Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

July 2025. Vol. 13, No. 3
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 730-740

Analysis of Mathematical Communication Skills of Grade X MA Students on the Material of Trigonometric Function Graphs Aided by Geogebrabook

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Received: April 2025; Revised: July 2025; Published: July 2025

Abstract

Mathematics is a supporting science for other branches of science as a medium for communicating mathematical problem solving. One of the abilities that must be possessed by students is the ability to communicate in trigonometry material. In this research, only 36.7% of students correctly identified the transformation of trigonometric function graphs in question number 9. However, there were some students whose explanations were not precise because their understanding of the material was not correct.. The purpose of this study is to analyze the mathematical communication skills of grade X MA students in the material of trigonometric function graphs. In this research, a qualitative research type with a descriptive approach is used. The test of mathematical communication ability in writing is in the form of a test that is done independently and tested on 6 students with a group of 2 high ability students, 2 medium ability students, and 2 ability students with the need for further guidance. While the test of mathematical communication skills orally answered together through the interview method. The significance of this research is the students become more focused in learning because students are instructed to do activities by shifting the slider so that the intended graph is formed according to the instructions of the given problem. The conclusion drawn from the results of the research conducted is that mathematical communication in the material of trigonometric function graphs is relatively low, both in writing and orally. This is based on the percentage in the analysis test of mathematical communication skills in writing where students answered 10 out of 18 items had below 50% incorrect written response rates, compared to 8 other items that students could answer correctly with a score above 50%, while in the oral mathematical communication ability analysis test there are still misconceptions in every question asked. This is based on this research data that some students still answer the items incorrectly.

Keywords: Geogebrabook; Trigonometric Function Graphs; Mathematical Communication Skills

How to Cite: Yustiani, N. R., Rosyadi, A. A. P., & Cholily, Y. M. (2025). Analysis of Mathematical Communication Skills of Grade X MA Students on the Material of Trigonometric Function Graphs Aided by Geogebrabook. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *13*(3), 730–740. https://doi.org/10.33394/j-ps.v13i3.15489

https://doi.org/10.33394/j-ps.v13i3.15489

INTRODUCTION

Mathematics is a supporting science for other branches of science as a medium for communicating mathematical problem solving (Cook et al., 2021). Based on this, it is known that the role of mathematics is very important and began to be given teaching to students starting from primary education to higher education (Hwang & Tu, 2021). According to Siregar et al. (2020), mathematics is formed from the results of human thought processes about mathematical reasoning and ideas. Mathematical ability describes a person's ability (literacy) in understanding, interpreting, and formulating mathematics in various contexts (Gal et al., 2020). Mathematics plays an important role as the foundation of reasoning for process standards in various aspects (Puspita et al., 2024).

One of the skills that students must have is communication skills. Communication is the most important thing in conveying information in learning mathematics. Furthermore, in achieving effective and efficient learning, it can be done through communication using certain methods (Akram et al., 2022). Through communication, either in written or oral form, it can build aspects of students' knowledge in mathematics learning (Cholily et al., 2024). Through this communication has an important role in discussion activities between students, where in the discussion activities carried out students can explain, describe, state to ask and respond to a discussion based on the analysis they have done (Aini, 2021).

According to Suhenda & Munandar (2023), mathematical communication skills are the ability to express ideas or ideas of statements or solutions to problems mathematically. Furthermore, mathematical communication skills also mean students who have the ability to communicate, understand, and interpret mathematical concepts both through speech and writing, including the use of symbols, notations, and various other mathematical representations (Naimah et al., 2022). Mathematical communication can be divided into written and oral communication (Lutfi & Elfitriadi, 2023). Written mathematical communication is the result of students' thinking process in the form of mathematical sentences, tables, graphs, and so on in writing (Asmana, 2022). While oral mathematical communication is the ability to convey ideas and present mathematical ideas orally (Suryawati et al., 2023). It is important for students to have mathematical communication skills, where students can interpret mathematical solutions concretely from what was previously an abstract thing. Facts in the field based on research by Yusoff et al. (2022), there are still some students who are found weak in mathematical communication and reasoning skills. Based on this, research is needed to analyze students' mathematical communication skills.

