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The Analysis of the Implementation of Research-Based Learning with STEM Approach to Improving the Students' Metaliteracy in Solving the Resolving Strong Dominating Set Problem on traffic CCTV placement

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ABSTRACT: Metaliteracy is urgently needed in the digital era, however, is still not widely owned by students. This metaliteracy requires high-level thinking skills to process various problems with various media sources, as well as it requires a collaborative environment. To achieve a good metaliteracy equipped with a higher thinking skill, we will implement research-based learning with a STEM approach in the learning process. This study uses a mixed-method by combining qualitative and quantitative methods. The subject of this study is the students of mathematics education as the candidates for teachers. They are grouped into two classes, namely, experiment class and control class. We used an independent sample *t*-test to determine the significant difference in the students' metaliteracy between the experiment class and the control class under the implementation of the research-based learning model with the STEM approach to resolve the strong domination problem. Before testing the significant difference, we tested the homogeneity. The test results on the pre-test items showed that the significance score is 0.747 > 0.05, meaning the two classes are homogeneous. The independent sample *t*-test showed that the score is 0.020 < 0.05, which indicates that the difference between the two classes is significant. It implies that implementing the research-based learning materials with a STEM approach affects the students' metaliteracy improvements.

KEYWORDS: Metaliteracy, Research-Based Learning, Resolving Strong Domination Problem, STEM.

INTRODUCTION

Along with industrial development in the 21st century, the government is increasingly enthusiastic about motivating every citizen to receive higher education. Not only that, but the Indonesian government also gives freedom to its citizens to obtain a quality education so that Indonesia's education can grow faster than in other developing countries. The government's efforts to answer the challenges of facing the industrial revolution 4.0 by applying the STEM approach to the learning process. The National STEM Education Center [11] states that STEM-based education develops an educational system that combines science, technology, engineering, and mathematics in the learning process to solve a real problem in everyday life. Indonesia has begun to pay attention to STEM elements in education by applying a scientific approach in learning the 2013 curriculum. However, it has not had a real impact on achieving educational goals because the four elements of STEM are still applied separately and are not related to each other [13], which are not following the provisions of STEM learning.

Sanders [14] argues that STEM is a combination of two or more fields of science or between areas of science contained in STEM in an approach to the learning process with one or more other school subjects. Therefore, learning using the STEM approach is very effective to use by educators such that the learning objectives are achieved effectively and it can improve the quality of education faster than before. Meanwhile, Dafik [4] has explained that research-based learning is a learning method that uses contextual learning, authentic learning, problem-solving, cooperative learning, inquiry discovery approach, and hands-on and mind-on learning. Research-based learning is learning based on the philosophy of constructivism, where students are required to have an active contribution to the learning process by building their knowledge by combining new information obtained and experience with the knowledge structure that already exists in their minds. Research-based learning is a learning model where students become the center of learning and lecturers integrate the research results and activities into the learning process in the classroom. Thus, this learning provides an

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opportunity for students to learn by doing and provides an opportunity to seek information related to research, develop tentative assumptions (hypotheses), collect data, analyze data, and make conclusions from all the data collected. The following is the syntax of research-based learning in Figure 1.

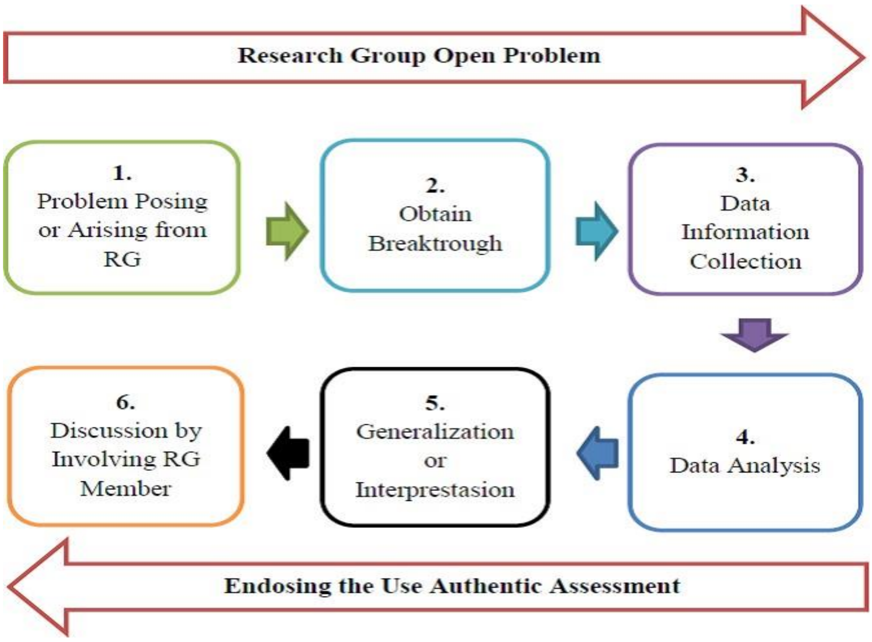

Figure 1. The Syntax of research-based learning

Our research aims to implement the combination of RBL-STEM to improve students' metaliteracy. Mackey and Jacobson [9] have explained that metaliteracy is the reframing and rediscovery of information literacy based on critical thinking and the pursuit of lifelong learning. Metaliteracy is a comprehensive framework of thinking and also a comprehensive independent reference compared to other types of literacy. Jacobson and Mackey [7] said that information literacy is a basic literacy of era metaliteracy. It requires higher order thinking skills to process various documents with various media formats.

