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Research Article

The Analysis of Student's Creative Thinking Skills in Solving "Rainbow Connection" Problem through Research Based Learning

Hassan Asy Syaibani[1], Dafik[2], Hobri[3]

[1]Mathematics Education Department, University of Jember, Jember, Indonesia
[2]CGANT Research Group, University of Jember, Jember, Indonesia
[3]Mathematics Education Department, University of Jember, Jember, Indonesia

Abstract: Creative thinking skills are needed in the 21st century learning. According to the P21 platform (Partnership for 21st century learning), someone will survive in the 21st century if they have some skills of one of them is creative thinking skill. By applying Research Based Learning (RBL), 64 students were given a problem namely Rainbow Connection. Through qualitative research, student results are analyzed to know the level of their creative thinking skills. The results shows that the data of students's creative thinking level are as follows: (i) In class A, 28 students have creative thinking skills of level 4, 2 students have creative thinking skills of level 3, and 4 students have creative thinking skills of level 2. (ii) In class B, 20 students have creative thinking skills of level 4, 2 students have creative thinking skills of level 3, and 8 students have creative thinking skills of level 2. It can be concluded that the level of students creative thinking skills in solving Rainbow Connection problems through RBL are relatively high.

I. Introduction

The development of the 21st-century is characterized by the utilization of information and communication technology in all aspects of life, including in the learning process. The space of work demands the workers to change and improve their skills associated with 21st-century skills. The abilities to think creatively, to think critically, to communicate using hypermedia, and to collaborate each others become an important competency in entering human beings life in this century. Thus, the producers of labor such as training institutions, schools, colleges must motivate students or high students to have this 21st-century thinking skills.

Rotherdam & Willingham (2009) explains that Partnership for 21st Century is possessed by a person with 21st-century skills that embrace innovative creative thinking skills, critical thinking skills, communication skills and collaborative skills. While according to the National Education Association, to achieve success and be able to compete in the global community, students must be experts and have the skills as communicators, creators, critical thinkers, and collaborators.

In this study we will examine students' creative thinking skills. Aziz (Syaibani, 2016) explains that creative thinking skills are the most important characteristics that humans must possess. By thinking creatively, human beings can develop their potential talents and view a problem from different points of view. Krulik & Rudnick (Siswono, 2010) explains that creative thinking is original, reflective, and produces a complex product. While Munandar (Happy and Listyani, 2011) explains creative thinking is the ability to find many possible answers to a problem, where the emphasis of it is on the quantity, efficiency, and diversity of answers based on the existing data or information.

Silver shows that an appropriate approach to identifying students' creative thinking skills is to use problem-posing and problem-solving. There are three components of creative thinking namely fluency, flexibility, and novelty. Each assess the various aspects of thought and is interdependent with one another. Fluency is demonstrated by the ability of students to solve many problems with correct solutions, flexibility refers to the ability of students to file or build problems with different solutions, novelty refers to a student's ability to develop a problem different from others (Siswono, 2010). To simplify the analysis of students' creative thinking skill, the researcher specifies the indicators as follows: (1) fluency indicator, students can give a rainbow connection coloring correctly and optimally, (2) flexibility indicator, students can determine graph cardinality and coloring function correctly and completely and (3) indicator of originality / novelty, students can create new graphs that have not been studied in the rainbow connection graph coloring study before.

Another thing to note apart from the indicator of creative thinking is the level of a students in the process of creative thinking. We know that not all students can meet all the indicators of creative thinking, sometimes students can only meet one indicator, two indicators or even students can meet three indicators. Therefore the level of students creative thinking needs to be developed. It is intended to level the work resulted by the students. Here, we describe the level of creative thinking level of students.

Table 1. Leveling of Creative Thinking Skill

Level	Indicator
Level 0 (Not Creative)	Students are unable to show all three aspects of problem-solving.
Level 1 (Less Creative)	Students are only able to show fluency in solving problems.
Level 2 (Simply Creative)	Students are able to show novelty or flexibility in solving problems.
Level 3 (Creative)	Students are able to show fluency and novelty or fluency and flexibility in solving problems.
Level 4 (Very Creative)	Students are able to demonstrate fluency, flexibility, and novelty or novelty and flexibility in solving problems.

