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The Effectiveness Of Inquiry Learning With The 5E Learning Cycle Model On Mathematical Communication, Learning Achievement And Student Interest

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Abstract–This study aims to describe the difference in effectiveness between Inquiry Learning with the 5E Learning Cycle Model and Inquiry Learning with the 3E Learning Cycle Model in terms of mathematical communication, learning achievement and student interest. This research is quasi-experimental research with the form of pretest-posttest non-equivalent group design. Data collection was carried out at one of the public junior high schools in Yogyakarta Regency in the 2023/2024 school year. The research sample consisted of two experimental classes were selected based on teacher recommendations to have equal mathematical abilities. Experimental class 1 was given inquiry learning with the 5E learning cycle model, while experimental class 2 was given inquiry learning with the 3E learning cycle model. Data collection techniques used in the form of giving pretests and post-tests related to mathematical communication, learning achievement and student interest. Hypothesis testing used independent sample t-test statistics. The results showed that Inquiry Learning with the 5E Learning Cycle Model was more effective than Inquiry Learning with the 3E Learning Cycle Model in terms of mathematical communication, learning achievement and student interest.

Key words: interest in learning, inquiry learning, mathematical communication, learning achievement, 5E learning cycle.

I. INTRODUCTION

Communication is one of the five process standards in the National Council of Teachers of Mathematics (NCTM) that the five process standards are problem solving, reasoning and proof, connection, communication, and representation [1]. Mathematical communication skills refer to students' abilities to (1) organize and connect their mathematical thinking through communication; (2) communicate their logic and clear mathematical thinking to peers, teachers, and others; (3) analyze and evaluate the mathematical thinking and strategies used by others; and (4) use mathematical language to express mathematical ideas correctly [1]. Mathematical communication is an important skill to be further developed for junior high school students in Indonesia [2]. Therefore, efforts to improve students' mathematical communication skills need to be made, because this is one of the learning outcomes of the cognitive aspect of mathematics learning that is important to develop [3]. Thus, it can be concluded that mathematical communication skills are very important for students to master.

The underdevelopment of mathematical communication skills in students affects their problems solving abilities, which in turn affects their learning achievement. Learning achievement is the knowledge, skills, and abilities acquired by students as a result of the learning process [4]. Learning achievement is used as a measure of the success of the learning process in schools. According to Illiyas & Charles, learning achievement is one of the most important goals in education [5] Meanwhile, learning achievement is the result of what students learn in learning, which is then considered an indicator of the success of learning strategies over a certain period of time and is usually measured by achievement tests [6]. The success of a student in achieving learning objectives can be seen from the learning outcome scores [7]. The quality of mathematics learning can be seen from the learning outcomes of students [8].

In addition to cognitive aspects, affective aspects are also needed by students. Assessment standards are not only based on knowledge, but also on students' attitudes and skills. Attitudinal aspects include interest, motivation, self-confidence, and independent learning. There is a significant relationship between interest in learning and mathematics achievement among junior high school students [9]. According to Hashim et al., interest in mathematics influences students' attitudes toward learning mathematics [10]. The parameters of interest in learning are as follows: 1) Students feel happy during the learning process, 2) Have an interest in learning, 3) Students pay attention while learning, 4) Students have a role during the learning process [11].

However, based on several previous studies, it appears that mathematical communication, learning achievement and student interest are still low [12,13,14,15]. An alternative solution to overcome the problems that arise is to apply a learning model. The purpose of selecting and applying this learning model is to help the teaching and learning process become more effective in order to improve mathematical communication, learning achievement and student interest. The application of the right learning model that is thought to be able to help solve the problems that arise is the learning cycle learning model. In general, this model is part of the inquiry approach developed based on Jean Piaget's thinking about the model of children's thinking development. Inquiry learning itself was first developed by Richard Suchman in 1962, to teach students to understand the research process and explain the results of their research. In this case, students are directed to ask why the event could happen, then students conduct experiments, collect, and analyze data, until finally students find the answer to the question [16].