In conveying mathematical communication can be done in various theories, concepts, or mathematical learning materials, for example in trigonometry material. Trigonometry is commonly found in mathematics subjects at the secondary school level. Trigonometry is one of the branches of mathematics which is an important component in the mathematics learning curriculum (Orhani, 2024). Some of the things learned in trigonometry material are trigonometric angles, trigonometric identities, trigonometric formulas, trigonometric equations, and trigonometric functions. According to Ningsih et al. (2020), trigonometry is one of the important materials learned by students. The things that students learn in trigonometry material are trigonometric comparisons, triangle formulas in trigonometry, trigonometric functions, sine or cosine subtraction addition operations, sine cosine multiplication, double angles, and the sum of the difference of two angles. Trigonometry can be used in problem solving. Students' mathematical abilities are needed to master trigonometry material.

Geogebra is one of the software that can be used as a math tool (Dahal et al., 2022). Geogebra can also be used as a technology-based math learning media (Vinsensia et al., 2024). One of the features in Geogebra is Geogebra Activity. Geogebra activity makes it easy for users to design math learning activities so that teaching math is better (Abidin et al., 2024). The collection of activities in Geogebra Activity can be put together in one unit using the Geogebra Book feature. Geogebra book is a collection or collection of Geogebra-based student materials and worksheets (Yustiani & Nasution, 2022). With the activities aided by Geogebra book, can help in analyzing students' mathematical communication skills.

Trigonometry is a basic topic in mathematics that provides a connection to the level of reasoning in graphs, geometry, and algebra (Ziatdinov & Valles, 2022). Some students illustrate the results of their thinking on contextual problems that discuss trigonometry correctly. However, there are some students whose explanation is not correct because the student's understanding of the material is not correct. There are also students who have thoughts by connecting previously acquired knowledge, but the material is from other fields of science so it is not synchronized with the contextual problems given (Aditya & Sukestiyarno, 2019).

Based on the above problems, research is needed on analysis of mathematical communication ability of grade X MA students on trigonometric function graph material aided by geogebrabook. The purpose of this study was to analyze the mathematical communication skills of grade X MA students in writing and oral on the material of trigonometric function graphs. This research is different from previous research about analysis of mathematical communication skills. Previous research about mathematical communication aided by geogebra by Kusumah et al. (2020) aimed to analyze the effect of GeoGebra in three-dimensional geometry learning on students 'mathematical communication ability as a whole and based on students' prior mathematical abilities. The different of the previous research than this research is on the materials. The material of previous research is about three-dimensional geometry, while the material of this research is about transformation of trigonometric function graph. Furthermore, Yustiani and Nasution (2022) intended to develop student activity sheet (research development). This previous research is on the same materials with this research, but this research is about analysis of mathematical communication skills.

METHOD

In writing this journal, it uses a type of qualitative research which is a way of examining in depth about a fact, reality, or symptom (Yusanto, 2020). Furthermore, the approach used is to use a descriptive approach. Descriptive approach is a form of research by analyzing data that aims to get conclusions about research results based on a sample (Syahrizal & Jailani, 2023). The implementation of this research activity was carried out at MA Muhammadiyah 2 Malang. Furthermore, the subjects in this research activity are 6 students representing 72 students of grade X who have low, medium, and high abilities. Low ability students are students who have difficulty in understanding or mastering learning materials, or show lower abilities compared to other students. Medium ability students are students who have the ability to learn and understand material at a moderate or average level. High ability students are those who demonstrate above average cognitive abilities, have potential to learn and develop in mathematics, and may have high mathematical intelligence. The selected students will carry out the mathematical communication ability test on the material of trigonometric function graphs aided by Geogebra book.

