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The Analysis of the Improvement of Student's Mathematical Communication Skills in Solving Problems of Circumference and Area of Circles under the Implementation of Inquiry-Based Learning

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ABSTRACT: Mathematical communication skills convey and interpret mathematical ideas through drawings, tables, diagrams, formulas, or demonstrations. The inquiry-based learning model allows students to discover data, facts, and information from various sources to provide experiences. This study aims to analyze students' mathematical communication skills, improve them using the inquiry-based learning model, and then deepen them through a description. This study uses an explanatory sequential method combining quantitative and qualitative research. The research subjects were 23 VIB students in the control class and 23 VIA students in the experimental class. The study results show that students' mathematical communication skills are divided into weak, moderate, and strong skills. The independent sample t-test results showed a significant influence of applying the inquiry-based learning model with a sig. 0.003 ($p < 0.05$). Strong and moderate mathematical communication skills showed an increase of 47.83% and 13.04%, while weak skill levels showed a decrease of 60.87%. The improvement of mathematical communication skills is presented as a description of observation and interview results. The research conclusion reveals that applying the inquiry-based learning model can improve students' mathematical communication skills in solving problems of circumference and area of circles in elementary school students.

KEYWORDS: area of a circle, expository learning, inquiry-based learning, mathematical communication, the circumference of a circle.

INTRODUCTION

At an early education level in the Indonesian education system, elementary school is one of the places that provide essential knowledge and skills. The elementary school level is the beginning for someone to learn everything. The stronger the foundation of critical knowledge and skills obtained at this level, the easier it will be to develop them in the subsequent levels.

Mathematics is one of the mandatory subjects taught in elementary school. The scope of mathematics is not only related to calculations, rules, and proofs. More than that, mathematics is a requirement for creating order in daily activities, developing science and technology, and also serving as a pinnacle of knowledge and a servant for other sciences [(Manalu & Zanthy: 2020); (Asih, Sunardi & Kurniati: 2015); and (Sunardi: 2016)]. The benefits of mathematics in daily life lead to essential skills, one of which is mathematical communication skills.

Mathematical communication skills refer to the ability to convey mathematical ideas by expressing and interpreting those ideas in the form of pictures, tables, formulas, diagrams, or demonstrations (Melati, Sunardi & Trapsilasiwi: 2017). This skill is related to students' mathematics learning outcomes. Good mathematical communication skills are one of the guarantees of achieving students' learning outcomes. Conversely, students' mathematics learning outcomes also reflect their level of mathematical communication skills. Both are essential parts of the literacy and numeracy process.

The mathematical communication indicators in this study adopt the written mathematical communication indicators used by Melati, Sunardi & Trapsilasiwi (2017). These indicators include expressing and writing problem-solving processes, converting problems into mathematical sentences, writing mathematical calculations, and using mathematical symbols. These indicators are suitable for elementary school students as they can measure students' mathematical communication skills in a simple way that is appropriate to their developmental characteristics.

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Table 1. Indicators of mathematical communication skills

No	Indicator	Description
1	Expressing/writing the problem-solving process	Reading and understanding the given problem Determining what is known in the problem Determining what is asked in the difficulty Performing the problem-solving process
2	Transforming the problem into a mathematical sentence	Understanding the situation of the problem Understanding the appropriate symbols to use Understanding the order of the problem-solving process Writing the mathematical sentence
3	Writing mathematical calculations	Understanding the types of mathematical operations Understanding the meaning of mathematical sentences Performing calculations according to the order of operations Checking the calculation results
4	Using mathematical symbols	Understanding the meaning of mathematical symbols Understanding the writing of mathematical symbols Selecting and using mathematical symbols

Source: Adaptation from Melati, Sunardi & Trapsilasiwi (2017)

Many factors, including the implementation of appropriate learning models, influence the improvement of students' mathematical communication skills. The keyword "interaction" is essential to improving mathematical communication skills. Gulo (in Sanjani: 2019) stated that interaction is one way to stimulate and activate critical thinking skills and solve problems. Interaction during the learning process is expected between students and teachers or among students themselves and with other learning sources.

Samsidar, Coesamin & Bharata: 2019, stated that the learning model that prioritizes communication and student interaction as the main subject is the inquiry-based learning model. [(Hapsari & Kristin: 2021); and (Rahmawati: 2022)] agree that the inquiry-based learning model can improve students' motivation and creativity and encourage the achievement of numeracy literacy. Improving mathematical communication skills as one of the indicators of numeracy literacy can be done by presenting relevant material and dividing it into sub-materials (Ardiyani, Saputro & Subekti: 2021).

As a comparison, the expository learning model emphasizes the mastery of learning material. The material is packaged neatly and systematically so students can digest it well (Hidayati, Fahmi & Farida: 2019). Student achievement is expressed by asking students to convey their understanding according to their characteristics. Roy Killen (in Safriadi: 2017) described four principles of the expository learning model, including orientation to objectives, prioritizing communication, student readiness to learn, and the continuity of the learning process.

Delving deeper into the inquiry-based learning model, [(Sutarti & Wibawa: 2018); (Mbari, Yufrinalis & Nona: 2018); and (Rohayani: 2018)] agree that in addition to emphasizing the process of searching and discovering, the inquiry-based learning model also prioritizes systematic, critical, and logical investigation activities. Reinforcing this, Chususiyah, Dafik & Prastiti (2020) assert that the inquiry-based learning model can develop and activate student thinking abilities if implemented with good planning at each stage. Directing the learning process using actual practices and discussions as learning activities is essential to learning planning (Priansa, 2017; Fitriyah, Suratno, Prastiti, Dafik & Hobri, 2020).

Abidin (2020) advises achieving maximum results by applying the inquiry-based learning model. The inquiry-based learning model will provide top results, especially regarding learning achievement, by connecting the material to daily life contexts. In response to this advice, researchers maximize it by connecting the material and utilizing supporting teaching aids on familiar and known things in students' lives.