Metaliteracy skills include four domains, namely behavioral, affective, cognitive, and metacognitive. Students must have these four domains to perform their metaliteracy. Mackey and Jacobson [10] explained that metaliteracy integrates metacognition to explore the students' awareness of their techniques used to solve some problems. The following are the indicators and the sub-indicators of metaliteracy, see Table 1.

Table 1. The Indicators and Sub-Indicators of Metaliteracy

Indicators	Sub Indicators
Produce	Identify the nature/characteristic of the problem Obtain Breakthrough Develop or define stages, phrases, Syntax, or algorithms
Incorporate	Identify the pattern of the solution Propose a generalization Using the Internet of Things, such as software, platforms, and applications to integrate some different techniques
Use	Test the results Analyze the results Interpret the results Apply the results by specific algorithm

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Share	By using the Internet of Things (Social Media, OER, MOOCs, Teaching Platform) Reflect and evaluate feedback Evaluating the number of participant responses Analyze the responses and read the pattern or trends using multiple software
Collaborate	Collaborate with several others using IoT platforms Increase the product by asking for some suggestions from others Encourage people to do more to contribute findings Get joint works and products to publish Defining future work together for the wider community

Furthermore, to improve mateliteracy we need to challenge the students with non-procedural problems. Dafik et al. [5] introduced the latest non-procedural problem in graph theory, namely a resolving strong domination set. This study combines two concepts namely, the metric dimension and the strong dominating set. To elaborate this problem into a STEM problem, we consider a real life problem, namely CCTV placement in a city traffic. We chose a Lamongan district to place an effective and efficient CCTV. A resolving set is a set of vertices S in graph G in which for any two vertices u, v, therefore $x \in S$, so the distances $d(u, x)$ are not equal to $d(v, x)$ [12]. A strong dominating set of a G is a set D subset vertex (G) with the element that for all vertices x in $V(G)$ intersection D, there is a vertex y neighborhood with vertex x intersection D with the degree of vertex x is less than or equal to the degree of vertex y. A vertex dominates the vertex not in D that has at least the same degree. In this situation, we say that y strongly dominates x [8]. The resolving strong dominating set is the set of $D_s \in V(G)$, where D_s satisfies the definition of the strong dominating set and the resolving set. Resolving strong domination number is denoted by $\gamma_{rst}(G)$, which is the minimum cardinality of the resolving strong dominating set provided that the conditions for both concepts are met, namely metric dimension (resolving set) and strong dominating set [2].
To equip the students to solve the problems, we develop some learning materials regarding the implementation of research-based learning with a STEM approach to improve the students' metaliteracy in solving the resolving strong domination problem on traffic CCTV placement. The materials include student worksheets, learning media, and the instrument test. Based on the definition of the resolving strong domination of graphs, students will label the element of graphs, determine the resolving strong dominating set, and determine the function of the vertex representation within the resolving strong dominating set.

METHODS

This research used a mixed-method, which combines two methods namely quantitative and qualitative research methods. The Quantitative method was used to analyze the significant difference of the students' metaliteracy between two classes, i.e. control and experiment classes, while the qualitative method was used to analyze the portrait phase of the students' metaliteracy when solving the problems [3]. We used the RBL-STEM learning materials. These materials have been developed in the previous research and the paper has been already published [1]. The learning materials include lesson plan, student worksheets, test instruments. We use all the learning materials with RBL model and STEM approach in the experiment class and we use the RBL model and STEM approach in the control class but without the learning materials. The following shows the research design using mixed methods in Table 2.

Table 2. The question experiment research design

Group	Pre-Test	Treatment	Post-Test
Experiment	O_1	X	O_2
Control	O_3		O_4

O_1, O_3 : Determining the initial students metaliteracy by using a pre-test instruments for both classes
X : The use of the learning materials with RBL model and STEM approach in the experiment class
O_2, O_4 : Obtaining the students metaliteracy by using a post-test instrument for both classes

Metaliteracy has five indicators: produce, incorporate, use, share, and collaborate. There are three metaliteracy thinking levels, namely high, medium, and low. We will obtain the score of the indicators produce, incorporate, and use by giving the students a pre-test and post-test, but for the indicators to share and collaborate, we will obtain them by doing interviews and observation.