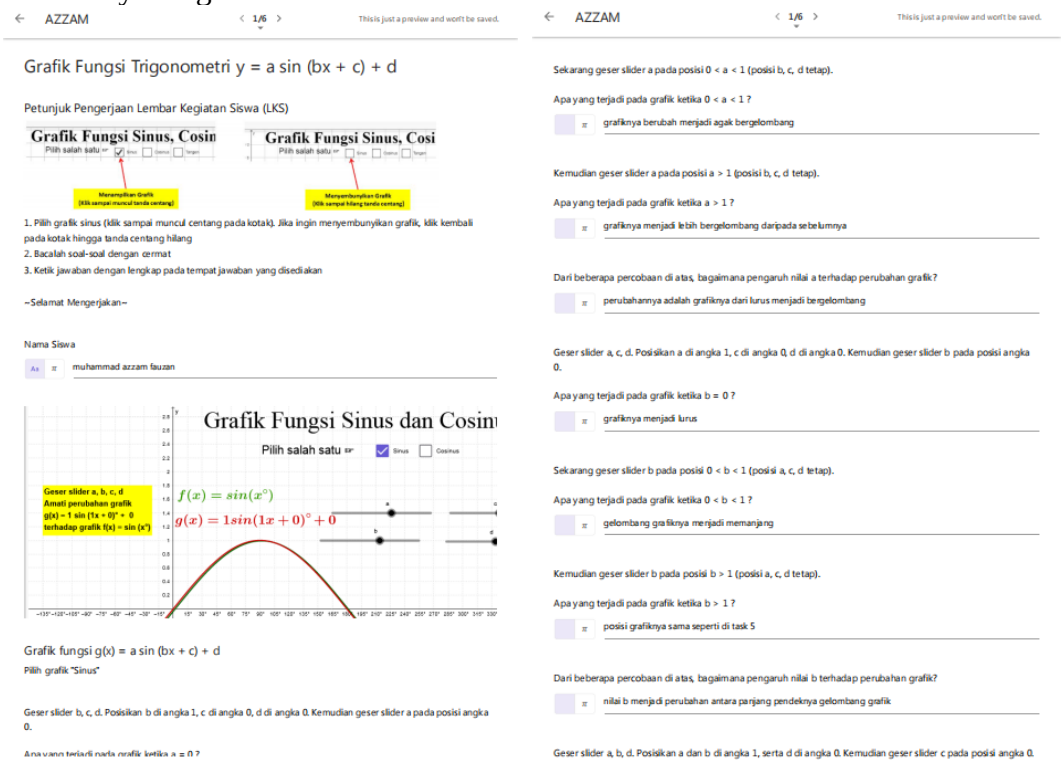

Figure 1. The snippet of worksheet that has been done by one of the students

The type of data used in this research is to use primary data and secondary data. The acquisition of primary data is a direct result of research activities, such as tests, interviews, and some findings of facts in the field. Meanwhile, secondary data is an analysis of literature review studies to support the findings in the results of primary data. Data collection techniques in the study were using interview techniques, documentation, and worksheets aided by geogebrabook. By using geogebrabook-aided worksheets, students will communicate mathematical thinking through the trigonometric function graphs presented, namely about how the function graph changes when the trigonometric function changes. Students will communicate the results of their understanding in the column provided. The structure contain of geogebrabook-aided worksheets such as trigonometric function graph in sine that the graph can be transformed by student used the slider, to answer some questions about the sine graph transformation. Each student works independently on the same worksheet. One of the questions on the worksheet is "On the function graph of $g(x) = a\sin(bx + c)° + d$ please slide the sliders b, c, d. Position slider b at 1, c at 0, and d at 0. Then slide slider a to the number position 0. What happens to the graph when a = 0?"

Figure 2. Documentation of students do the task (worksheet) independently

Furthermore, this study uses data instruments that have a role in measuring research variables to obtain information related to the formulation of the problem. The instruments used in this study include (1) the researcher as the subject conducting the research, (2) the test of mathematical communication skills aided by geogebrabook, and (3) validation instruments. After the data is collected, then the data analysis technique is presented in Figure 3.

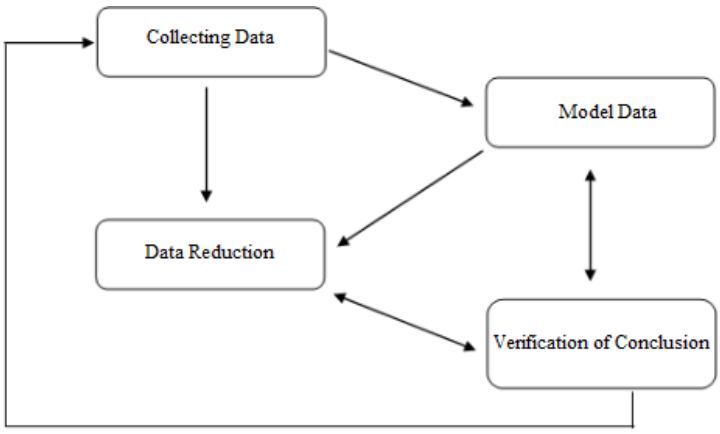

Figure 3. Technic (Method) of Data Analysis

Table 1. Rubric for assessing students' mathematical communication skills in writing