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During the inquiry-based learning model implementation phase, Banchi and Bell (Jazimah, 2020) stated that there are four levels of inquiry-based learning model implementation. These four levels of implementation are confirmed inquiry, structured inquiry, guided inquiry, and open inquiry or free inquiry. These four levels of implementation are related to the consideration of problems raised, as well as the procedures and solution aids provided in their implementation.

In implementing the inquiry-based learning model in primary schools, using the available or accessible inquiry level is unnecessary. In this study, a modified level of structured inquiry implementation was used. The emergence of problems and procedures has been conditioned, while the solution takes place naturally. However, when there are obstacles in the solution process, the teacher plays a role in triggering the emergence of solution ideas from students to ensure that the process runs smoothly.

The syntax of the inquiry-based learning model in this study adopted the syntax presented by Sanjaya (Sinesis, 2016). This syntax includes six stages: problem orientation, formulating problems, formulating hypotheses, collecting data, testing hypotheses, and formulating conclusions. The following table explains the syntax of the inquiry-based learning model.

Table 2. The syntax of implementing an inquiry-based learning model

No	Step	Teacher's Activities	Student's Activities
1	Problem orientation	Explaining the topic, objectives, learning outcomes, main activities, the importance of the topic, and learning activities	Observing and understanding the explanation
2	Problem formulation	Ensuring the presence of students' initial skills and providing triggers for students to formulate problems	Formulating problems that invite problem-solving based on initial skills
3	Hypothesis formulation	Asking questions that encourage students to formulate tentative hypotheses	Formulating possible answers to the problem being studied
4	Collecting data	Asking questions that can encourage students to think about finding the information they need	Finding information needed to prove the tentative hypothesis
5	Testing the hypothesis	Ensuring the level of confidence of students in the answers provided	Providing convincing answers based on the process that has been carried out
6	Formulating conclusions	Providing constructive feedback to build students' understanding	Alternately presenting conclusions and writing them systematically for easy recall

Sanjaya (in Sinesis: 2016)

METHODS

This research design uses a mixed-methods approach of sequential explanatory type. The sequential explanatory design combines quantitative research followed by qualitative research. According to Creswell (2016:299), "The sequential explanatory mixed-methods approach is a design in mixed-methods that is attractive to individuals with a strong quantitative background or from fields that are relatively new to qualitative approaches."

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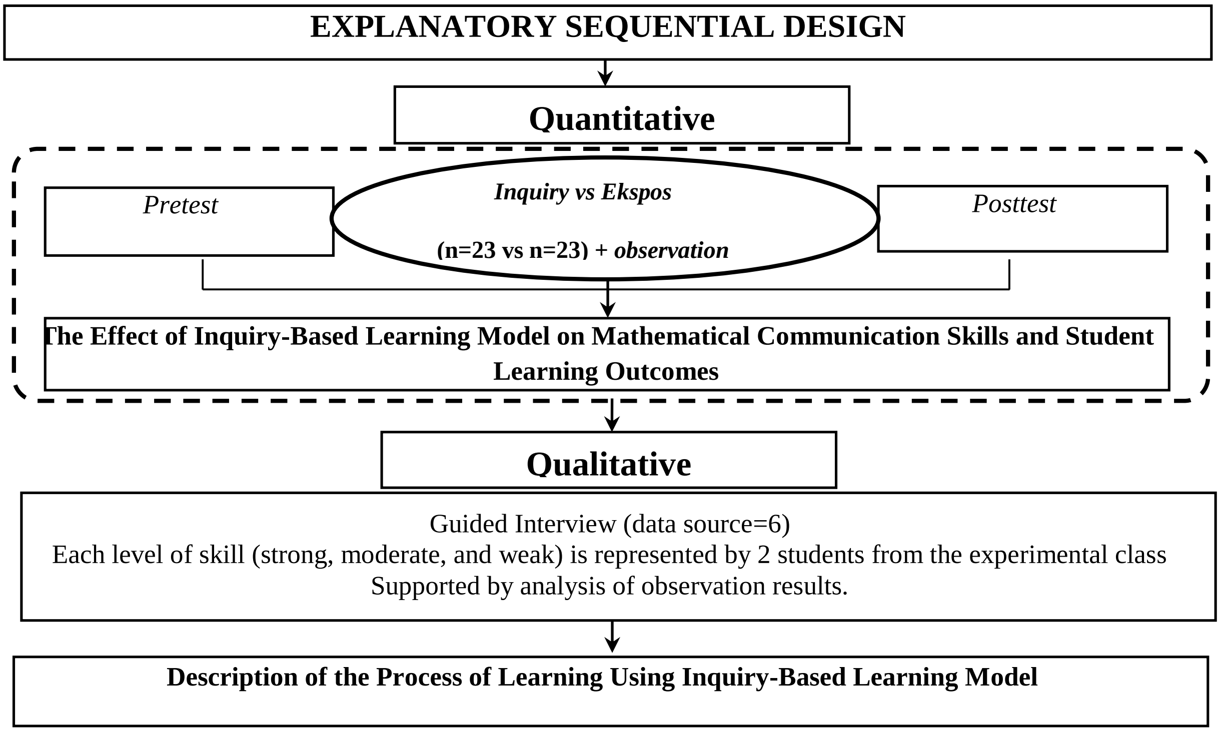

Fig 1. The flow chart of the research methodology

Two phases of research are used to classify the potential in the quantitative phase to be further explored in the qualitative phase. The quantitative method conducted first in the sequential explanatory research serves to determine the problem/potential and prove the improvement of the problem/potential. The problem/potential is deepened and expanded using qualitative methods. Sugiyono (2016) explained that the combination method with a sequential explanatory design is carried out to answer the research problem formulation of quantitative and qualitative research that complement each other. The modeling of this research method can be better understood through the following flowchart diagram.

