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The analysis of problem-based learning implementation and its effect on students creative innovative skills in solving rainbow antimagic coloring based on cognitive style

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Abstract. This study aims to determine the application of problem based learning and its effect on students' creative innovative skills in solving rainbow antimagic coloring based on cognitive style. This study used mixed method which combination of qualitative and quantitative research method. This study used research subjects of 41 students in the experiment class and 32 students in the control class who were students in 3rd semester. Qualitative method is applied to analysis students' creative innovative skills which used data from test result and phase portraits results while quantitative method is used to statistical analysis. There were differences between control and experiment class when it was given a treatment. In control class used conventional learning while in experiment class, we used problem based learning. The statistical result indicates that the sig (2-tailed) significance of the independent sample t-test in post-test was 0.000 or $\alpha \leq 0.05$. it can be concluded that there is an effect of used problem based learning in creative innovative skills on solving rainbow antimagic coloring.

1. Introduction

Learning mathematics is not only about formulas that must be memorized by students but also helps them to be able to solve mathematical problems in everyday life. The problems in mathematics of higher education are in the distribution of courses, which include calculus, geometry, statistics, discrete mathematics, graph theory, and various other subjects. If there are problems, then a solution is needed, and the solution requires thinking ability to do it. There are various kinds of thinking skills which include critical thinking skills, creative thinking abilities, higher-order thinking skills, and so on.

Creative thinking is a mental activity to find "new ideas" under the objectives, by generating ideas, synthesizing those ideas and implementing them [11]. Furthermore, [12] defines creative thinking as a mental activity that someone uses to construct new ideas fluently and flexibly. [8] argues that innovative thinking is a process that gives solutions or ideas outside the shared knowledge frame (conservative frame), both in terms of the knowledge of individuals who think and from the dominant knowledge in their environment.



Table 1. Indicators of creative innovative

Aspects	Indicators	Number
High productivity	Write down more than one method/strategy	1A
	Write down only one method/strategy	1B
High elasticity	Using the method/strategy correctly	2A
	Using a strategy but there are errors in the calculation	2B
High originality	Write down the novelty and uniqueness of more than two answers found than the previous answer	3A
	Write down the novelty and uniqueness of the two answers found than the previous answer	3B
High sensitivity	Re-check the results of calculations and concepts more than / equal to twice.	4A
	Re-checking the results of calculations and concepts once.	4B
	Re-checking only the results of calculations or concepts only once.	4C
	Do not do checks	4D

There is a way to unleash the innovative creativity of students by applying problem-based learning. Several studies use problem-based learning as a learning model including [1], [10]. According to [9] defining PBL is a learning (and curricular) approach that is student-centered that empowers students to conduct research, integrate theory and practice, and apply knowledge and skills to develop feasible solutions to determined problems.

The steps on PBL according to [2] can be presented in the figure below.

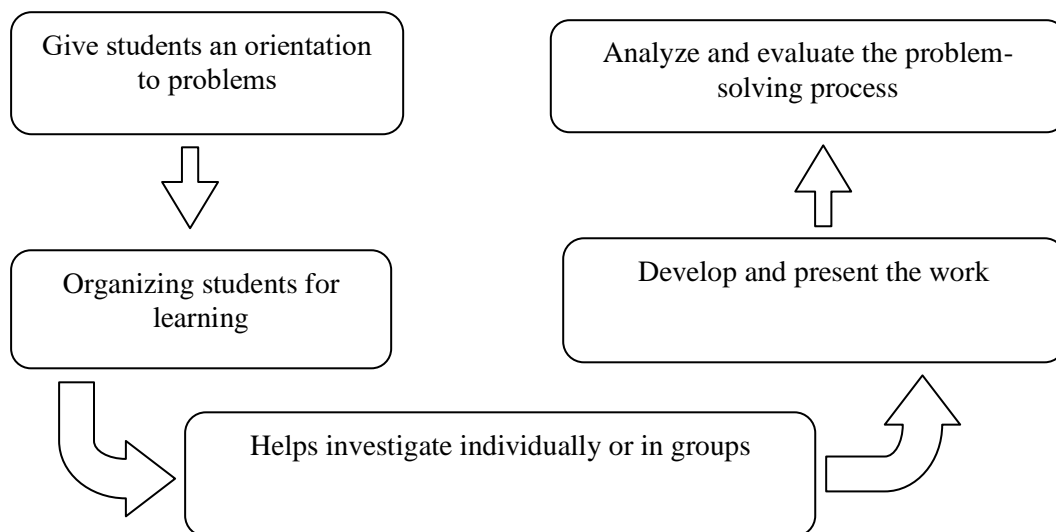


Figure 1. Syntax Problem-Based Learning

The term "cognitive style" was used by Allport in 1937, and it is described as a person's characteristic or habit in solving problems, thinking, understanding, remembering, organizing and representing information [3], [5], [6], [7].