This learning cycle learning model directs students to find their own concepts and teachers position themselves as facilitators in the learning process. Learning cycle is an inquiry model for learning that continues to show significant effectiveness in the classroom [17]. The learning cycle learning model was first introduced by Atkin and Karplus in 1967 and included in the Science Curriculum Improvement Study (SCIS). The SCIS learning cycle model consists of three stages, which are referred to as the 3E learning cycle model: exploration, invention (explanation), and discovery (elaboration). Biological Sciences Curriculum Study (BSCS) developed this model into five phases, known as the 5E learning cycle model: Engage, Explore, Explain, Elaborate, and Evaluate [18]. The 5E learning model can help students understand concrete experiences to the application of principles. This model provides students with the opportunity to deeply and meaningfully remember what they know [19].

Toraman & Demir in Turan & Matteson state that 43 studies show that research on the effectiveness of learning with the 5E learning cycle model has been conducted in various disciplines and learning contexts from elementary school to university level [20]. However, the focus of most existing literature has been on investigating the use of the 5E learning cycle model in science education. However, empirical studies show that the 5E learning cycle model is also effective for teaching mathematics. Based on several studies, the 5E learning cycle model influences students' communication skills [21, 22]. In addition, the 5E learning cycle also affects learning achievement [23,24]. Research by Susanti et al. shows that the 5E learning cycle has an effect on students' interest in learning [25]. This study was conducted to add empirical evidence regarding the effectiveness of the 5E Learning Cycle model. Therefore, the aim of this study is to examine and describe the effectiveness of inquiry-based learning using the 5E Learning Cycle model in terms of mathematical communication skills, learning achievement, and learning interest among junior high school students.

II. METHODES

The hypothesis in this study is that Inquiry Learning with the 5E Learning Cycle Model is effective in facilitating students' mathematical communication, learning achievement and student interest. There are two criteria for effective learning. The criteria are the post-test score reaches the set KKM and the minimum proportion of students who reach the KKM value on the mathematical communication, learning achievement and student interest is 75%.

This study used a quantitative approach with a quasi-experimental design. Data collection was carried out at one of the public junior high schools in Yogyakarta in mid-March 2024 to mid-April 2024. The research design is a modified pretest-posttest nonequivalent control group design that does not have a control class, so that both groups used are experimental groups that are given treatment [26]. The sampling technique used in this study was purposive sampling. The research sample consisted of two sample classes were selected based on teacher recommendations to have equal mathematical abilities. The population in this study consisted of all Grade VIII students, while the sample included 35 students from Grade VII C as the experimental class 1, which was taught using the Inquiry Learning with the 5E Learning Cycle Model, and 35 students from Grade VII D as the experimental class 2, which was taught using the Inquiry Learning with the 3E Learning Cycle Model. The following is the table of the research design used:

Table 1. Pretest-Posttest Nonequivalent Group Design

Group	Pretest	Treatment	Posttest
E_1	O_1	T_1	O_2
E_2	O_1	T_2	O_2

Description:

E_1: Experimental Class 1

E_2: Experimental Class 2

T_1: Using Inquiry Learning with the 5E Learning Cycle Model

T_2: Using Inquiry Learning with the 3E Learning Cycle Model

O_1: Pretest given to both experimental classes

O_2: Posttest given to both experimental classes

The independent variable in this research is the assisted Inquiry Learning with the 5E Learning Cycle Model. The dependent variables in this study are the mathematical communication, learning achievement and student interest. The data collection technique used a test technique consisting of pretest and post-test. The pretest was given before the learning was done to see students' initial abilities regarding mathematcal communication, learning achievement and student interest. While the post-test is given after learning. The test was prepared based on indicators of the three dependent variables which were then validated using content validity based on expert assessment, namely two mathematics education lecturers. The results of this content validity show that all instruments can be used. The instruments were then tested on students who were not included in the research sample. The results of this trial were then estimated for reliability using the Cronbach Alpha formula. The instrument is said to be reliable if it reaches a minimum value of 0.65 [27]. The results showed that the pretest and post-test instruments of mathematical communcation, learning achievement and student interest were reliable.