(Siswono, 2011)

One of the learning models that are considered to train students' creative thinking skill is a Research-Based Learning (RBL) model. RBL is not only for improving cognitive knowledge but also skills of critical and creative thinking (Sota and Peltzer, 2016). The RBL model is a derivation of ITL (inductive teaching and learning) because it is an inductive approach centering on the learner and centering on the process. RBL also has several characteristics that distinguish itself from other ITL models, for example (1) The time duration is longer than the other models, a learner is involved in research project; (2) The scope is clear and associated with research objectives; and (3) Promotion of teamwork and individual excellence. (Yawen Li, 2015)

According to Dafik (2015), RBL is a learning method that uses contextual learning, authentic learning, problem-solving, cooperative learning, hands-on & minds-on learning, and inquiry discovery approach. Meanwhile, according to Khamdit, RBL is a learning approach that emphasizes learning by exercises, learning from real situations, generating things from thinking process, functioning systematically, shaping individual knowledge, using research process to solve problems, raising answers of doubt and analyzing their own data. This approach will inspire learners to develop all the potential talent that they have. Singh (2014) added that RBL can provide benefits for students, among others (1) they are often inspired by educators who are experts in the field, so they are more enthusiastic about the subject of learning, (2) students tend to learn more when they are actively involved in research, (3) through RBL students can develop critical intellectual thinking skills as well as transferable skills.

The target of RBL implementation is to encourage the creation of high-level thinking skills of the lecturers and students themselves. Students are not only given with information and science but their must be taken to a high level of creating or communicating activities. Achievement of this level in learning theory is known by achieving higher order thinking skills (HOTS) (Dafik, 2015).

RBL is an important model in teaching and learning process by using research element into learning process (Sota and Peltzer, 2016). At the moment there are many research studies that can be brought into the learning process. One of the study studies that can be brought in the learning of the study of discrete modeling. Discrete modeling can be used to train students' creative thinking skills because there are many problems in the real world that can be solved by discrete modeling.

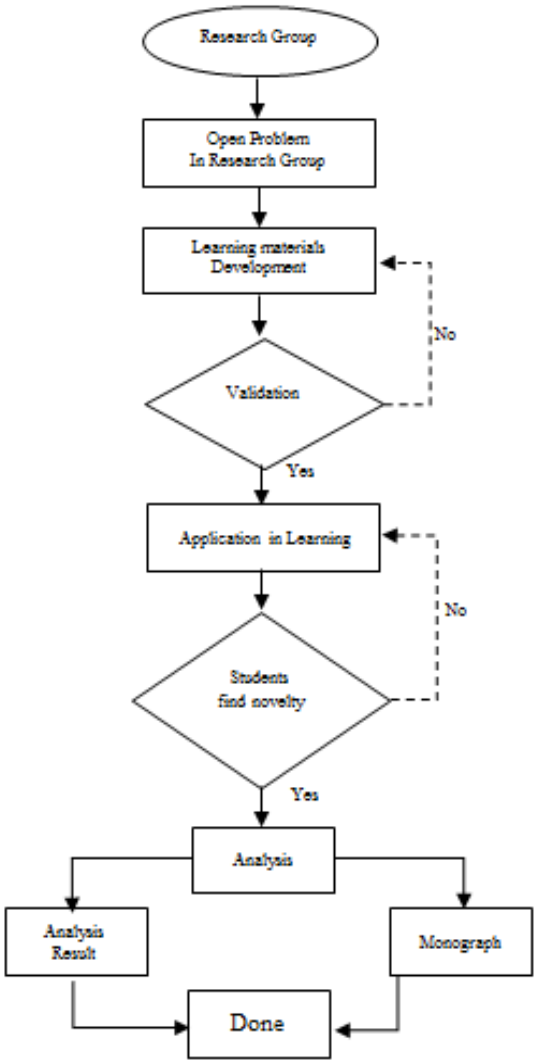
A relatively new discrete modeling study is a rainbow connection study. Let G be a nontrivial connected graph on which is defined a coloring $c : E(G) \rightarrow \{1, 2, \ldots, k\}, k \in \mathbb{N}$, of the edges of G, where adjacent edges may be colored the same. A u-v path P in G is a rainbow path if no two edges of P are colored the same. The graph G is rainbow-connected (with respect to c) if G contains a rainbow u-v path for every two vertices u and v of G. In this case, the coloring c is called a rainbow coloring of G. If k colors are used, then c is a rainbow k-coloring. The minimum k for which there exists a rainbow k-coloring of the edges of G is the rainbow connection number $\mathrm{rc}(G)$ of G. A rainbow coloring of G using $\mathrm{rc}(G)$ colors is called a minimum rainbow coloring of G (Chartrand et al., 2008).