As it is known that there are a variety of cognitive styles, one of them is the "Field Dependent and Field Independent" cognitive styles. Field Dependents (FD) and Field Independent (FI) are derived from the results of a study conducted by Witkin [5], [14]. There are differences between FI individuals and FD individuals and that was reviewed by the researchers in their study. Annis [4] explained the results of her study that FI individuals were better than FDs in recalling the information obtained. Furthermore, Annis also believes that FI individuals are more active in extracting important information, while FD individuals act passively where they depend on the characteristics of the learning task [4].

2. Research method

This study used a mixed-method which combination of qualitative and quantitative research methods. There is much research using the mixed method, for example [10], [13]. Qualitative method is applied to analyze students' creative innovative skills which used data from test results and phase portraits results while the quantitative method is used to statistical analysis. This study used research subjects of 41 students in the experiment class and 32 students in the control class. the research subjects were students in the 3rd semester. Both of them (the class) were given pre-test and post-test which contain indicators of creative innovative skills in it.

Different treatments are given in each class, where the experimental class uses PBL while the control class with a different treatment. The research method can be seen in figure 2 below.

Class	Pre-Test	Treatment	Post-Test
Experiment Class (<i>n</i> = 41)	<i>R</i> ₁	Problem-Based Learning and Students' Worksheet	<i>R</i> ₂
Control Class (<i>n</i> = 32)	<i>R</i> ₃	Problem-Based Learning	<i>R</i> ₄

Figure 2. Research Method

2.1. Population

This study used research subjects of 41 students in the experiment class and 32 students in the control class who were students in 3rd-semester undergraduate students of mathematics education, University of Jember.

2.2. Instruments

This research uses instruments including pre-test, post-test, observation, and interview. Pre-test and post-test have a rating with a range of 0-100. For observation have a rating with a range 0-4, the details are as follows 4 for very creative, 3 for creative, 2 for quite creative, 1 for less creative, and 0 for not creative.