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Task

The students involved in this study will join the pre-test and post-test. Students also will work on worksheets to present their metaliteracy [6]. The pre-test and post-test will be given to students on the experiment and control groups. The students of the control class will be taught by RBL-STEM but without the learning materials developed in this research, while the students of the control class will be taught by RBL-STEM together with the learning materials developed in this research. We ask students to work and solve the resolving strong dominating set problem, visualize it, expand the graph, express the notation, determine the cardinality, and apply the resolving strong dominating set function on a graph. The student worksheet contains two questions, the first question has a STEM problem regarding the placement of police monitoring posts. The second question, students are given a graph, see in Figure 2, and asked to give a name of the graph, write the vertex set, the edge set, order, and size, and determine the resolving strong domination set, the resolving strong domination number, do the generalization of resolving strong dominating set and resolving strong domination number of the graph

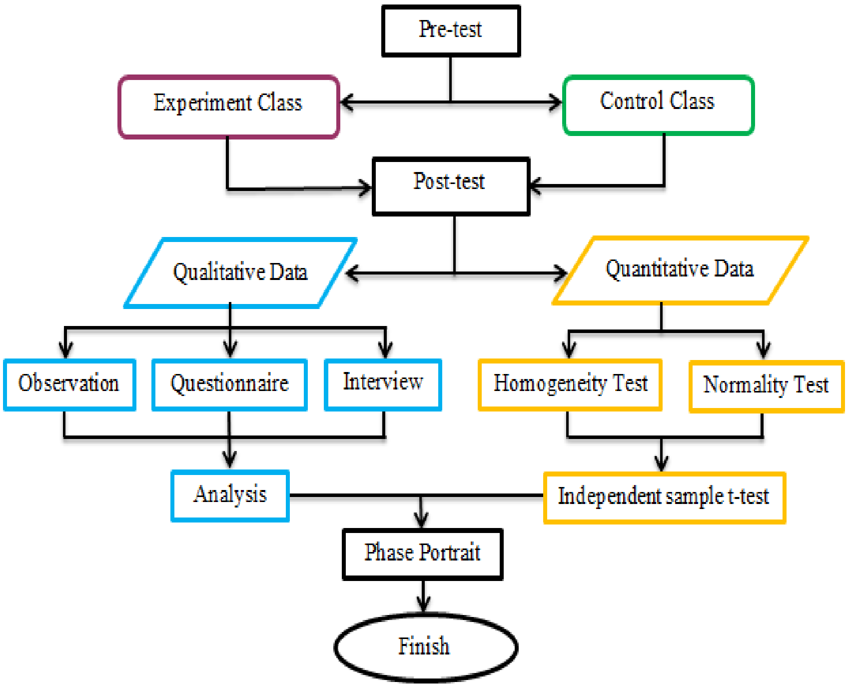

Figure 2. The mix method of research design diagram

STEM Problem

Lamongan Local Government, in collaboration with the transportation service, has installed some CCTV (close circuit television) used to facilitate the Traffic Police Unit to monitor traffic flow at 23 crossroad points. CCTV is placed at prone points, traffic jams and accidents areas. The CCTV used is a fixed type of CCTV that records events or incidents at traffic intersections. The CCTV function is to record and playback some anomaly accidents. The two criteria should be considered to place the CCTV:

- The points have the most connectivity to other points
- The points can reach all CCTV points

Determine the location points and minimum number of CCTVs required. If one police monitoring post costs Rp. 6,000,000.00, what is the range of costs that must be spent to create police monitoring posts in Lamongan city? The STEM aspects for this problem are:

a. Science: Overview the Lamongan city crossroads from Google maps.
b. Technology: Install CCTV type at a predetermined point, use of computer technology in the form of software such as Geogebra App, Microsoft Word, Microsoft PowerPoint, and others to draw graphs.
c. Engineering: Use the space syntax in the placement of CCTV and determine the location of police monitoring posts by using the concept of resolving a strong dominating set.

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d. Mathematic: Utilize the mathematical calculations in determining the location of the police monitoring post using the concept of a resolving strong dominating set.

RESULT

We describe a framework of integrating STEM in research-based learning to improve students' metaliteracy in solving the problem related to police monitoring posts by using a strong dominating set of the graph. In the first step, we developed research-based learning materials with a STEM approach to improving students' metaliteracy. The research method used the 4-D Thiagarajan model to establish the STEM materials, namely define, design, develop, and disseminate. Two validators from the mathematics education department at the University of Jember validated the learning materials. After the validator gave the validation results, we conducted a field test to determine practicality and effectiveness, and the result showed that the implementation of the learning materials was considered to be in the "good" category. The following are the results of the student pre-test, see in Figure 3.