II. Method

The method used in this research is a descriptive qualitative method. This research is studying and analyzing student ability in solving problems that arise through RBL. Population in this research is all student of semester 6 which sit for modeling subject course. The number of students is 64 people. A-class students are 34 people and C-class are 30 people.

The steps in this study are divided into three stages: the preparation stage, the implementation stage, and the final stages of the research. **The preparation stage** includes the formation of a research group consisting of several researchers/lecturers which have the same reseach of interest. In this stage, we develop syllabus, RPS, RTM, LKM and joint lecture contract to implement RBL in a learning process. **The implementation stage** covers the implementation of RBL learning process and the provision of research activity test (RAT). This stage includes (1) providing basic information on the subject matter which will be studied, (2) showing the results and open problems arising from research group (3) dividing students into discussion groups, 4) assigning assignments for students in group discussio which covers the following: (a) the open problem of research, (b) the research process, (c) the way of analysis, (d) the formulation of conclusions, and (e) the points arising out of research results, (4) led student to conduct inter-group discussion, (5) together with student and lecturer to make conclusion. At this stage, students are more likely to be involved in learning (student-centered learning). Lecturers play more role as facilitator. If possible during the discussion, if there have some problems that require literature, lecturers can show it through online media (internet) so that the problems faced by students can be resolved. **The final stage**, they are processing, doing data analysis, and developing conclusions.

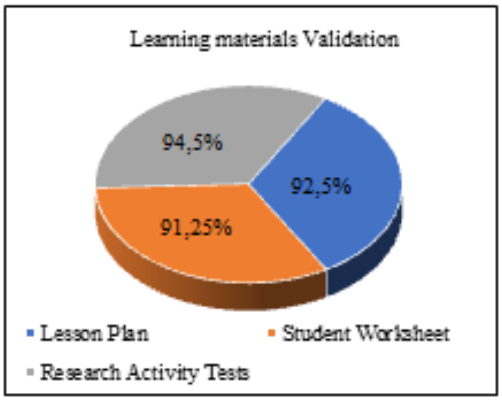
Those above steps can be illustrated in the following flowchart:



In this research, the collected data is generated from students creative thinking skill test through Research Activities Test (RAT). The test focus the students construction of a new graph that has not been studied in rainbow connection research before. The result of RAT is then collected and analyzed to know the students' creative thinking skill based on three indicators: fluency, flexibility and originality /novelty indicators. We then determine the level of student creative thinking based on the compliance of these indicators.

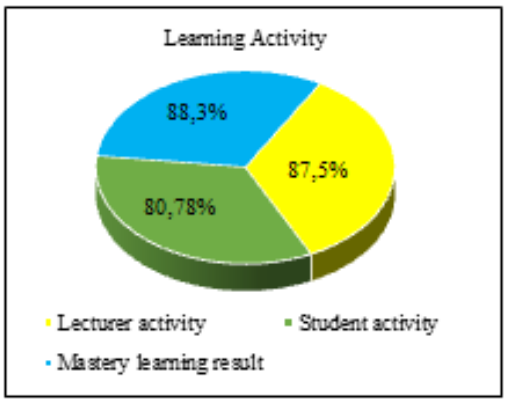
III. Results and Discussion

The initial activity of this research is to carryout research in a research group and bring them into a class. We firstly develop a best teaching plan and establish some indicators which are needed to analyze the students' creative thinking skill. We also develop a research activity test. We the also develop the learning materials needed in the research and we ask some experts to validate them. Learning material validation results which include Learning Plans, Student Worksheets and Research Activity Tests can be shown in the pi chart.