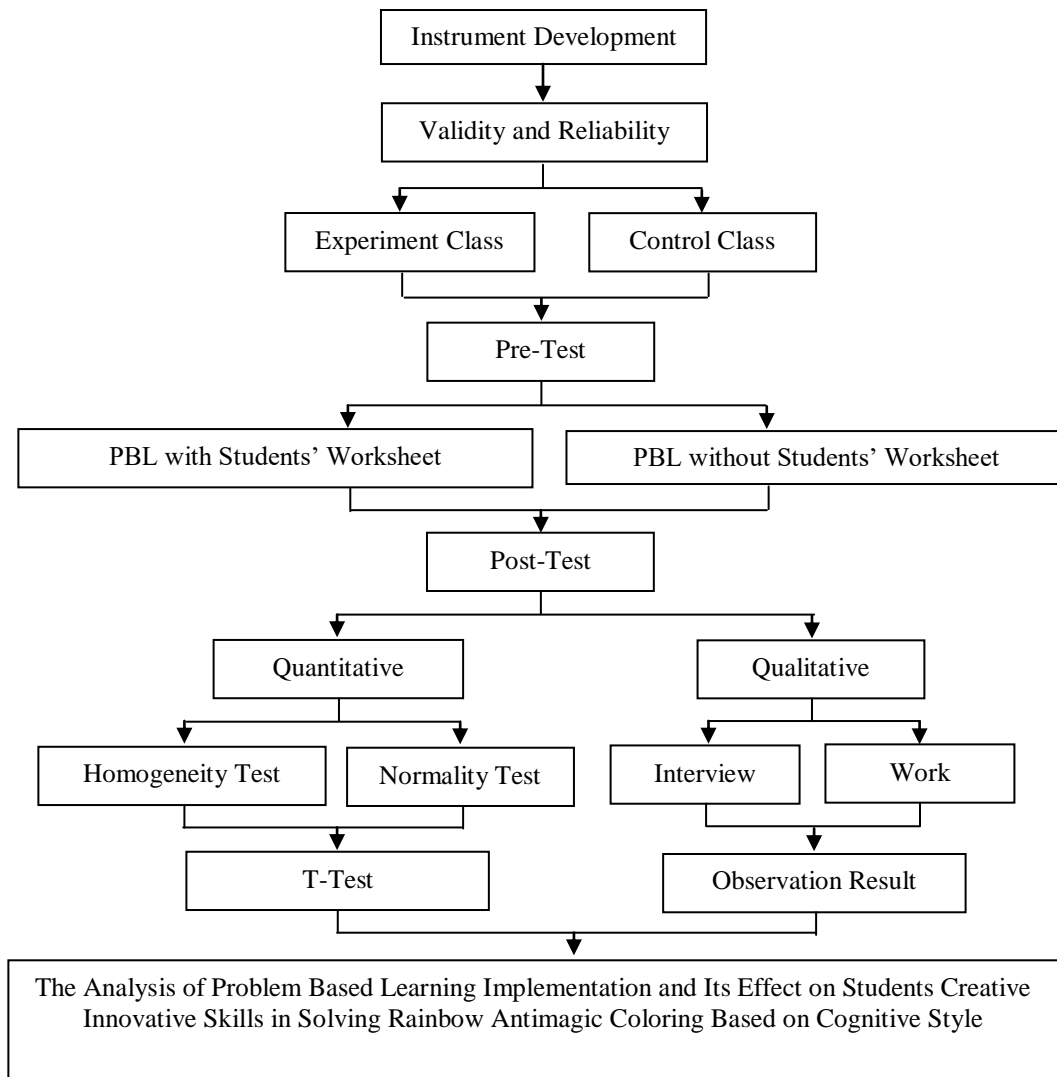


Figure 3. The Mixed Method Model

2.3. Task

To find out students' innovative creative thinking skills, tasks are given including pre-test, post-test, and student worksheets. Control and experiment classes are given pre-test and post-test sheets in both classes, but the student worksheets are only given to the experimental class. The task and the guidance as follow:

$$V = \{x_1, x_2, \dots, x_4\}$$

$$E = \{x_1, x_2, \dots, \dots, \dots\}$$

$$|V| = n$$

$$|E| = \dots \dots \dots$$

Menentukan fungsi titik

$$f(x) = 1$$

$$f(y_1) = 2$$

$$f(y_2) = \dots$$

$$f(y_3) = \dots$$

Figure 4. Determine the cardinality of the graph

Figure 5. Determine the vertex function

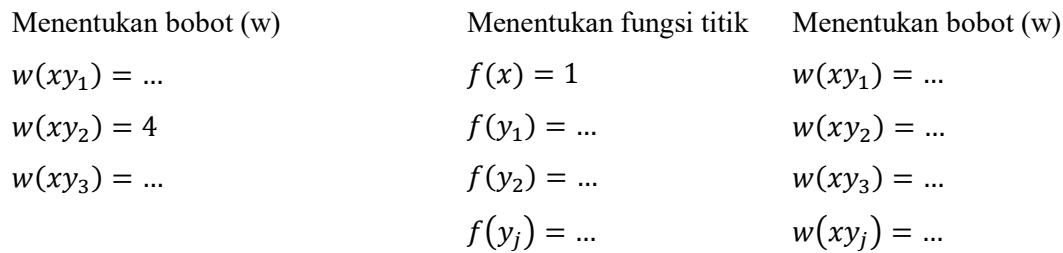


Figure 6. Determine the edge weights

Figure 7. Determine the vertex function and edge weights up to n-point

2.4. Data Collection and Data Analysis

An interview, observation, and ordinal data are used for qualitative data, meanwhile, the t-test is used for quantitative data. The statistical data were obtained from the average, standard deviation and frequency values, while inferential data related to research-based learning was using normality test, homogeneity test and independent test between the control class and the experimental class. Independent samples were used to compare the two classes, with a significance value of the difference at the 0.05 level.

3. Research result

This research used a qualitative method, with validity test and reliability test on the post-test question. By using validity and reliability test for makes sure the accuracy of the measurement instrument in performing its measuring function. This research used 41 students for the sample in validity and reliability test. The following table presents the results of the validity and reliability test.

Based on table 2, it's clear that the value from the question 1 was 0.552, question 2 was 0.528, question 3 was 0.313, question 4 was 0.645, question 5 was 0.625, question 6 was 0.703, question 7 was 0.382, question 8 was 0.609, meanwhile r_{table} for $n = 41 - 2 = 39$ was respectively 0.3081 for 0.05 level and 0.3978 for 0.01 level. Based on that result, all of those questions were valid because of the value from the question $> r_{table}$.

After that, the result from the reliability test was 0.659 and r_{table} for 0.05 with $df = n = 41 - 2 = 39$, which was 0.3081, from where it can be concluded that the instruments were reliable because the result from reliability test $> r_{table}$.

Table 2. Result of question validity

		Probl em 1	Probl em 2	Probl em 3	Probl em 4	Probl em 5	Probl em 6	Probl em 7	Probl em 8	Total
Problem 1	Pearson Correlation	1	.225	.060	.296	.256	.302	-.022	.196	.552**
	Sig. (2-tailed)		.157	.708	.060	.106	.055	.893	.219	.000
	N	41	41	41	41	41	41	41	41	41
Problem 2	Pearson Correlation	.225	1	-.161	.080	.486**	.311*	.026	.038	.528**
	Sig. (2-tailed)	.157		.315	.619	.001	.047	.871	.816	.000
	N	41	41	41	41	41	41	41	41	41
Problem 3	Pearson Correlation	.060	-.161	1	.282	.084	.184	.352*	.059	.313*
	Sig. (2-tailed)	.708	.315		.074	.601	.249	.024	.715	.047
	N	41	41	41	41	41	41	41	41	41
Problem 4	Pearson Correlation	.296	.080	.282	1	.044	.222	.428**	.737**	.645**
	Sig. (2-tailed)	.060	.619	.074		.787	.164	.005	.000	.000
	N	41	41	41	41	41	41	41	41	41