III. RESEARCH RESULTS

Data collection was carried out for 6 meetings with details of meeting 1 giving pretest, meeting 2-5 giving material, meeting 6 giving post-test. This study began with a pretest to determine the initial mathematical communication skills and learning achievement of students in both classes before receiving the learning intervention and completing a questionnaire to assess students' initial learning interests. Subsequent meetings included the learning process, which was carried out according to the teaching modules designed for each class. The material covered in this study was "Straight Line Equations," which was divided into six sections: understanding the form of straight line equations, explaining Cartesian coordinates, drawing straight line equations, and determining the gradient of a straight line, solving problems using the concept of gradient, determining the equation of a straight line, and solving contextual problems related to the equation of a straight line. At the end of this study, a post-test was conducted to obtain and describe data on students' mathematical communication skills, learning achievement, and learning interest after the

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treatment. The following table details the quantitative data of students' mathematical communication, learning achievement and student interest.

Table 2. Description of Mathematical Communication Ability Test Results

Description	Experimental Class 1		Experimental Class 2	
	Pretest	Posttest	Pretest	Posttest
Number of student	35	35	35	35
Average	34,76	82,14	34,52	78,33
Standar Deviation	16,1	10,72	17,4	11,29
Maximum score	66,67	100	75	100
Minimum score	8,33	58,33	8,33	58,33

Table 3. Description of Learning Achievement Test Results

Description	Experimental Class 1		Experimental Class 2	
	Pretest	Posttest	Pretest	Posttest
Number of student	35	35	35	35
Average	38,43	84	36,29	81,71
Standar Deviation	12,3	9,22	15,64	18,31
Maximum score	65	100	65	100
Minimum score	15	65	10	65

Table 4. Description of Student Interest

Description	Experimental Class 1		Experimental Class 2	
	Pretest	Posttest	Pretest	Posttest
Number of student	35	35	35	35
Average	66,31	81,83	65,77	76,69
Standar Deviation	12,15	5,48	9,98	7,62
Maximum score	89	92	86	92
Minimum score	44	70	45	64

From the table above, it can be seen that on the variables of mathematical communication, learning achievement and student interest, the average value of the post-test in the experimental class 1 is greater than the experimental class 2. In addition, there is also an increase in the average value from pretest to post-test in the experimental class 1 and experimental class 2. The instruments prepared in this study included a teaching module, Student Worksheets, and test questions in the form of a pretest and posttest. After obtaining quantitative data, assumption tests, and learning effectiveness tests were carried out.

The normality and homogeneity tests were conducted as assumption tests that needed to be met. The normality test was performed using Henze-Zirkler test. The decision criterion used in the multivariate normality test is if the p-value > 0.05, which means that H_0 is accepted.The results of the normality test presented in Table 5 below.

Table 5. Normality Test of Pretest and Posttest Data

Kelas	Variabel	Kelas	Sig
mathematical communication	Pretest	LC 5E	0,152
		LC 3E	0,089
	Posttest	LC 5E	0,0535
		LC 3E	0,068
learning achievement	Pretest	LC 5E	0,565
		LC 3E	0,24
	Postest	LC 5E	0,26
		LC 3E	0,277
	Pretest	LC 5E	0,568

student interest		LC 3E	0,846
	Posttest	LC 5E	0,664
		LC 3E	0,083

From the table above, it can be seen that the Sig. value of the pretest-posttest in the experimental class 1 and experimental class 2 is greater than α = 0.05, so H_0 is accepted. Thus, it can be concluded that the average pretest and posttest scores of students' mathematical communication, learning achievement and student interest are normally distributed. Meanwhile, the homogeneity test was conducted using Box's M Test. The decision criteria are that if the significance value obtained is greater than 0.05, then the covariance matrix is homogeneous or the data obtained in both classes is homogeneous.The results presented in Table 6 below.