The initial quantitative research phase uses the pretest-posttest control group design experiment method. It begins with administering a pretest, followed by the learning process. The inquiry-based learning model is used in the experimental class, while the expository learning model is applied in the control class. The final session of the quantitative research phase involves conducting a post-test.

Table 3. Pretest-posttest control group design

Group	Pretest	Treatment	Post-test
Experiment (n=23)	O1	X1	O3
Control (n=23)	O2	X2	O4

Description :
O1 : Pretest result of the experimental group
O2 : Pretest result of the control group
X1 : Treatment for the experimental group - inquiry-based learning model
X2 : Treatment for the control group - expository learning model
O3 : Post-test result of the experimental group
O4 : Post-test result of the control group

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The analysis of the pretest, learning process, and post-test serves as the basis for determining the influence of the inquiry-based learning model on mathematical communication skills. This also forms the basis for sampling in the qualitative phase. In addition to observation, guided interviews were conducted with representatives from each skill level.

The research population consists of all sixth-grade students in elementary schools in Banyuwangi Regency. The sample consisted of 46 students, divided into 23 from class 6A and 23 from class 6B at State Elementary School 1 Panderejo. The sampling technique used was simple random sampling. Meanwhile, for the learning process sessions, the sampling was done using the purposive sampling technique by considering the preliminary activities related to a mathematics learning process that had taken place in both classes. In addition, daily assessments and mid-semester math report grades were also analyzed.

It was determining and selecting data sources in the qualitative phase using a disproportionate stratified random sampling technique on the category of mathematical communication skill levels in the experimental class. The research data sources for guided interviews were representatives from the experimental class. Six students were selected, with two students representing each skill level.

The instruments used in the quantitative phase are tests (pretest and post-test) and non-test instruments (observation sheets and supporting teaching materials). The pretest and post-test instruments are designed based on the blueprint and are tested for validity and reliability using Pearson correlation and Cronbach's alpha. The non-test instruments are communicated and validated by experts.

The instruments used in the qualitative phase are non-test instruments in the form of guided interviews. Guided interviews are conducted to obtain in-depth information about the student's learning process and mathematical communication skills. In guided interviews, the data sources are also given confirmation post-test questions.

Before analyzing the data, the researcher checks the validity of the data using normality and homogeneity tests. Then, an independent sample t-test is performed to describe the effect of applying the inquiry-based learning model on students' mathematical communication skills and learning outcomes. The observation results of the learning process are presented in a descriptive analysis.

In the qualitative phase, the study results describe the inquiry-based learning model applied in the experimental class. The results are obtained from observing the learning process in the experimental class. The observation results are confirmed in the guided interview session with the data sources representing the three levels of mathematical communication skills.

RESULTS

Based on the conducted research, the results are divided into two parts. The first part is the effect of the inquiry-based learning model on students' mathematical communication skills. The second research result describes the implementation of mathematics learning using the inquiry-based learning model on the topic of the circumference and area of a circle.

The research results showing the influence of the application of the inquiry-based learning model on mathematical communication skills were obtained from the independent sample t-test on the post-test and pretest scores of both classes. Meanwhile, the description of the learning process using the inquiry-based learning model in the experimental class is shown by the analysis of the learning process. Moreover, it is also supported by the confirmation of guided interviews with data sources representing each level of skill.

A. The Effect of Inquiry-based learning Model on Mathematical Communication Skills and Student Learning Outcomes

The Proof of the Effect of the Inquiry-based learning Model on Mathematical Communication Skills is Presented Through Analysis of Pretest and Post-test Scores. The presentation of the pretest and post-test analysis results describes the changes in mathematical communication skills. Moreover, the pretest and post-test analysis results also serve as the basis for conducting an independent sample t-test, which indicates whether or not there is an influence of the inquiry-based learning model on students' mathematical communication skills.

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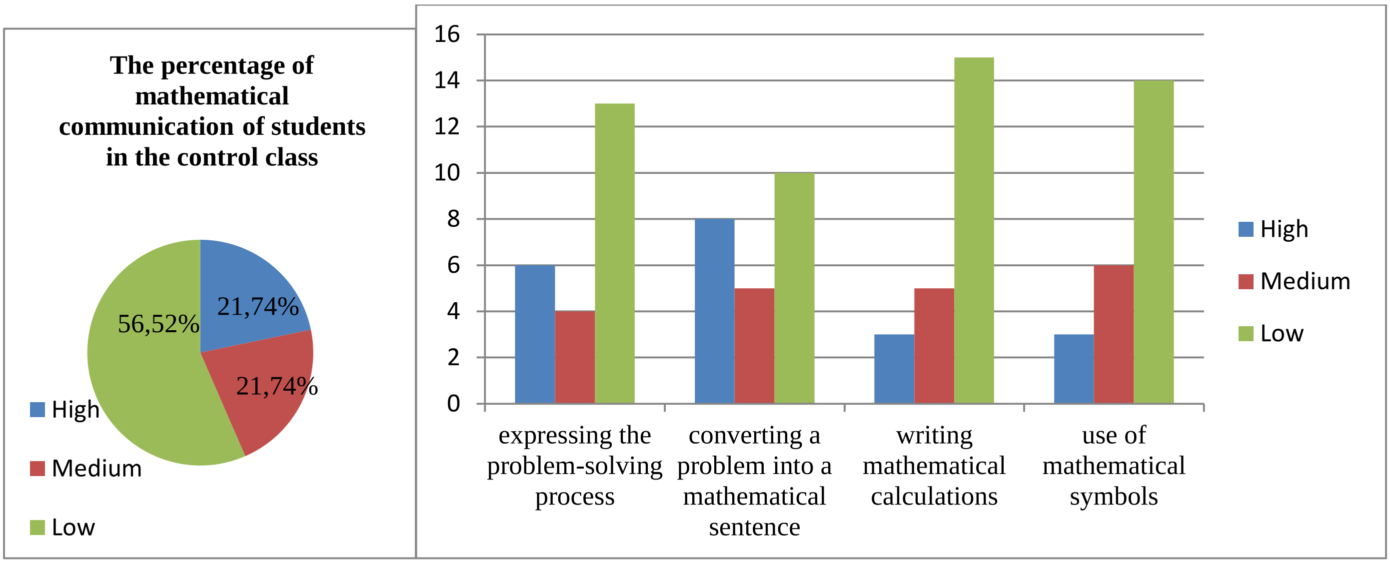

Fig. 2. Distribution of mathematical communication skills in the control class pretest session.