Problem 5	Pearson Correlation	.256	.486**	.084	.044	1	.697**	-.085	.025	.625**
	Sig. (2-tailed)	.106	.001	.601	.787		.000	.598	.877	.000
	N	41	41	41	41	41	41	41	41	41
Problem 6	Pearson Correlation	.302	.311*	.184	.222	.697**	1	-.042	.233	.703**
	Sig. (2-tailed)	.055	.047	.249	.164	.000		.796	.142	.000
	N	41	41	41	41	41	41	41	41	41
Problem 7	Pearson Correlation	-.022	.026	.352*	.428**	-.085	-.042	1	.399**	.382*
	Sig. (2-tailed)	.893	.871	.024	.005	.598	.796		.010	.014
	N	41	41	41	41	41	41	41	41	41
Problem 8	Pearson Correlation	.196	.038	.059	.737**	.025	.233	.399**	1	.609**
	Sig. (2-tailed)	.219	.816	.715	.000	.877	.142	.010		.000
	N	41	41	41	41	41	41	41	41	41
Total	Pearson Correlation	.552**	.528**	.313*	.645**	.625**	.703**	.382*	.609**	1
	Sig. (2-tailed)	.000	.000	.047	.000	.000	.000	.014	.000	
	N	41	41	41	41	41	41	41	41	41

Table 3. Result of question reliability

Cronbach's Alpha	N of Items
.659	8

Furthermore, given a test to determine the cognitive style of students by using the Group Embedded Figures Test (GEFT) developed by Witkin. The following are presented the results of the tests for the experimental class in Diagram 1. Based on the diagram, it can be seen that there are 76% of students with Field Independent cognitive styles and 24% of students with Field Dependent cognitive styles out of a total of 41 students in the experimental class.

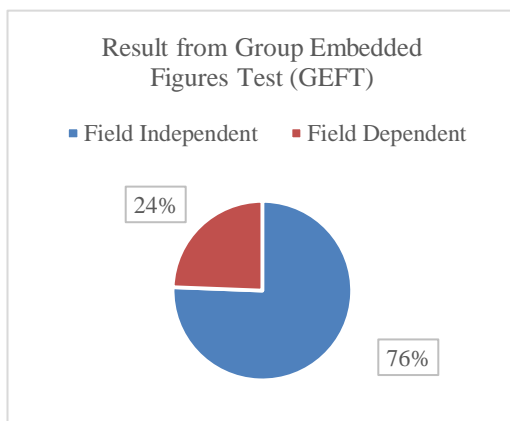


Chart 1. Result from group embedded figures test (GEFT)

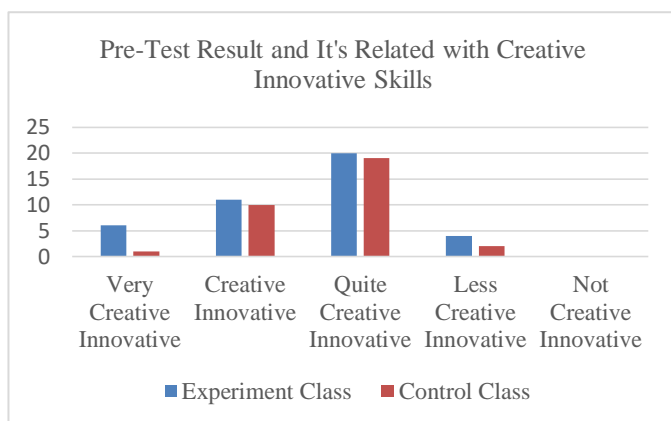


Chart 2. Pre-test result and it's related with creative innovative skills

This research used pre-test and post-test in the control and experiment classes with 73 students. Based on the data provided in fig 2, In the experiment class, 6 students were very creative innovative, 11 students were creative innovative, 20 students were quite creative innovative, 4 students were less creative innovative. In the control class, 1 student was very creative innovative, 10 students were creative innovative, 19 students were quite creative innovative, 2 students were less creative innovative.

From the control class and the experimental class, data was taken about the pre-test and post-test. Qualitative data analysis was performed using t-tests while quantitative data used interviews, observation, and data analysis. In this study using the normality test, homogeneity test, and independent tests in both classes to obtain statistical data. The homogeneity test from the pre-test obtained sig 0.207 results. It can be seen as this result is greater than 0.05, so the results of the pre-test control class and the experimental class are homogeneous. Furthermore, it can be seen in Table 4 below.