Based on the result of learning material validation, it was obtained that the average value is more than 80%, this result indicates that the learning material can be used as instruments of research. After validating the learning material, then we carry out the research in the classroom. The implementation of the research was conducted four times meeting, where the first meeting until the third is to introduce the concept and implement research based learning in graph theory, namely rainbow connection.

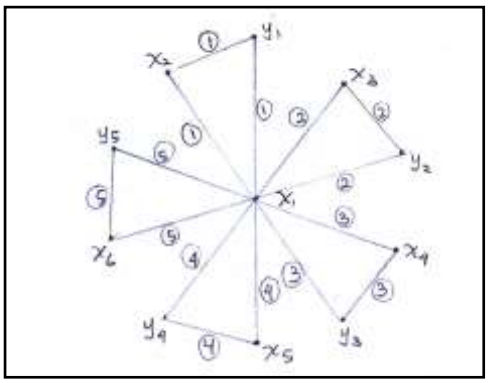
During the learning process, the researcher's activity in managing the class and the activity of the students in the class is assessed by the observer. It aims to measure whether the learning process is going well or not. The average results provided by the observer indicate that the researcher can manage the class well and the students are active during the learning process. Here is the result average of observation of learning activities which include the activity of lecturer /researcher in managing learning and activity of student activeness in learning during three meeting.



Implementation of learning through RBL method aims to introduce the concept of rainbow connection as a problem of this study. After the introduction and explanation of the concept of rainbow connection through RBL, then student sit for Research Activity Tests (RAT). Through this test, students can produce new findings in the rainbow connection graph coloring which has never been studied before. The results of RAT conducted by students are then analyzed to determine the level of creative thinking of students.

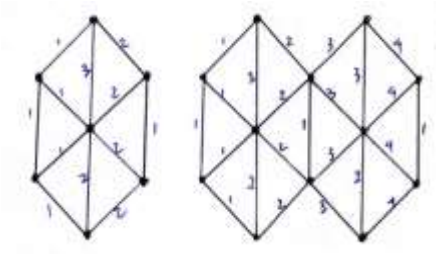
In a test of research activity that has been done by other researcher on this interest of research can be seen in the following pictures.

a. Answer by student A



The strong rainbow connection number of amal gamation of graph, denoted by Amal (C_3,*v*,*n*), is on optimal number, but the notation of vertices can be easier written if the center is labeled as "*p*" and other points with x_i, y_i for $1 \leq i \leq n$.

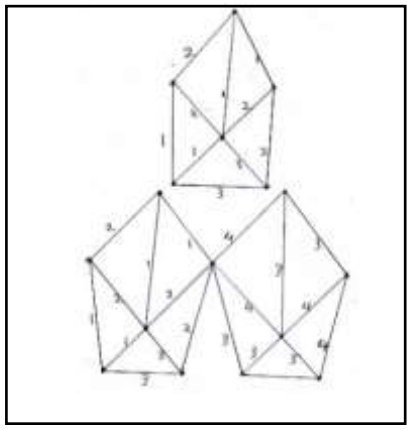
b. Answer by student B



(a) (b)

The rainbow connection number of the graph (a) is *rc* = 3, but this color is not optimal one, it should be enough to use 2 colors, while the coloring in the graph (b) is correct. Usually if the color on the basic graph is not optimal then the color of the expanded graph is also not optimal.

c. Answer by student C

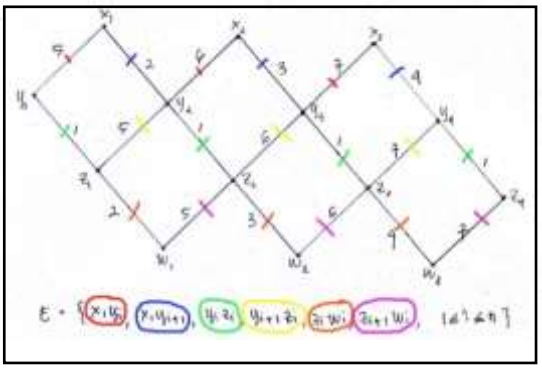


The coloring above is not optimal. Actually, the coloring of the base graph is enough to be given 2 colors, while the coloring of the expanded graph for *n* = 2 can be given 4 colors, so the coloring required in the expand graph above is *rc* = 2*n*.