Based on the results of the pretest of the control class shown in Fig. 2, mathematical communication skills are divided into three levels. These three levels are strong, moderate, and weak. Strong mathematical communication skills account for 13.04%. The moderate and weak categories are at 17.39% and 69.57%, respectively.

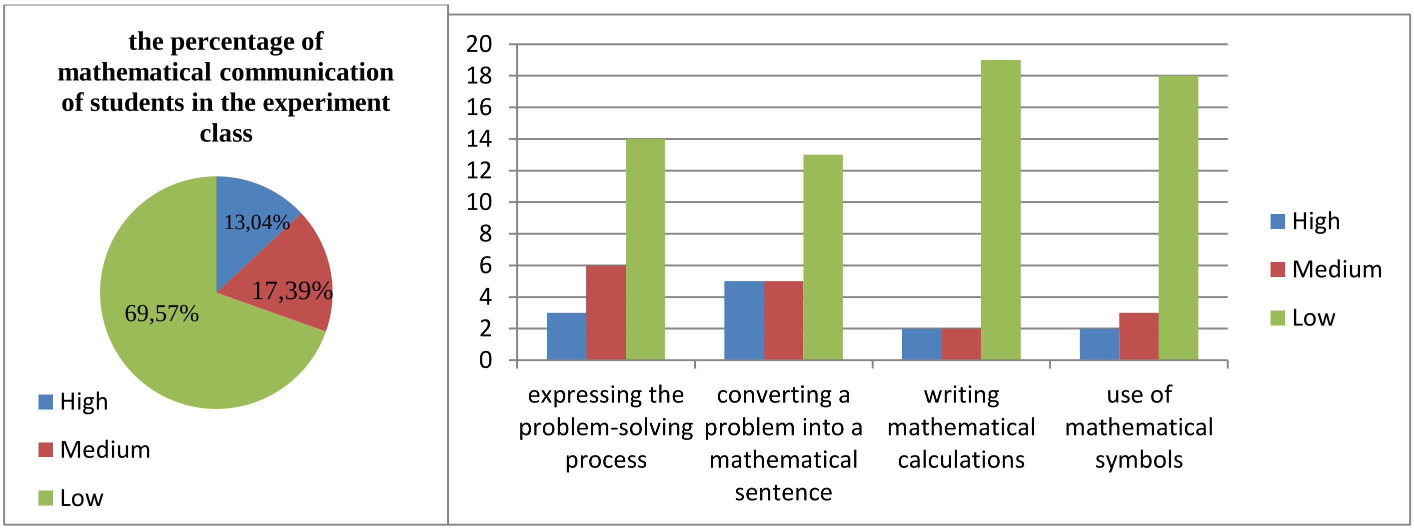

Fig. 3. Distribution of Mathematical Communication Skills in the Experimental Class Pretest Session.

In more detail, Fig. 2 shows that the indicator of expressing problem-solving processes in order of 6, 4, and 13 students is in the strong, moderate, and weak categories, respectively. For the indicator of converting problems into mathematical sentences, 8 and 5 students are in the strong and moderate categories, while 10 students are still in the weak category. In the indicator of writing mathematical calculations, weak mathematical communication skills still dominate with 15 students, while moderate and strong show 5 and 3, respectively. The indicator of using mathematical symbols shows 3, 6, and 14 for the strong, moderate, and weak categories, respectively.

Furthermore, Fig. 3 shows the results of the pretest of the experimental class. Strong mathematical communication skills account for 13.04%. Meanwhile, the moderate and weak categories are at 17.39% and 69.57%, respectively.

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Fig. 3 shows that for the indicator of expressing problem-solving processes, 3, 6, and 14 students are categorized as strong, moderate, and weak, respectively. Meanwhile, for the indicator of translating problems into mathematical sentences, 5 students are categorized as strong, 5 as moderate, and 13 as weak. As for the indicator of writing mathematical calculations, 19 students have weak mathematical communication skills, while only 2 students each have moderate and strong skills. The indicator of using mathematical symbols shows 2, 3, and 13 for strong, moderate, and weak categories, respectively.

Table 4. Results of Pretest in Control and Experimental Classes.

Group	N	Mean	Std. Deviation	Std. Error Mean
Control	23	57,130	26,6821	5,5636
Eksperimen	23	51,913	25,6797	5,3546

The results of the pretest scores of both classes in Table 4 above show a relatively balanced condition. The control class pretest shows an average of 57.13 with a standard deviation of 26.68 and a standard error of 5.56. Meanwhile, the experimental class shows an average of 51.91, a standard deviation of 25.6797, and a standard error of 5.3546.

Based on Table 4, the difference in the mean scores between the control and experimental classes is insignificant. The control class has a slightly higher average score of 57.13, slightly higher than the experimental class score of 51.91. However, the slight difference in mean scores must still be tested with inferential statistical tests.

The inferential statistical test is carried out by conducting an independent sample t-test. The independent sample t-test above is performed after the prerequisite test (normality) has been completed. Meanwhile, the homogeneity prerequisite test is conducted simultaneously with the independent sample t-test.