Table 4. The homogeneity test result of pre-test in the control class and experiment class

Levene Statistic	df1	df2	Sig.
1.625	1	71	.207

After homogeneity testing, the normality test is then performed. Based on table 5, the normality test results obtained in the experimental class with a value of 0.200 and in the control class the value of 0.200 is obtained. Based on the two results it can be said that the data distribution is significant because it exceeds a significant value of 0.05. Thus, data from both classes are normally distributed.

Table 5. The result of normality test of pre-test in the control and experimental classes

Class	Kolmogorov-Smirnov ^a			Shapiro-Wilk			
	Statistic	df	Sig.	Statistic	df	Sig.	
Pre-Test Value	Experiment Class	.086	41	.200*	.981	41	.713
	Control Class	.120	32	.200*	.965	32	.376

Based on table 6 presented the average results of the experimental class and the control class. The average value obtained in the experimental class was 67.1707, while in the control class the average value obtained was 66,000. The average value of the experimental class is greater than the control class. Furthermore, based on the results of the independent tests, Sig. (2-tailed) is 0.421 where this value is more than 0.05 so H_0 is accepted which means that there is no difference between the experimental class and the control class.

Table 6. The results of independent pre-test in the control class and experimental class

Class	N	Mean	Std. Deviation	Std. Error Mean	Levene's Test for Equality of Variances					t-test for Equality of Means				
					F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		
											Lower	Upper		
Pre-Test Value	Experiment Class	41	67.1707	6.73017	1.05108									
	Control Class	32	66.0000	5.26706	.93109									
Pre-Test Value	Equal variances assumed	1.625	.207	.809	71	.421	1.17073	1.44700			-1.71450	4.05596		
	Equal variances not assumed			.834	70.997	.407	1.17073	1.40417			-1.62911	3.97057		

The homogeneity test from the post-test obtained sig 0.609 results. It can be seen that the result is greater than 0.05, so the results of the post-test of the control class and the experimental class are homogeneous. Furthermore, it can be seen in Table 7 below.

Table 7. The homogeneity test result of post-test in the control class and experiment class

Levene Statistic	df1	df2	Sig.
.264	1	71	.609

After the pre-test, given treatment in Figure 2, the students in both classes were given a post-test to find out students' achievement. There was 8 question in post-test about rainbow antimagic coloring. It is easy to see in chart 3 that was the post-test result from both classes. In the experimental class, 18 students were very creative innovative, 14 students were creative innovative, 9 students were quite creative innovative. In the control class, there were 8 students were very creative innovative, 17 students were creative innovative, 7 students were quite creative innovative.

After homogeneity testing, the normality test is then performed. Based on table 8, the normality test results obtained in the experimental class with a value of 0.165 and in the control class obtained a value of 0.090. Based on the two results it can be said that the data distribution is significant because it exceeds a significant value of 0.05. Thus, data from both classes are normally distributed.

Table 8. The Result of Normality Test of Post-Test in The Control and Experimental Classes

Class	Kolmogorov-Smirnov ^a			Shapiro-Wilk			
	Statistic	Df	Sig.	Statistic	df	Sig.	
Post-Test Value	Experiment Class	.118	41	.165	.970	41	.342
	Control Class	.144	32	.090	.894	32	.004

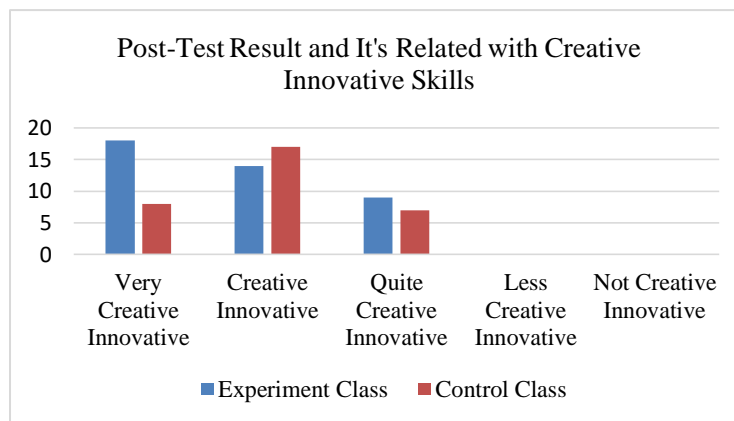


Chart 3. Post-Test Result and It's Related with Creative Innovative Skills

Based on table 9, the average results of the experimental class and the control class are presented. The average value obtained in the experimental class was 72.5122, while in the control class the average value obtained was 67.2813. When viewed from the average value, it is clear that the average value of the experimental class is greater than the control class. Furthermore, based on the results of the independent tests, Sig. (2-tailed) is 0.001 where this value is less than 0.05 so H₁ is accepted which means that there is no difference between the experimental class and the control class.