The basic graph in the graph above is a wheel W_n. The answer of student B is using the basic graph W_6, then the student C is using the basic graph W_5. The coloring of rainbow connection on graph W_n has been found, where for graph W_n for $4 \leq n \leq 6$ has *rc* = 2, so the coloring of the basic graph by student B and C are not optimal.

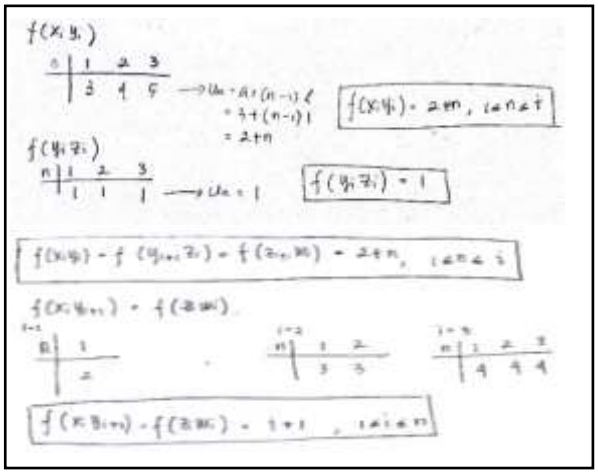
If we refer to the originality indicator, students B and C using wheel graphs as the object of research on this coloring of rainbow connection still show the novelty indicator as the two students use graph operation *shackle* to generalize the wheel graph and it is different from the previous findings.

d. Answer by student D



The graph on the above is a *shakle*(P_3,*e*,*n*) for *n* = 3. There is a bit of mistake on the edge notation $y_i z_i$ for $1 \leq i \leq n$, the boundary should be $1 \leq i \leq n+1$ because if the limit is $1 \leq i \leq n$ so the edge $y_4 z_4$ does not exist.

The additional error on writing the set of edge, there is also an error in writing the coloring function while for the provision of rainbow connection coloring pattern is correct and optimal. The following errors in the developing of coloring function of shakle graph (P_3,*e*,*n*).



The function written above is based on the coloring pattern of a *shakle*(P_3,*e*,*n*) for *n* = 3. On the edge $x_i y_i$, they are written the coloring 3, 4, 5, while the edge $x_i y_i$ of the graph above have colors 5, 6, 7. The coloring function should not be $f(x_i y_i) = 2 + n$, for $1 \leq n \leq i$, but it should be $f(x_i, y_i) = n + i + 1$ for $1 \leq i \leq n$

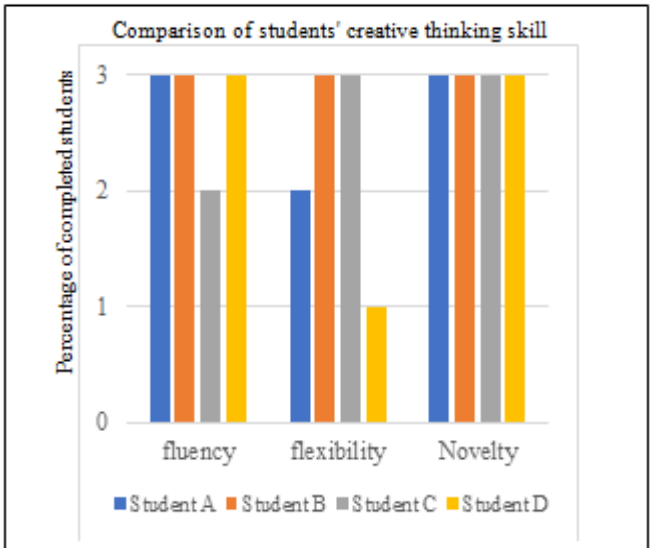
Whilst, the coloring function in the above answer shows a mistake on the edge $x_i y_i, z_i y_{i+1}, w_i z_{i+1}$. If the graph is expanded, then the coloring function should be written as

follows.