As shown in Table 5 below, in the homogeneity test section, the results of the independent sample t-test show a Sig. Value of 0.682>0.05 (not significant). This indicates and proves that the two data groups are identical/homogeneous. Thus, the two prerequisite tests were fulfilled before conducting the independent sample t-test. Next, an independent sample t-test is conducted on the pretest scores of the 46 students in the control and experimental classes. The results of the independent sample t-test in Table 5 below show a Sig. (2-tailed) value of 0.503>0.05 (not significant).

Table 5. The results of the different tests on the average pretest value used an independent t-test sample

Independent Samples Test										
		Levene's Test for Eq.of Var		t-test for Equality of Means						
		F	Sig.	t	df	Sig.(2-tailed)	Mean Differ	Std. Error Differ	95% Confid Interval of the Difference	
									Lower	Upper
Pretest	Eq. variances assumed	,170	,682	,676	44	,503	5,217 4	7,7217	-10,35	20,78
	Eq. variances not assumed			,676	43,94	,503	5,217 4	7,7217	-10,35	20,78

Therefore, the hypothesis decides to reject HA or, in other words, accept H0. There is no difference in the average pretest scores between the control and experimental groups. This is the beginning of the improvement of students' mathematical communication skills. Özsoy and Ataman (2009) stated that a non-significant result allows different treatments to be given to groups because they are equal.

After implementing each learning model, further testing was conducted to prove the results. The post-test average scores in both classes were relatively higher than the pretest. The following diagram shows students' mathematical communication skills distribution in the post-test session.

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The result of the post-test in the control group, as shown in Figure 4 below, shows that solid mathematical communication skills account for 30.43%. The moderate skill category is at 26.09%. Meanwhile, the weak skill category still shows a significant percentage at 43.48%.

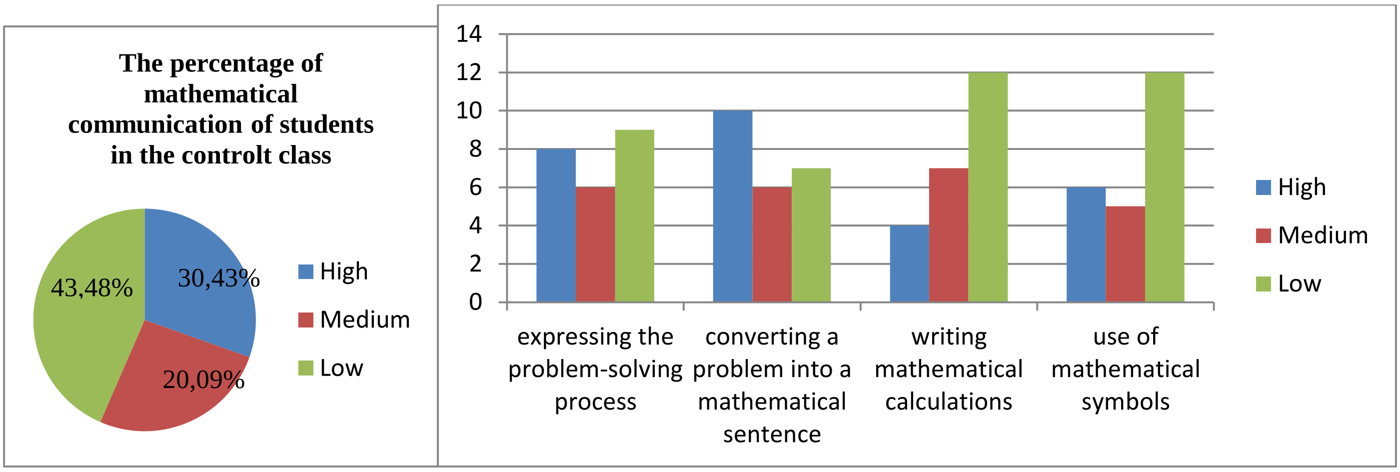

Fig. 4. The distribution of mathematical communication skills in the post-test session control class

The expression indicators of the problem-solving process showed that 8, 6, and 9 students were in the strong, moderate, and weak categories, respectively. For the indicator of converting problems into mathematical sentences, 10 and 6 students were in the strong and moderate categories, while seven were still in the weak category. Regarding the indicator of writing mathematical calculations, many students still showed weak mathematical communication skills, 12 students, while 7 and 4 students showed moderate and strong skills, respectively. The last indicator, using mathematical symbols, showed 6, 5, and 12 students for the strong, moderate, and weak skills categories, respectively.

Next, figure 5 below shows the results of the post-test scores in the experimental class with the implementation of the inquiry-based learning model. The strong mathematical communication skills category showed a percentage of 60.87%. The moderate category of mathematical communication skills was in the range of 30.42%. Meanwhile, the weak category of mathematical communication skills still accounted for 8.70%.