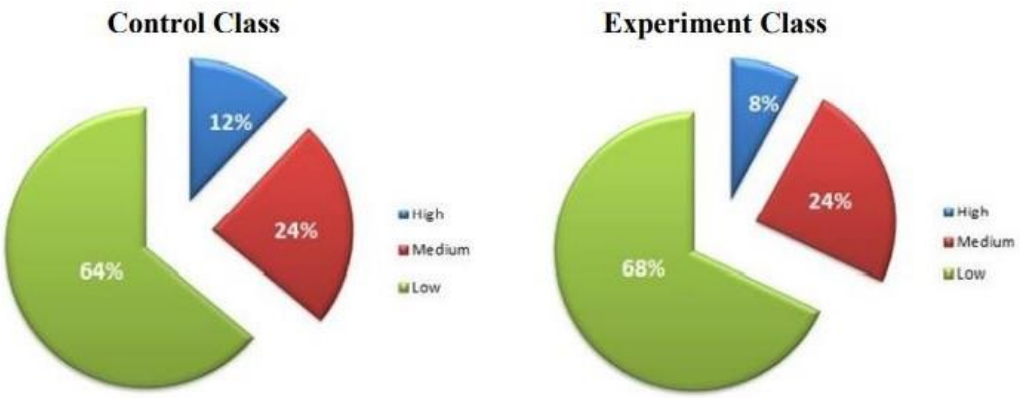

Figure 3. The distribution of student metaliteracy on pre-test

The pre-test results from the control class showed that there were 12% of students at a high level, 24% at a medium level, and 64% of students at a low level. In contrast, the pre-test results from the experiment class showed that there were 8% of students at a high level, 24% of students at a medium level, and 68% percent of students at a low level.

Before we proceed further, we tested the homogeneity and normality as the condition to analyze the independent sample *t*-test. We use a homogeneity test to determine the similarity of variance between several groups. The normality test determines whether the data distribution of the group has a normal distribution or not. At the same time, the independent sample t-test determines whether or not there is a significant difference in students' metaliteracy between the control class and the experiment class. The results of the homogeneity and normality tests on the pre-test are in Tables 3 and 4.

Table 3. Output Homogenity Test on Pre-Test

		Levene Statistic	df1	df2	Sig.
Student's Metaliteracy	Based on Mean	.105	1	48	.747
	Based on Median	.138	1	48	.712
	Based on Median and with Adjusted df	.138	1	47.998	.712
	Based on Trimmed Mean	.101	1	48	.752

Based on Table 3, the significance value is 0.768, more than 0.05. We may say that the two groups have the same variance, which is homogeneous. While on Table 5, the significance value for experiment data and control data in the Kolmogorov

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Smirnov column were 0.071 for the experiment class and 0.119 for the control class, which were more than 0.05, it means that both classes have data of normal distribution.

Table 4. Output Normality Test on Pre-test

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Class	Statistic	df	Sig.	Statistic	df	Sig.
Student's Metaliteracy	Experiment	.167	25	.071	.992	25	.056
	Control	.156	25	.119	.929	25	.047

For the next step, after picking up the homogeneity test and normality test result, we did the independent sample *t*-test to oppose the mean of both classes. The independent sample *t*-test on the pre-test can be seen in Table 5.

Table 5. Output Independent Sample t-test on Pre-Test

		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
Student's Metaliteracy	Equal variances assumed	.081	.777	-.833	48	.409	-1.400	1.681	-4.780	1.980
	Equal variances not assumed			-.833	48.000	.409	-1.400	1.681	-4.780	1.980

Based on Table 5, we can conclude that the average learning outcomes between the experiment class and the control class have no difference because the (2-tailed) significance value is 0.777, which is more than 0.05. After giving pre-test to both classes, the research continued to provide research-based materials with STEM approach in the experiment class and research-based materials in the control class. After the treatment, we performed a post-test in both classes.

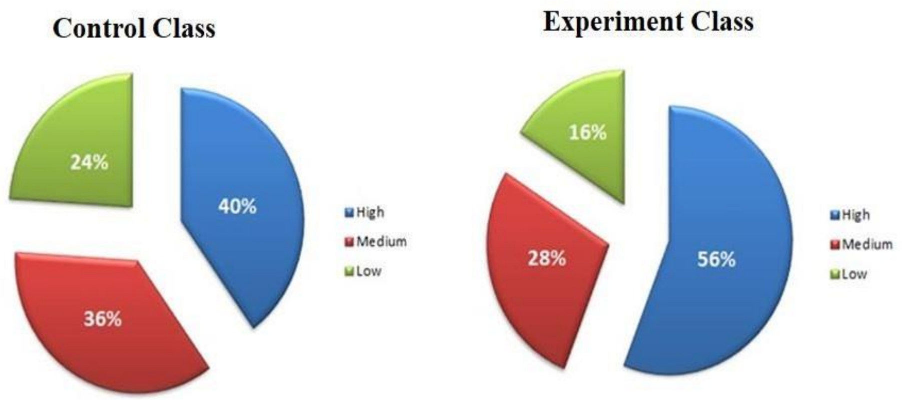

Figure 4. Distribution of metaliteracy on Post-Test

Based on Figure 4, the post-test results from the control class showed that the metaliteracy of students at a high level which was initially 12%, increased to 40%, at medium level, which was initially 24% increased to 36%, and at low level which was initially 64% decreased to 24%. While the post-test results from the experiment class showed that the metaliteracy of students at a high level which

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was initially 8%, increased to 56%, at medium level, which was initially 24% increased to 28%, and at a low level, which was initially 68% decreased to 16%. The data we got was tested for homogeneity and normality as a condition for conducting an independent sample *t*-test. Then we used the independent sample *t*-test to see the average difference between the two classes.