$$f\{e\} = \begin{cases} 1 & ,e = y_i z_i \text{ for} 1 \le i \le n+1 \\ i+1 & ,e = z_i w_i = x_i y_{i+1} \text{ for} 1 \le i \le n \\ n+i+1, & e = x_i y_i = z_i y_{i+1} = w_i z_{i+1} \text{ for} 1 \le i \le n \end{cases}$$

Value

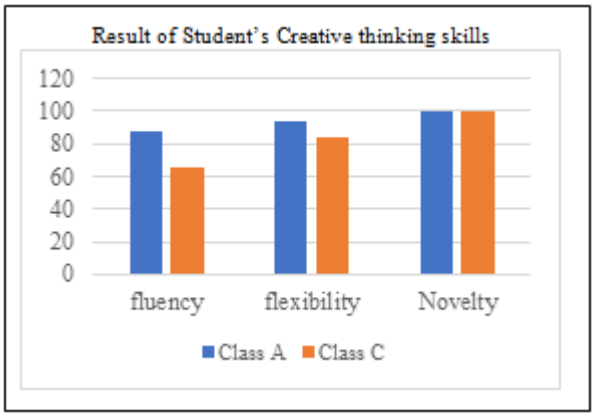
Finally, we can show the analysis result of creative thinking skills from the four students. It can be presented in the graphic below.



Information:
- Fluency indicator
  - Value 3 = Gives coloring correctly and optimally
  - Value 2 = Gives coloring correctly but not optimal
  - Value 1 = Incorrect coloring
- Flexibility indicator
  - Value 3 = Write the cardinality and coloring function correctly and completely
  - Value 2 = Write the cardinality and coloring function correctly but not complete
  - Value 1 = Cardinality or coloring function is wrong
- Indicator of originality/novelty
  - Value 3 = Create a new graph that has not been studied before
  - Value 2 = Create a graph that has been researched before
  - Value 1 = Unable to create an image

In the fluency indicator, only student C sufficiently meet the indicator which means that student is able to provide rainbow connection coloring on the graph, but the coloration used is less optimal. For the flexibility indicator, student sufficiently meet the indicator but the coloring function is also less optimal. While student D does not meet the flexibility indicator as the coloring function is wrong.

We finally also can show the recapitulation of creative thinking skills analysis of class A and class C students in the following picture.



Based on the graphics above, we can describe that all students are able to meet the indicators of originality, this can happen due to during learning process, students are required to create a new graph that has never been studied before. While few students meet the fluency indicator, this happens because the concept of rainbow connection coloring studied is different from the concept of graph coloring that the students learn so that there are some students who are still affected by the concept of coloring of the previous special graph.

IV. Conclusion

Lecturers can bring their research into learning process through RBL method. The students can understand the progress of the latest research and students can gain experience in doing research. Students are not only stuffed with information and science but also taken to a high level of creating or communicating. Creating on this research is how students can find a new rainbow coloring of graph that has never been studied before. All the activities while carried out by the students in their research was analysed to know the level of creative thinking of the students.

Based on the data analysis above, we can also conclude that the skill level of student creative thinking can be grouped into four creative thinking level. In class A, there are 28 students with creative thinking skill of level 4, 2 students are of level 3, and 4 students are of level 2. While in class C, there are 20 students with creative thinking skill of level 4, 2 students are of level 3, and 8 students are of level 2.

We have found the students level of their creative thinking skill when we implement the RBL in a class especially working on finding a rainbow coloring of graph. Based on the result analysis, we proposes the following suggestions for further research:

a. What is the impact of implementing RBL to their students learning outcomes?
b. How big is the novelty of result research obtained from the classroom?
c. How complex is the generalization a research result obtained from RBL?
d. How can we increase easily the students creative thinking skills through the implementation of RBL?

V. Acknowledgement

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