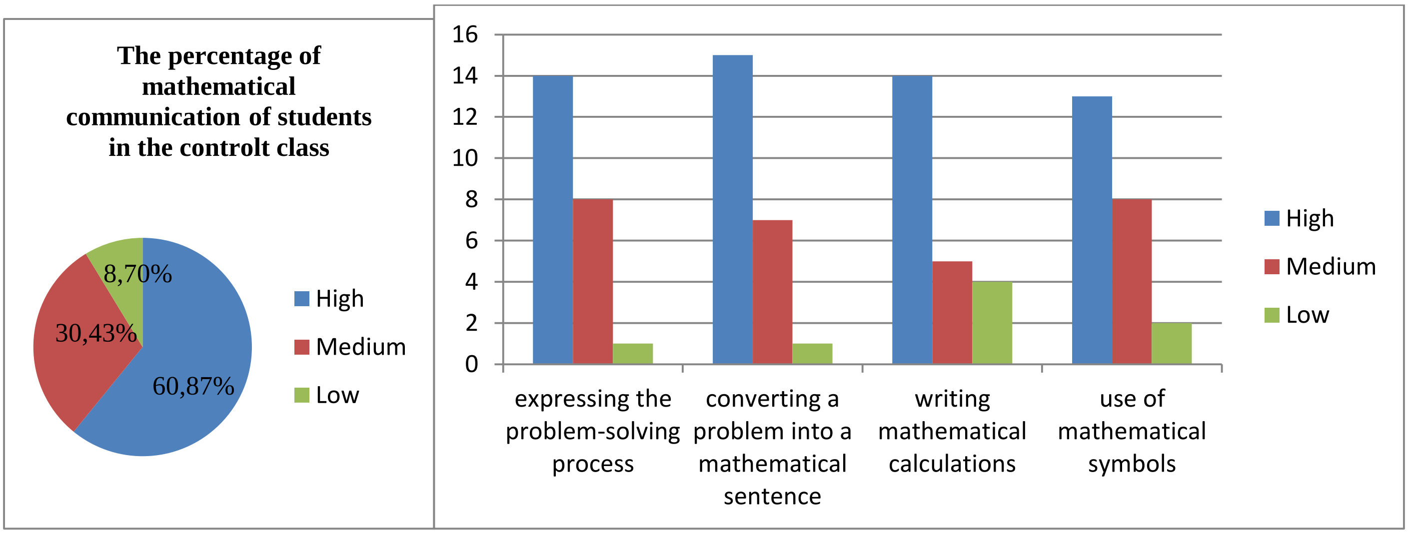

Fig. 5. The distribution of mathematical communication skills in the post-test session experimental class

The distribution of mathematical communication skills of the experimental class in the post-test session shown in Figure 5 indicates that for expressing problem-solving processes, 14, 8, and 1 students are categorized as strong, moderate, and weak,

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respectively. For the indicator of translating problems into mathematical sentences, 15 and 7 students are categorized as strong and moderate, respectively, while one student remains in the weak category. For the indicator of writing mathematical calculations, four students are categorized as weak, while 5 and 14 students are categorized as moderate and strong, respectively. The last indicator, using mathematical symbols, has 13, 8, and 2 students in the strong, moderate, and weak categories, respectively.

The descriptive statistical analysis of the post-test scores of the control and experiment classes is presented in Table 6 below. The results show a noticeable difference between the two classes. The mean score of the control class is only 69.84, with a standard deviation of 19.84 and a standard error of 4.14. In contrast, the mean score of the experiment class is 86.09, with a standard deviation of 15.66 and a standard error of 3.27. This suggests that the experimental intervention, which aimed to improve mathematical communication skills, has positively impacted the students' learning outcomes. However, further analysis may be necessary to draw more conclusive results.

Table 6. Post-test results of control and experimental classes

Group	N	Mean	Std. Deviation	Std. Error Mean
Control	23	69,304	19,8413	4,1372
Experiment	23	86,087	15,6609	3,2655

Based on table 6 above, there is a significant difference in the average values obtained by the control and experimental groups. The experimental group's average score is higher than the control group's. However, from a generalization perspective, this can only be confirmed after conducting a test for the difference in means. Prerequisites for normality and homogeneity tests must be carried out before conducting an independent sample t-test.

Similar to what was done for the pretest scores, a normality test has also been conducted for the post-test scores. The normality test was carried out before conducting an independent sample t-test, and the data was found to be normally distributed. Meanwhile, the homogeneity test was conducted simultaneously with the independent sample t-test.

Table 7. The results of the post-test mean difference test using an independent t-test sample

Independent Samples Test										
		Levene's Test for Eq.of Var		t-test for Equality of Means						
		F	Sig.	t	df	Sig.(2-tailed)	Mean Differ	Std. Error Differ	95% Confid Interval of the Difference	
									Lower	Upper
Pretest	Eq. variances assumed	2,94	,093	-,318	44	,003	-16,78	5,2707	-27,41	-6,16
	Eq. variances not assumed			-,318	41,75	,003	-16,78	5,2707	-27,42	-6,14

The independent t-test was conducted to test whether there was a significant difference in the mean between the two data groups. The null hypothesis (H0) was that there was no significant difference in the mean between the post-test scores of the control and experimental groups. The alternative hypothesis (HA) was that there was a significant difference in the mean between the post-test scores of the control and experimental groups.

The results of the independent t-test conducted using SPSS v.25 showed a Sig. (2-tailed) [$t(46)=0.003<0.05$] (significant at the 5% level of significance). This result indicates that the null hypothesis was rejected, and the alternative hypothesis was accepted. Thus, there was a significant effect of the inquiry-based learning model applied in the experimental group on the mathematical communication skills of sixth-grade students on the circumference and area of a circle.

B. *Description of the Learning Process by Applying the Inquiry-based learning Model The description of the learning process is based on the six stages contained*

There are six stages or syntaxes in implementing the inquiry-based learning model. These six syntax stages include the problem orientation stage, the problem formulation stage, the hypothesis formulation stage, the data collection stage, the hypothesis testing stage, and the conclusion formulation stage. These six stages influence students' mathematical communication skills.

Several observations can be conveyed based on the results of observations during the experiment class using the inquiry-based learning model. Which stage of the inquiry-based learning model has an influence will be discussed. The following are the results of observations that will be presented in a general description in paragraph-by-paragraph order.

In the problem orientation stage, the influence is mainly seen in the first indicator of mathematical communication skills. This stage has a positive impact in that it can provide a good impact on how students express the problem-solving process. The first indicator of mathematical communication skills, the expression of the problem-solving process, emerges and is honed well during group discussions and individual problem-solving.