Table 6. Output Independent Sample *t*-test on Post-Test

		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
Student's Metaliteracy	Equal variances assumed	2.581	.119	2.403	48	.020	6.400	2.663	1.045	11.765
	Equal variances not assumed			2.403	44.766	.020	6.400	2.663	1.035	11.765

According to Table 6, the post-test data was homogeneous for both classes because Levene's significance test for equality of variance is 0.119, more than 0.05. The independent samples t-test result showed that the significance value (2-tailed) is 0.020, less than 0.05. The mean difference is 6.400, and it concludes that there was a difference in the average of the learning results between the experiment and control classes.

The following are the post-test results of students finding solutions to the STEM problem and the resolving strong dominating set. We use the interviews to support the post-test data from students.

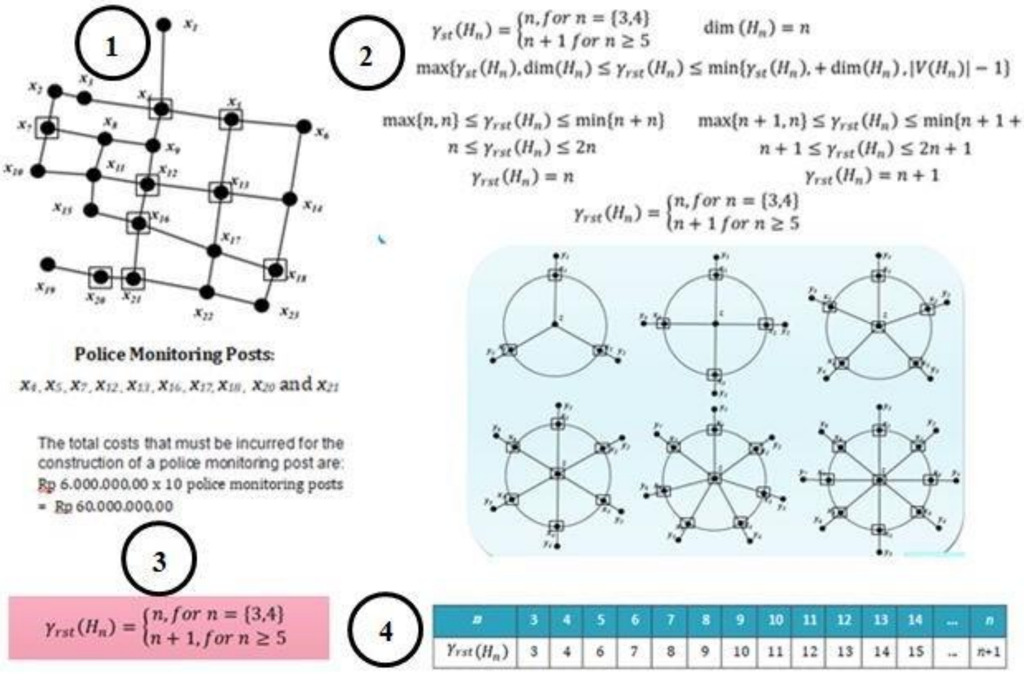

Figure 4. Student metaliteracy on High Level.

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From Figure 4 on the results of the student post-test, we can see that student with metaliteracy at a high level has been able to solve STEM problems, namely the placement of police monitoring posts. This result indicates that students can correctly draw the graph from map images. Students can also determine the minimum number of police monitoring posts by using the resolving strong dominating set. Student wrote that there were police monitoring posts located at points x_4, x_5, x_7, x_{12}, x_{13}, x_{16}, x_{17}, x_{18}, x_{20}, x_{21}, the cost range is IDR 60,000,000.00. In the next question, the student can determine the vertex set, edge set, order, and size of the Helm graph and determine the resolving strong dominating set of the Helm graph using the lemma presented in the post-test sheet. Still, there are some spelling mistakes though not too bad. Students use Geogebra software during the post-test process and utilize the Internet of Things. The illustration of the first work can be seen in Figure 5.