Table 6. Homogeneity Test of Covariance Matrices

Group	Chi-square	Sig
Before learning	5,69	0,458
After Learning	5,62	0,54

Based on the table above, it can be seen that the conditions before learning and after learning, the p-value is greater than 0.05. So, H_0 is accepted. The assumption of homogeneity of the variance-covariance matrix is met, meaning that the research data obtained from both classes have a homogeneous variance-covariance matrix, or the data comes from a homogeneous population for both classes before and after treatment. Next, a hypothesis test was conducted using the Independent Sample T-test to examine the effect of the inquiry with the 5E leaarning cycle model and inquiry with the 3E learning cycle model on students' mathematical communication, learning achievement and student interest. The results of the Independent Sample T-test are presented in Table 7 below.

Table 7. Independent Sample T-Test

Class	Variable	t	Sig
Experimental class 1	Mathematical communication	3.95	0.00019
	Learning achievement	5.78	8.275e-06
	Student interest	14.93	2.2e-16
Experimental class 2	Mathematical communication	1.75	0.044
	Learning achievement	4.79	1.615e-05
	Student interest	6.75	4.725e-06

From the test results, the all Sig. (2-tailed) was less than α = 0.05, leading to the rejection of H_0. At a significance level of 0.05, it was concluded that the average mathematical communication, learning achievement and student interest in experimental class 1 and experimental class 2 has reached the specified KKM value. After that, the achievement of the second criterion of learning effectiveness can be determined by conducting a proportion test using the z-test. The result of the proportion test are resented in the table 8.

Table 8. Proportion Test

Class	Variable	t	Sig
Experimental class 1	Mathematical communication	1.865	0.0474
	Learning achievement	1.865	0.0474
	Student interest	3.42	0.00062

Experimental class 2	Mathematical communication	1.475	0.1
	Learning achievement	1.865	0.0474
	Student interest	1.865	0.0474

Based on the proportion test, it can be seen that for the experimental class 1 the all Sig. (2-tailed) was less than α = 0.05, leading to the rejection of H_0. At a significance level of 0.05, it shows that the number of students who have reached the KKM in the experimental class 1 of mathematical communication, learning achievement and student interest variables has reached ≥75%. However, in experimental class 2 the result obtained is a p-value of mathematical communication is 0.1 < 0.05, H_0 is accepted. At a significance level of 0.05, this indicates that mathematical communication inexperimental class 2 ≤75%.

IV. DISCUSSION

Based on the analysis of research data and hypothesis testing, it was found that inquiry learning using the 5E learning cycle model was effective in terms of junior high school students' mathematical communication skills, learning achievement, and learning interest, as it met both of the predetermined learning effectiveness criteria. These research findings align with research by Aini et al. that found the 5E learning cycle model was able to improve students' mathematical communication skills. Based on the results of the one-sample t-test, the mathematical communication ability obtained a p-value of 0.00019 < 0.05, so the H_0 was rejected. The average posttest for inquiry learning using the 5E learning cycle model was 80.24. This means it exceeds the KKM score of 75. Each indicator also experienced significant improvement. Inquiry learning using the 5E learning cycle model is effective in terms of mathematical communication skills.

The one-sample t-test for student learning achievement yielded a p-value of 0.0126 < 0.05, thus rejecting the H_0. The posttest average for inquiry learning using the 5E learning cycle model was 81.86, which exceeded the minimum competency criteria of 75. Each indicator also experienced significant improvement. Based on the frequency distribution, 27 students (77.1%) achieved the KKM. Inquiry learning using the 5E learning cycle model was effective in terms of learning achievement. The one-sample t-test for student learning interest yielded a p-value of 0.0028 < 0.05, thus rejecting the α0. The posttest average for inquiry learning using the 5E learning cycle model was 80.83, which exceeded the minimum competency criteria (KKM) of 68. Each indicator also experienced significant improvement. Based on the frequency distribution, all students (100%) achieved the threshold criteria. Inquiry learning using the 5E learning cycle model was effective in terms of student interest.