The second stage of the inquiry-based learning model is slightly different in its influence. A specific finding emerged at this stage in the form of differences in the influence on students with low and moderate abilities who struggle to translate problems into mathematical sentences. This is because, in addition to using logic, students must use their previous knowledge. However, this stage presents no significant obstacles for students with strong abilities. Instead, this stage becomes an excellent opportunity for students with strong skills to hone their skills.

Formulating hypotheses as the third phase influences improving skills, especially in the indicators of expressing and writing problem-solving processes. Students with strong and moderate skills can combine mathematical symbols, such as the approximation of pi (π) and the relationship between diameter and radius, to formulate hypotheses for the formula for the circumference and area of a circle. Meanwhile, students with weak skills still require adaptation with the help of teachers to combine and connect symbols to form a hypothesis for the formula.

The fourth stage, the data collection stage, is the most famous stage among all students, regardless of their skill level. In this stage, all learning resources can be used to support the hypothesis. The teacher also acts as a learning resource by guiding students to obtain accurate data that supports their hypothesis. This stage mainly influences the indicators of writing mathematical calculations, using/recognizing mathematical symbols, and confirming the proposed hypothesis. In general, the data collection stage can confirm all indicators of students' mathematical communication skills while also answering the hypothesis.

Furthermore, the fifth stage, which is the hypothesis testing stage, has an impact on many indicators of mathematical communication skills. This stage is the right time to see students' understanding, especially their mathematical communication skills. At least four indicators improve in this stage: expressing the problem-solving process, transforming problems into mathematical sentences, writing mathematical calculations, and using mathematical symbols in problem-solving. The discussion section will discuss a more precise explanation of the impact of the hypothesis testing stage.

Finally, the application stage of the inquiry-based learning model is the stage that can depict students' achievements related to all indicators of mathematical communication skills. The learning process that provides guided freedom for students to think actively, confirm from various sources, and give opinions will be seen when students present their conclusions. In this stage, the conclusions are presented verbally and demonstrated through students' problem-solving performance.

After the six stages and their overall impact according to the researcher's observations have been presented, the qualitative research phase will be conducted. Guided interviews will be conducted with selected samples. This will provide an overview of the level of students' mathematical communication skills after going through the learning process by applying the inquiry-based learning model. The following are sample questions to be answered during the guided interview to confirm the students' understanding and absorption during the learning process with the inquiry-based learning model.

1. A bicycle wheel has a diameter of 75 cm. The wheel rotates 14 times, what is the distance traveled by the wheel in meters?
2. A swimming pool has a circular shape with a diameter of 40 meters. The pool is surrounded by a path that is 2 meters wide. If the path will be paved and the installation cost is Rp22,000 per meter, how much does it cost to install the paving?

Fig. 6. Guided interview assistant questions

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1. *Sample #1 of students with weak mathematical communication skills.*

Researcher : Can we talk briefly?
Sample 1 : Yes, we can.
Researcher : Do you like learning about the circumference and area of a circle with Mr. Danial?
Sample 1 : Yes, I like it.
Researcher : How many times have you learned about the circumference and area of a circle?
Sample 1 : Four times.
Researcher : For each meeting, the same thing is done, right? Can you remember how many types of learning methods there are?
Sample 1 : Yes, we keep learning.
Researcher : Okay, usually at the beginning, it is explained, then asked to observe, right?
Sample 1 : Yes, I like drawing a coin and making a line (meaning the student recognizes the circle elements by drawing a circle using a coin).
Researcher : Yes, if you like to learn like that, what do you do next?
Sample 1 : After that, if the radius is multiplied by two, the result is called the diameter.
Researcher : Okay, what is next?
Sample 1 : Then we are given challenges and asked to guess what if like this, what if like that?
Researcher : Oh, then what is next?
Sample 1 : Afterward, we rotate and ask our friends, open the internet with Mr. Danial while reading and asking again, and answer together.
Researcher : But you like it, right? What is next?
Sample 1 : Mr. Danial gave an example of how to work on the problems and then asked us to try it ourselves. After that, we asked questions again while being asked to write.
Researcher : Oh, like that. However, can you work on the problems? Would you like to work on problems if the teacher gives you problems?
Sample 1 : Yes, I would like to. I can do it.

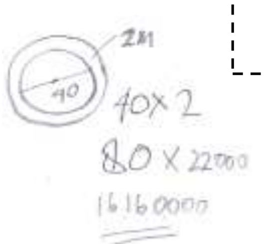
The researcher gave a worksheet and time for the sample to complete it, and here are the student's answers.

Question 1:

The student understands a circle's elements but needs help calculating the relationship between diameter and radius.

The problem-solving process will be more straightforward if the student completes division or understands the relationship between r and d.

The student already understands the concept of rotation with the circle's circumference.



Question 2:

The student can illustrate the problem but still needs help using the relationship between the elements of a circle to solve the problem with accurate calculations.

2. *Sample # 2 students with moderate mathematical communication skills*

Researcher : Can we talk briefly?
Sample 2 : Sure.
Researcher : Do you like learning about the circumference and area of a circle with Mr. Danial?

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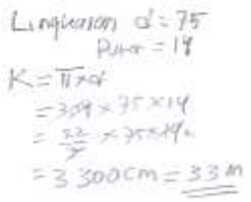
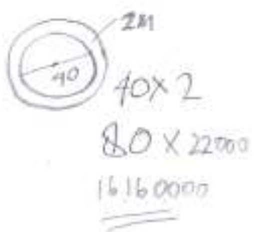
Sample 2 : Yes, I like it.
Researcher : How many times have you studied the circumference and area of a circle?
Sample 2 : Four times.
Researcher : Usually, in each meeting, the method used is the same, right? Try to remember, how many types of learning methods are there?
Sample 2 : There is a flow, I forgot, but it is enjoyable.
Researcher : Okay, it is usually explained and then asked to observe, right?
Sample 2 : Yes, that is observation and writing.
Researcher : Yes, you enjoy learning like that. Next, what is asked to do after observation?
Sample 2 : After that, connect some rules.
Researcher : Okay, after that, what are you asked to do?
Sample 2 : Then, asked to write the formula.
Researcher : I see. After that, what are you asked to do?
Sample 2 : After that, it is explained again. The internet is open to reading and asking again and answering together.
Researcher : I understand. However, can you do the problems? If the teacher gives you a problem, can you solve it?
Sample 2 : Insha Allah (God willing), I can.