Table 9. The Results of Independent Post-Test in The Control Class and Experimental Class

Class	N	Mean	Std. Deviation	Std. Error Mean	
Post-Test Value	Experiment Class	41	72.5122	5.98800	.93517
	Control Class	32	67.2813	7.09945	1.25502

		Levene's Test for Equality of Variances		t-test for Equality of Means						
				95% Confidence Interval of the Difference						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Post-Test Value	Equal variances assumed	.264	.609	3.413	71	.001	5.23095	1.53246	2.17532	8.28657
	Equal variances not assumed			3.342	60.522	.001	5.23095	1.56512	2.10079	8.36110

The following presents an analysis of the results of student work in the rainbow antimagic coloring to know the completion process that is done by students in student worksheets to obtain the final results. This analysis is used to support information obtained from interviews according to the results of the student's work.

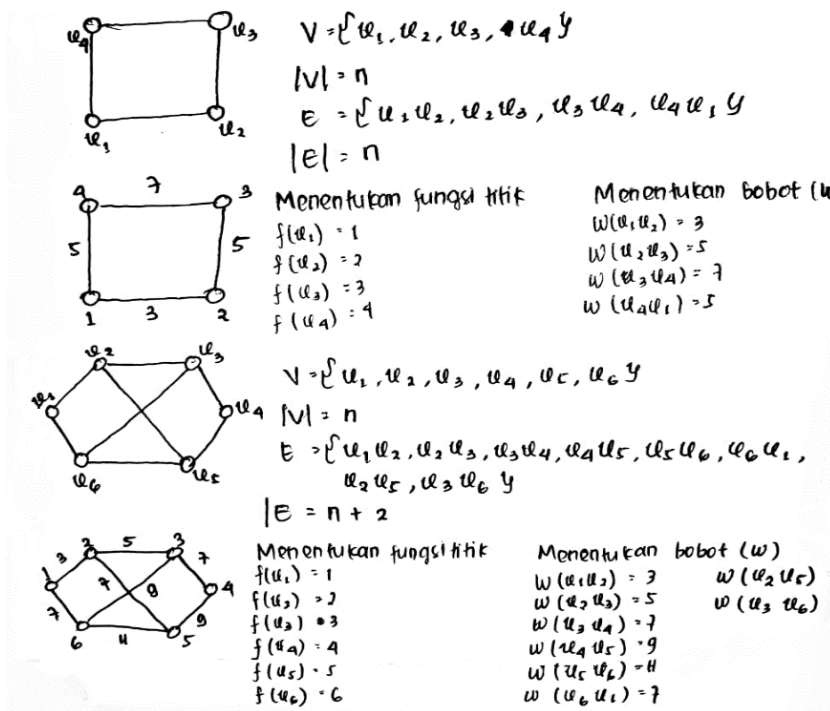


Figure 8. The result of student 1 (very creative innovative)

There was the result of student 1 in figure 8 when finding the cardinality of that graph, the vertex's function, and the edge's weight from the graph by itself. The student makes 2 graphs by themselves and named each vertex and find the minimum color to make rainbow antimagic coloring. The first requirement of rainbow antimagic coloring had been fulfilled by student 1.

After finish the rainbow antimagic problem, the student gets the interviews to frame students' minds. The following are excerpts of interviews between researcher and student 1:

- Researcher : Do you understand the problem that you are working on?
- Student 1 : Yes, sir.
- Researcher : What problem are you working on?
- Student 1 : It is about rainbow antimagic coloring problem.
- Researcher : Then what did you do first?

- Student 1 : I try to make a new graph and find out the cardinality of that graph.
 Researcher : Then?
 Student 1 : I tried to find the smallest possible numbers in the rainbow antimagic coloring. After that, I write down the vertex's function and edge's weight. After I finish the first graph, I make a new graph and do the same way like that.
 Researcher : Do you find the difficulties to solve that problem?
 Student 1 : Actually yes, sir.
 Researcher : What kind of difficulties did you find out?
 Student 1 : To find out the smallest possible numbers. I have to keep trying repeatedly until I am sure that I found the smallest one.
 Researcher : After you find the answer, do you double-check your answer?
 Student 1 : Of course sir. To make sure the answer I wrote.

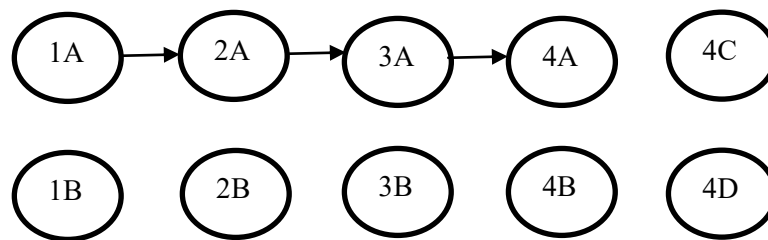


Figure 9. The phase portrait of student 1

By seeing figure 10, can be seen as the result of student work who quiet creative innovative. The student can make only one graph but confused about the edge's weight. After finish the rainbow antimagic problem, the student gets the interviews to frame students' minds. The following are excerpts of interviews between researchers and student 2:

