject of TBK, Dhika Elvira M.



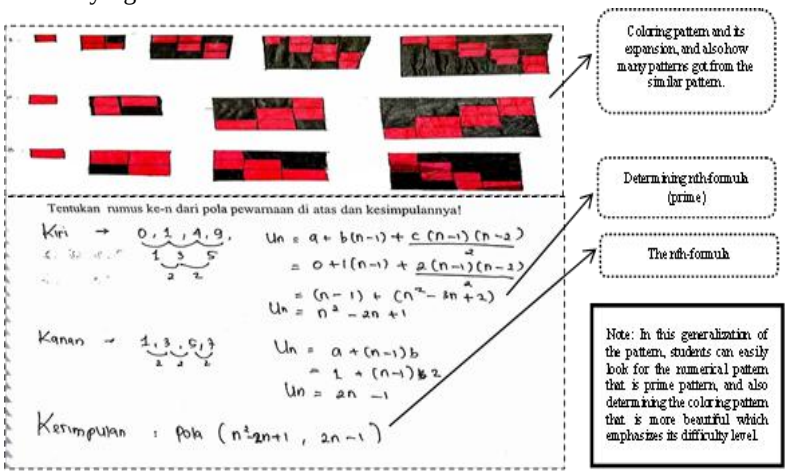
The diagram of 2nd subject phase (medium-score students)



3rd Subject (Low-Ability Students)

Low-ability students are in the stage of understanding the problems by explaining ideas that are known in connecting the concept and the ideas owned by medium-ability students. These low-ability students are still hard to define the coloring patterns in determining an easy numerical pattern for clarifying nth-formula. Low-ability students are less creative and innovative therefore they utilize prime pattern which can be easily guessed its nth-formula.

The result of LKM 1 is good, but LKM 2 (the formula of function) cannot be continued. The subject of TBK 2, Frisdianti Krisa Gotama.



The diagram of 3rd subject phase (low-ability students)

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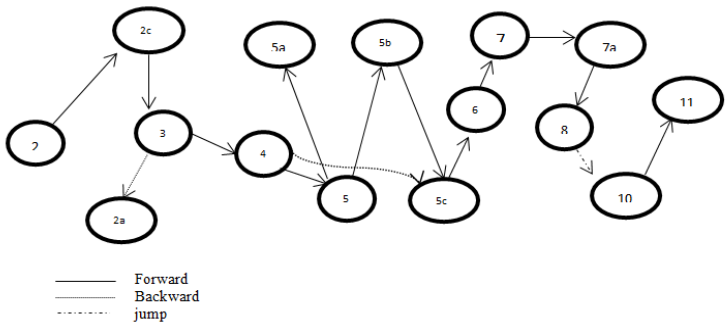
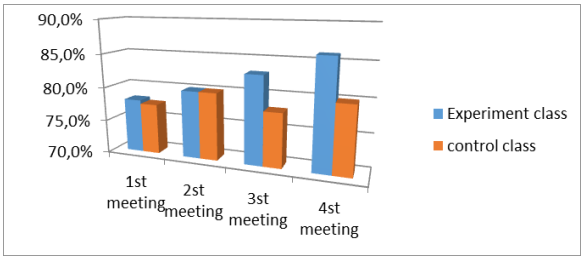


To discover students' opinion in this research, the researcher had interviewed and given questionnaire to a student in experimental class. This is one of following results obtained from open-questionnaire to the students:

1) What are the applications of staining square arrangement? Please, explain it briefly!
   Answer: For the pattern of floor tiles, wall tiles, color on the carpets and clothes, and tiles' color.
2) When you color it, describe what strategies do you use so that you can get beautiful arrangement or configurations color!
   Answer: I dabble to organize the pattern on tile boxes by combining the thoughtful forms.
3) Does the color pattern that you find quite beautiful or complicated? Link this statement whether the more complicated will be the more beautiful color patterns or not.
   Answer: I think the patterns found are medium patterns which are not too complicated. I think more complicated patterns are indicated more beautiful as long as the colors are well-designed and the aesthetics includes as subjective matter.
4) Will any patterns be always generalizable to the formula? So, what will you do if you do not find the generalization?
   Answer: 1) Yes, it will. As each patterns are regular, it can be generalized its formula. 2) Looking for another easier pattern to discover formula's generalization.
5) If you find a certain pattern, do you figure out other better patterns, but with high complexity? Which one do you want to choose? Give a reason why you choose particular pattern.
   Answer: Yes, I do. I sometimes think the other patterns. I prefer to choose my pattern since I am confident that this pattern is good enough.
6) When you find a pattern after examining carefully, is it possible to find the generalization of formula?
   Answer: Yes, it is. I can detect the formula's generalization.
7) Do you always color the rectangular arrangement until you see the regularity of the pattern and there is no doubt to exploit it?
   Answer: Yes, I do. There is no doubt for me in exploiting it as it has already looked well-ordered and beautiful.

From those responses above, students had been suited with the steps provided and each students can reply with different answers as a demand for completion of open-ended questions in accomplishing the problems of LKM 1 and LKM 2. Nevertheless, there are several students becoming the concern to improve their innovative thinking in solving the problems. As for the recapitulation of students activity shows on experiment class and control class.



VIII. DISCUSSION

This research is held to enhance the students innovative thinking skills and to apply discovery based learning. As the findings of this study, it is clarified that there are some improvements on students to present their interest to study. On pre-test done in control class, there are 7 students reaching medium level and 13 students on high level. In addition, there are 9 students attaining medium level and 18 students on HOTs level in the experiment class as regards to Ming and Manaf's research (2014). After examining the effectivity in applying discovery based learning, The post-test result signifies improvement on control class as it is shown that there are 4 students reaching medium level and 16 students on high level. Besides, there are 4 students on medium level and 18 students on high level in the experiment class. Therefore, the effectivity in applying discovery based learning research has met valid criteria including simple and effective. After examining kolmogorov smirnov test, it can be uncovered that Sig. score on Levene's test for equality of variances in the amount of 0,977 > 0,05. Thus, the result of students innovative thinking skills is claimed

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homogeneous so that the decision-making uses equal variances assumed method. In this method, it acquires 0.000. (<0.05) of Sig. score (2-tailed). Because the significance score is less than 0.005, it means that H_0 is rejected and H_a is received, hence the study of students innovative thinking skills with discovery based learning model on experiment class is better than control class.

IX. ACKNOWLEDGEMENTS

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