The researcher gave the question sheet and sample time to complete it, and the following are the results of the students' answers.



The first question:
- The students understand the elements of a circle and can use the relationship between r and d.
- The students are also able to choose the correct phi approach.
- They can apply their previous knowledge, such as converting cm to m.



The second question:
- The student understands the meaning of the problem, but not perfectly. It appears that the student is not yet able to plan how to solve it.
- The student has understood another concept (multiplication) to be a part of the solution, but because of the incorrect conversion of the problem into a math sentence.
- The student ended up with an inaccurate answer

3. *Sample #3 students with strong mathematical communication skills*

Researcher : Hi, can we chat for a moment?
Sample 3 : Sure.
Researcher : Do you like learning about the circumference and area of a circle with Mr. Danial?
Sample 3 : Yes, I do.
Researcher : How many times have you learned about the circumference and area of a circle?
Sample 3 : Four times.
Researcher : The learning activities are the same for each meeting, right? Can you remember how many types of learning activities there are?
Sample 3 : There is a flow. If I am correct, it is observing, converting to math language, making a self-quiz, searching for data, calculating, and drawing a conclusion.
Researcher : Okay, how about the observation activity?
Sample 3 : It is enjoyable.
Researcher : I see you like learning like that. After the observation, what do you do?
Sample 3 : Next, we write a mathematical sentence based on the problem.

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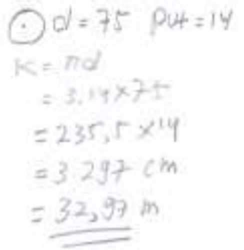
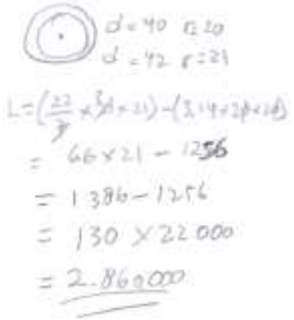
Researcher : Okay, after that, what are you asked to do?
Sample 3 : Guessing the answer, but with a specific method.
Researcher : I see. What happens after that?
Sample 3 : This is the part I like, searching for the solution method.
Researcher : But you enjoy it, right? What happens next?
Sample 3 : We are given an example of how to solve the problem and then asked to try to solve it ourselves. After that, there are questions, and we are asked to solve problems and draw conclusions.
Researcher : I see. However, can you solve problems? If the teacher gives you a problem, can you solve it?
Sample 3 : Yes, I can.

The researcher gave the question sheet and sample time to complete it, and the following are the results of the student's answers.



The first question:

- The students have understood the elements of a circle correctly and can use the relationship between the radius and diameter in problem-solving.
- The students can choose the appropriate phi approach.
- The students can apply their prior knowledge of converting cm to m.



The second question:

- The students fully understood the meaning of the problem.
- The students needed to plan the solution better.
- The students already used prior knowledge in understanding other concepts (multiplication) as part of the solution and were able to convert the problem into a math sentence. However, they obtained an answer that needed to be more appropriate.
- The calculation was done correctly, and the result was accurate.

DISCUSSION

Based on the research findings, the researcher will discuss several points. The pretest results showed that both classes had a balanced condition in terms of mathematical communication skills. The coding of the control and experimental classes was based on the researcher's consideration. The research process went well and produced tangible results.

Based on the descriptive statistical results of the quantitative research, the range of difference between the post-test and pretest results showed a relatively significant difference. Similarly, the difference in post-test scores between the expository and inquiry classes also showed a significant difference. Although the control class with the expository learning model also improved, it still could not surpass the improvement in the experimental class. The research results and observation findings further strengthen the influence of the inquiry-based learning model in improving students' mathematical communication skills. This further reinforces previous research that has used the inquiry-based learning model to improve various skills, including mathematical communication skills.

Several aspects were considered in this study, particularly how the inquiry-based learning model was planned effectively. Breaking down the material into sub-topics, utilizing real-life media, repeating the process, and providing enough space for students to express their learning styles were among the considerations that needed consideration. This is in line with and reinforces the findings of Hapsari and Kristin's research in 2021 and considers all the supporting factors in learning so that the inquiry-based learning model can provide maximum results.

Research findings related to the improvement of mathematical communication skills reinforce the research [(Setiawan, Dafik, and Laili: 2017) and Suratno, Komaria, Dafik, and Wicaksono: 2019)] that individual competencies are derived from processes that touch on self-assessment aspects and the accompanying impact of improvement, including an increase in mathematical communication skills, enabling students to adapt and actively participate in 21st-century learning in a better and more comprehensive way.

CONCLUSION

Implementing the inquiry-based learning model in the learning process can improve students' mathematical communication skills. Strong and moderate mathematical communication skills increased by 47.83% and 13.04%, respectively, while weak communication skills decreased by 60.87%. The independent sample t-test significantly influenced the implementation of the inquiry-based learning model in the experimental class with Sig. (2-tailed) [$t(46)=0.003<0.05$]. The application of the inquiry-based learning model has an impact on students' mathematical communication skills and learning outcomes in mathematics.

The learning activities using the inquiry-based learning model were relatively successful in all six phases. In the problem orientation phase, formulating hypotheses and conclusions supported the achievement of skills in expressing and writing problem-solving processes. Although there were some obstacles in formulating problems, especially in translating problems into mathematical sentences, the hypothesis testing phase significantly impacted all indicators of students' mathematical communication skills.

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