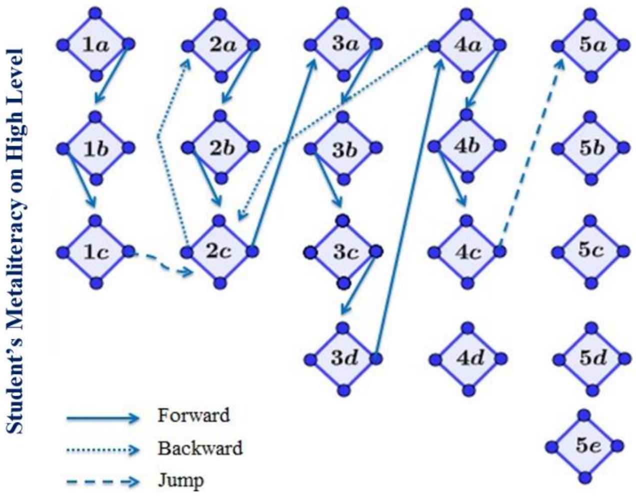

Figure 5. The Results of Phase Portrait Student Metaliteracy on High Level.

After in-depth interviews and learning processes, we can analyze the students' thinking processes in detail. metaliteracy thinking processes can be described using phase portraits. We can uncover students' thinking steps from beginning to end in solving the STEM problem and resolving a strong dominating issue. A phase portrait diagram is formed by connecting each step with a direct line. The phase portrait of students' metaliteracy with high level can be seen in Figure 9. Figure 9 is the work of students' metaliteracy at a high level. In steps 1a to 1c, the student can identify the solution to the STEM problem. The student also gets the obtain breakthrough and defines the algorithms from the study of resolving strong dominating set. Then the student jumps to step 2c, where the student uses the Internet of Things to solve the STEM problem, and then the student jumps to step 3a to 3d, where the student-test the results, analyze the results, interprets and apply the results of STEM problem. From steps 3a to 3d, the student goes back to steps 2a to 2c. The student determines the generalization of vertex set, edge set, the cardinality of helm graph, and the function of resolving strong domination number graph ($\gamma_{rst}(H_n)$). Next, in steps 3a to 3d, the student-test the results, analyze the results, interpret and apply the results of resolving strong dominating set of helm graphs. For step 4a, the student uses the Internet of Things to finish the work and discuss during the learning process. For step 4b, the student can reflect and evaluate feedback from other groups during the learning process. After step 4b, the student jumped to step 5a, where the student worked with several people in the group using IoT platform and skipped steps 4d and 5b to 5e.

The following are problem-solving results from students' metaliteracy on a medium level. From Figure 6 from the result of the student post-test, we can see that student with metaliteracy at medium level has been able to solve STEM problems, namely the placement of police monitoring posts. This result indicates that the student can correctly draw a graph from a map image. The student can also determine the minimum number of police monitoring posts by using the resolving strong dominating set. The student wrote that the location of the police monitoring post was at the point x_4, x_5, x_7, x_{12}, x_{13}, x_{16}, x_{17}, x_{18}, x_{20}, x_{21}, but the student had not mentioned the range of costs used to build the police monitoring post. In the following question, the student can determine the vertex set, edge set, order, and size of the helm graph, the student can also determine the strong dominating set of the helm graph and determine the resolving strong domination number function of the graph using the lemma that has been presented in the post-test sheet, but the

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student only completed half of the completion process in determining the resolving strong domination number (only mention $\gamma_{rst}(H_n) = n + 1$ for n 3). Students use Corel Draw software and other software in the post-test process and take advantage of the Internet of Things (IoT).

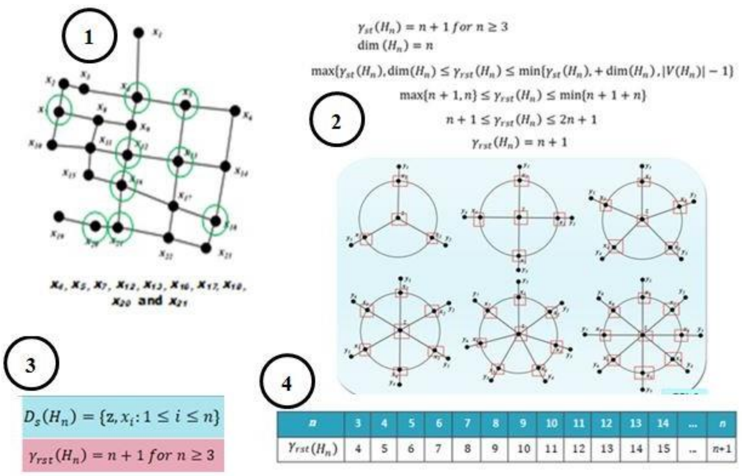

Figure 6. Student metaliteracy on Medium Level.