- Researcher : Do you understand the problem that you are working on?
 Student 2 : For the first time, I was confused about what I had to do first. after a while I read the problem and reread the previous explanation, I understood that I was trying to find ways to solve the rainbow antimagic coloring problem.
 Researcher : What problem are you working on?
 Student 2 : It is about rainbow antimagic coloring problem.
 Researcher : Then what did you do first?
 Student 2 : First of all, I made a graph. After that, I determine the cardinality of the graph I have made.
 Researcher : Then?
 Student 2 : Of course, I tried to find a rainbow antimagic coloring on the graph. Try a variety of the smallest possible numbers needed in coloring even though it feels a bit difficult. So, that's why I was only able to do one graph.
 Researcher : Do you find the difficulties to solve that problem?
 Student 2 : Yes, sir.
 Researcher : What kind of difficulties did you find out?
 Student 2 : I have difficulty in doing the coloring so that I also have difficulty in writing the vertex's function and determining the edge's weight.
 Researcher : After you find the answer, do you double-check your answer?
 Student 2 : No, sir. Because I was confused. What I've done is done. That's all I can do.

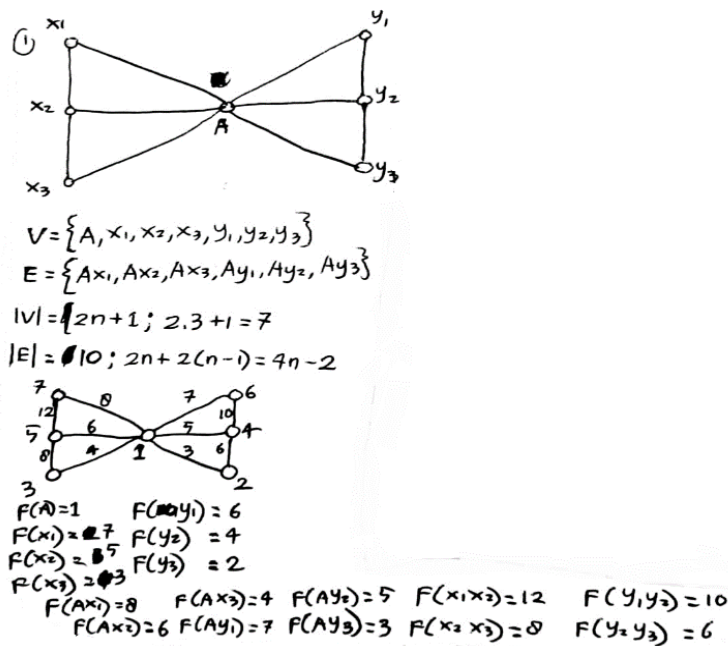


Figure 10. The result of student 2 (quiet creative innovative)

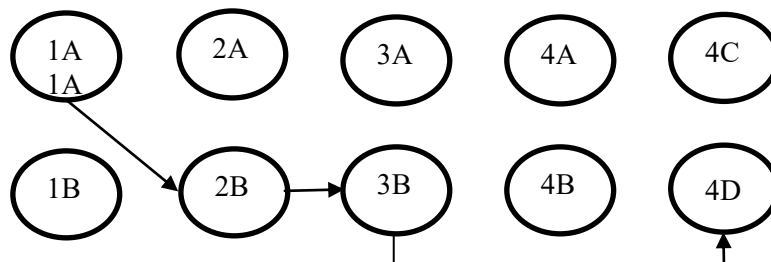


Figure 11. The phase portrait of student 2

The following are excerpts of interviews between researchers and student 3:

- Researcher : Do you understand the problem that you are working on?
- Student 3 : I'm really confused about what I have to do, sir
- Researcher : What problem are you working on?
- Student 3 : If I'm not mistaken, it's about rainbow antimagic coloring, am I right?
- Researcher : Yes. Then what did you do first?
- Student 3 : Well, I captured information about finding cardinality from a graph. So that's what I'm working on.
- Researcher : Then?
- Student 3 : I colored the graph but I was confused in determining the vertex function and determining the edge weights. After that, I draw the second graph and find the cardinality of the graph.
- Researcher : Do you find the difficulties to solve that problem?
- Student 3 : Yes, sir.
- Researcher : What kind of difficulties did you find out?
- Student 3 : I was confused in determining the vertex function and determining the edge weights. I can draw the graph and determine the cardinality of the graph.
- Researcher : After you find the answer, do you double-check your answer?
- Student 3 : No, sir.