In this study, inquiry-based learning using the 5E learning cycle model has stages that must be passed through in the learning process. The first stage is engagement, which is the stage where teachers attract students' attention and arouse their curiosity about the concepts or topics to be learned. In addition, at this stage, teachers also inform students of the learning objectives to be achieved. During the engagement stage, the teacher captures students' attention using images and videos related to the material being studied. After capturing the students' attention, the teacher poses questions related to the learning topic to be discussed in each session. The students then provide responses in the form of ideas or answers. These ideas and answers serve as the students' prior knowledge about the material to be presented. This first phase helps increase students' interest in learning.

Next, in the second stage, exploration, students work together in small groups. At this stage, small groups of 4-5 students are formed, and they are given the opportunity to work together in small groups without direct instruction from the teacher. Each group is given worksheets based on the learning objectives that must be achieved. In each meeting, the worksheets are designed based on mathematical communication indicators, namely: (1) Using mathematical symbols or notation to create appropriate problem models; (2) Expressing mathematical ideas or concepts through writing or graphs; (3) Communicating mathematical thoughts logically; and (4) Drawing conclusions based on the solutions obtained. Each group is given worksheet based on the learning objectives that must be achieved. In the material on linear equations, the learning objectives to be achieved are (1) understanding the form of linear equations; (2) drawing equations of straight lines in Cartesian coordinates; (3) determining the gradient of straight lines; (4) solving problems using the concept of gradient; (5) determining the equation of straight lines; (6) determining the solution of an equation of straight lines; (7) solving contextual problems related to equations of straight lines.

At this stage, the teacher acts as a facilitator and motivator. Basically, the purpose of this stage is to check whether the students' knowledge is correct, incorrect, partially incorrect, or partially correct. In the process of completing the worksheets, students discuss and express their opinions with each other, thereby improving their mathematical communication skills. This is in line with Dale, who states that through group discussions, students will gain direct experience in expressing their opinions, thereby improving their communication skills. This aligns with Dale, who stated that through group discussions, students gain direct experience in expressing their opinions, thereby improving their communication skills for effective learning.

In the third stage, explanation, students are required to explain the concepts they are learning in their own words. In this study, after students discussed with their groups, they presented the results of their exploration in a class discussion using their own language. This third stage is known as the stage for presenting concepts, processes, and skills briefly. This is consistent with what Konicek & Keeley stated, that when someone has understood a concept, one of the indicators is that they will convey what they have discovered using their own words. The researcher plays a role in reinforcing students' findings, re-explaining concepts that students have not yet understood by involving the discussion process, giving students the opportunity to ask questions and express their opinions.

The fourth stage is elaboration, which encourages students to use the concepts they have learned to work on the questions. The fifth stage is evaluation. In addition, during the evaluation phase, teachers guide students to draw conclusions about the learning activities. At this stage, teachers can observe the knowledge or understanding of students in applying new concepts. Students can conduct self-evaluation by asking open-ended questions and seeking answers using observations, evidence, and explanations obtained previously. The results of this evaluation can be used by teachers as evaluation material regarding the implementation process of the learning model being applied, whether it is running very well, fairly well, or still needs improvement. Similarly, through self-evaluation, students can identify shortcomings or progress in the learning process that has been carried out. Additionally, tests can be used to determine how well students understand the material being taught.

V. CONCLUSION

The conclusion of this research is that inquiry learning with 5E learning cycle model is effectively applied to facilitate students', mathematical communication, learning achievement and student interest. This can be proven from the results of inferential static tests using the one sample t-test, and the percentage of achievement of KKM. Suggestions that can be given to future researchers are to use other abilities or other materials to see the effectiveness of inquiry learning with 5E learning cycle model.

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