After in-depth interviews and learning processes, we can analyze the students' thinking processes in detail. metaliteracy thinking processes can be described using phase portraits. We can uncover students' thinking steps from beginning to end in solving the STEM problem and resolving a strong dominating problem. A phase portrait diagram is formed by connecting each step with a direct line. The illustration of the phase portrait of students' metaliteracy with medium level can be seen in Figure 7. Figure 7 is the work of students' metaliteracy with medium level. In steps 1a to 1c, the student can identify the solution to the STEM problem. The student also gets the obtain breakthrough and defines the algorithms from the study of resolving strong dominating set. Then the student jumps to step 2c, where the student uses the Internet of Things to solve the STEM problem, and then the student jumps to step 3a to 3c, where the student tests the results, analyzes and interprets the results of the STEM problem, and skip the step 3d. From steps 3a to 3c, the student go back to steps 2a to 2c, where the student determine the generalization of vertex set, edge set, the cardinality of the helm graphs, and the function of resolving strong domination number of helm graph ($\gamma_{rst}(H_n)$), but in this case, the student only finishes half of the work. Next, in steps 3a to 3c, the student tested the results, analyzed the results, and interpreted the resolving a strong dominating set of helm graph. The student skips steps 3d and 4b to 5e. The illustration of the first work can be seen in Figure 7.

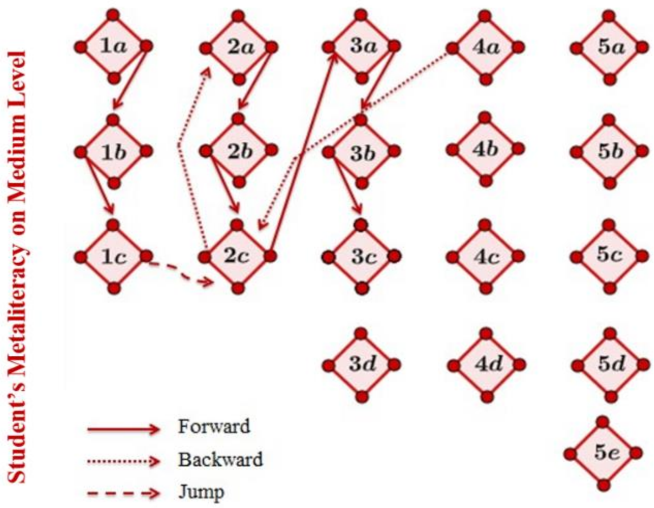

Figure 7. The Results of Phase Portrait Student Metaliteracy on Medium Level.

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The following are problem-solving results from students' metaliteracy on the low level.

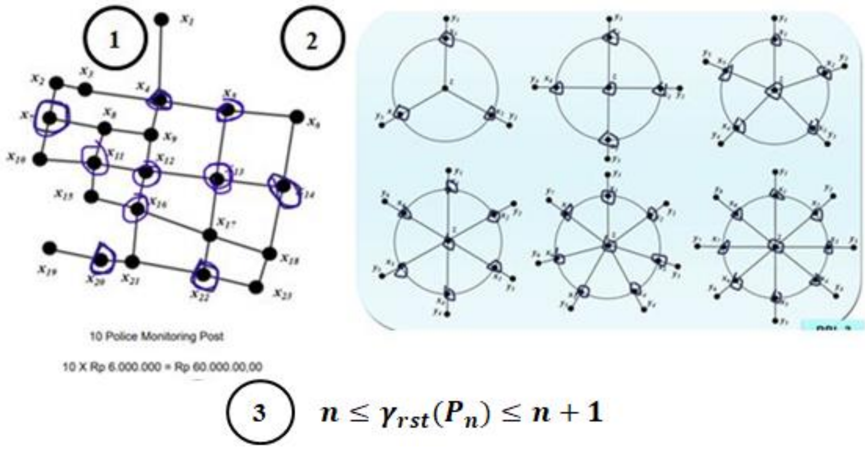

Figure 8. Student metaliteracy on Low Level.

From Figure 8 from the result of the student post-test, we can see that student with metaliteracy at a low level is less precise in solving STEM problems. This result indicates that students can correctly draw a graph from a map image and determine the minimum number of police monitoring posts. However, the placement of police monitoring posts still does not follow the concept of resolving a strong dominating set. The student wrote the police monitoring post were located at x_4, x_5, x_7, x_{11}, x_{12}, x_{13}, x_{14}, x_{16}, x_{20}, x_{22}, with a cost of IDR 60,000,000.00. Then in the next question, students can determine the vertex set, edge set, order, and size of the helm graph, but the student has not been able to determine the strong dominating set of the helm graph and determine the resolving strong domination number function of the graph. Students use GeoGebra software and other software in the post-test process and take advantage of the Internet of Things.

After in-depth interviews and learning processes, we can analyze the students' thinking processes in detail. We describe the metaliteracy thinking processes by using phase portraits. Metaliteracy thinking processes can be described using phase portraits. We can uncover students' thinking steps from beginning to end in solving the STEM problem and resolving a strong dominating problem. A phase portrait diagram is formed by connecting each step with a direct line. We can see the student's metaliteracy with a low level in Figure 8. In steps 1a to 1c, the student can identify the solution to the STEM problem. The student also gets the obtain breakthrough and defines the algorithms from the study of resolving strong dominating set. Then the student jumps to step 2c, where the student uses the Internet of Things to solve the STEM problem. Next, the student goes back to step 2a, where the student determines the generalization of vertex set, edge set, the cardinality of helm graph. The student skips steps 2b and 3a to 5e. The illustration of the first work can be seen in Figure 9.