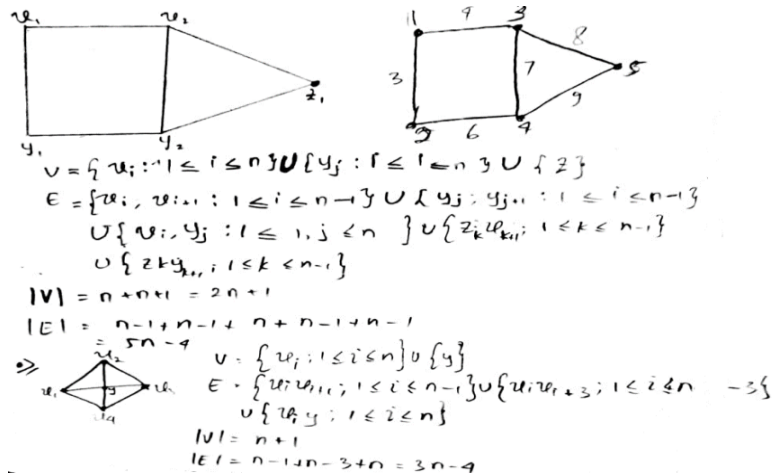


Figure 12. The result of student 3 (less creative innovative)

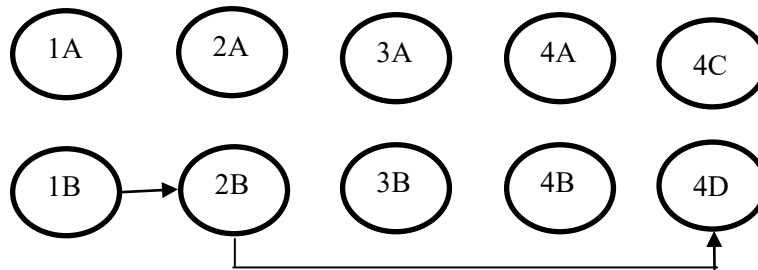


Figure 13. The phase portrait of student 3

Based on observations of student activities on the application of problem-based learning in solving rainbow antimagic coloring, it was found that there was a significant impact of the application of problem-based learning on improving students' creative innovative skills in solving rainbow antimagic coloring problems. Based on Chart 4, it can be seen that more students actively participate during the learning rather than the opposite.

The Distribution of Student Activities during PBL Implementation

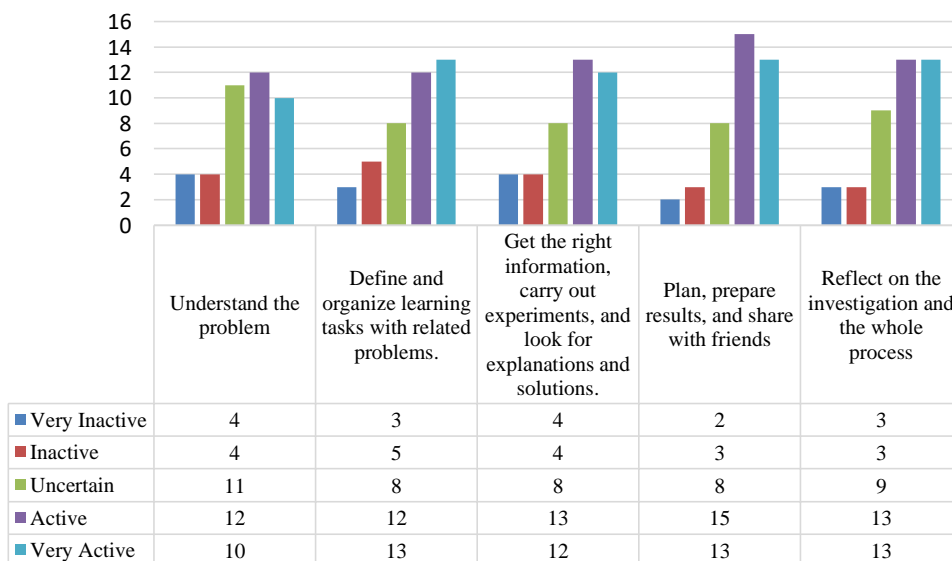


Chart 4. The distribution student activities during pbl implementation

4. Discussion

This study aims to analyze the implementation of problem-based learning (PBL) on creative innovative skills of students in solving rainbow antimagic coloring problems. This study shows the findings that there are significant results on the alleged ability of students in the experimental class. Based on the findings of this study, it can be seen that there is an increase in student learning outcomes and creative innovative skills.

The results of this study found that in the experimental class there were 18 students at the very creative innovative level, 14 students at the creative innovative level, and 9 students at the quite creative innovative level, while in the control class there were 8 students at the very creative innovative level, 17 students at the innovative creative level, 7 students at quite creative innovative level.

5. Conclusion

Based on the results of the study, it can be concluded that there is a significant influence between the implementation of PBL by using student worksheets on the creative innovative skills of students in the experimental class. The experimental class gets better learning outcomes than the control class and this also goes hand in hand with the improvement of creative innovative skills. Thus, it can be concluded that PBL learning by using student worksheets can improve students' innovative creative skills very well.

Acknowledgements

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