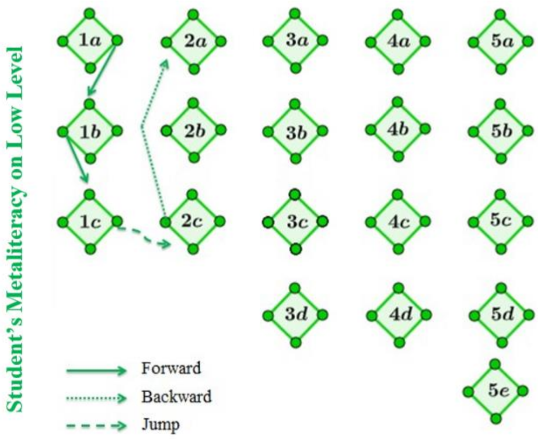

Figure 9. The Results of Phase Portrait Student Metaliteracy on Low Level.

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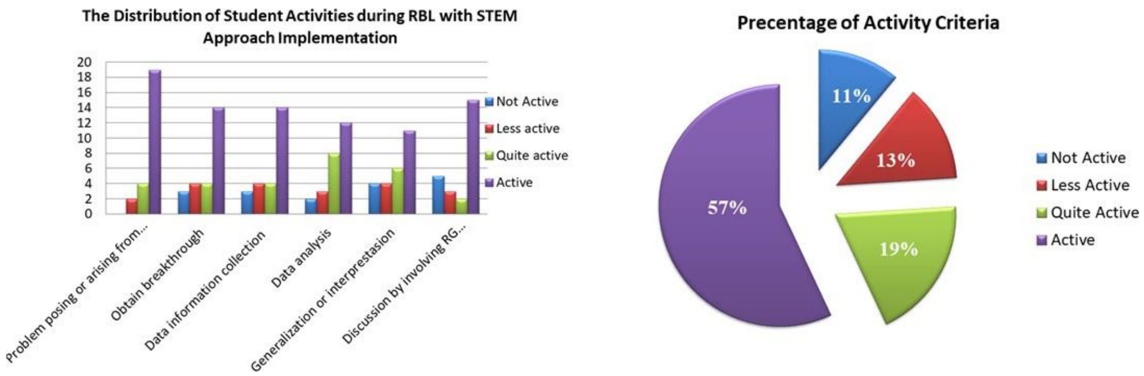

Figure 10. Observation result of RBL steps

The observations in Figure 10 showed 11% of not active students, 13% were less active students, 19% of students were quite active, and 57% of active students.

DISCUSSION

This study explores the effectiveness of applying research-based learning with a STEM approach to improve students' metaliteracy skills. The research instrument in the experiment class uses a research-based learning instrument with a STEM approach, while the control class only uses a research-based learning instrument. The STEM problem discussed in this study is the placement of police monitoring posts using the resolving strong dominating set. Then after solving the problem, students are expected to be able to apply the topic of the resolving strong dominating set to other graphs.

The t-test concludes that there is no significant or homogeneous difference in the pre-test scores of the two classes. After being given treatment in research-based learning with a STEM approach, the post-test scores of the two classes experienced a significant difference with a Sig. 2-Tailed value of 0.002. The test results data from 50 students showed that the metaliteracy of students experienced a significant change. From 25 students in the control class, the post-test results from the control class showed that the metaliteracy of students at a high level which was initially 12% or 3 students, increased to 40% or 10 students, at medium level, which was initially 24% 6 students increased to 36% or 9 students. At the low level initially 64%, 16 students decreased to 24%, 6 students. Meanwhile, 25 students in the experiment class showed that the metaliteracy of students at a high level initially 8% or 2 students increased to 56% 14 students, at medium level which was initially 24% or 6 students increased to 28% or 7 students. At a low level initially, 68% or 17 students decreased to 16% or 4 students.

Research-based learning with a STEM approach significantly impacts traditional learning in improving students' metaliteracy skills. With this learning, students become more active and dare to try new things so that knowledge can occur in two directions and positively impact students. Research-based learning model with STEM approach improves students' metaliteracy abilities. The test results and student activities conclude that the metaliteracy skills in the experiment class are better.

CONCLUSION

In this research, the results of implementing a research-based learning approach and STEM approach obtained a significant observable influence on the metaliteracy of students in the experiment class. Almost all students in the experiment class can solve the STEM problems using the concept of resolving strong dominating set, and they can apply the topic to other graphs. Implementing research-based learning with STEM approach can help improve students' metaliteracy, such as within the experiment class that got way better grades since implementing research-based learning with STEM approach. We suggest that future researchers develop more details on metaliteracy skills and implement STEM approach to learn by creating different thinking skills based on the results of this study.

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