Description	Score
The student can answer correctly, in detail, and completely	5
The student can answer correctly, in detail, but not completely	4

Description	Score
The student can answer correctly, in detail, and completely	5
The student can answer correctly, but not in detail and completely	3
The student can answer correctly, but there are still a few misconceptions	2
The student could not answer correctly	1
The student did not give an answer	0

RESULTS AND DISCUSSION

In learning mathematics, of course, we need communication aspects to exchange information related to working procedures, formulas, and the benefits and uses of learning mathematics. Teachers convey mathematics learning materials to students in teaching and learning activities through communication (Church et al., 2024). Of course, math learning is not optimal if the teacher is inadequate in terms of communication to students (Pohan & Fitria, 2021). For example, students are given a worksheet. Students will have difficulty in understanding what to do with the worksheets that have been distributed if there are no instructions from the teacher. So in this case, communication is fundamental in teaching and learning activities including in mathematics learning.

Communication is a very important part of human activity. Communication is a series of actions or events and is related to each other within a certain period of time (Anas, 2021). According to Pertiwi et. al. (2020), mathematical communication includes how to convey mathematical ideas and clarify understanding. Students' mathematical communication skills when solving problems based on differences in mathematical abilities must be understood by the teacher. Mathematical communication can be seen in terms of completeness and accuracy. Mathematical communication in terms of completeness can be seen from how students can communicate a mathematical problem completely and systematically or sequentially. While mathematical communication in terms of accuracy can be seen from how students can communicate a mathematical problem precisely.

The implementation of research activities was carried out to determine mathematical communication skills. Collecting data by test of mathematical communication skills in writing tested on 6 students with a group of 2 high ability students, 2 medium ability students, and 2 low ability students. This 6 students representing 72 students of grade X. Every student work the test independently. The significance of this research is the students become more focused in learning because students are instructed to do activities by shifting the slider so that the intended graph is formed according to the instructions of the given problem. Model data by interview method in the test of mathematical communication skills in orally answered together by students. Data reduction of research data by results or scores of independent work on the analysis of mathematical communication skills in writing presented on the Table 1, while the results of analysis of mathematical communication skills in oral, the students's answer presented in Table 2 that describes related to the percentage of mathematical communication skills in writing.

Table 2. Percentage of Mathematical Communication Skills in writing

Question	MAF	MID	SAL	ESZ	RA	MA	Total	Percentage
1	5	5	5	5	5	5	30	100
2	5	5	5	5	5	5	30	100
3	3	4	3	4	1	1	16	53.3
4	2	3	3	5	1	1	15	50
5	5	5	5	1	5	5	26	86.7
6	2	5	2	1	1	1	12	40
7	1	2	2	1	0	1	7	23.3
8	4	1	1	3	1	1	11	36.7

Question	MAF	MID	SAL	ESZ	RA	MA	Total	Percentage
9	1	5	2	1	1	1	11	36.7
10	5	5	1	1	1	1	14	46.7
11	5	5	1	1	1	1	14	46.7
12	4	4	1	5	1	1	16	53.3
13	1	5	3	1	0	1	11	36.7
14	5	1	5	3	1	1	16	53.3
15	5	1	5	1	1	1	14	46.7
16	5	3	3	5	0	1	17	56.7
17	5	1	5	1	1	0	13	43.3
18	5	3	4	1	0	0	13	43.3

High ability students represented by MAF and MID, average ability students represented by SAL and ESZ, and low ability students represented by RA and MA. Based on Table 1, students' ability in mathematical communication in writing in question number 1 was 100%, question number 2 was 100%, question number 3 was 53.3%, question number 4 was 50%, question number 5 was 86.7%, question number 6 was 40%, question number 7 was 23.3%, question number 8 was 36, 7%, question number 9 by 36.7%, question number 10 by 46.7%, question number 11 by 46.7%, question number 12 by 53.3%, question number 13 by 36.7%, question number 14 by 53.3%, question number 15 by 46.7%, question number 16 by 56.7%, question number 17 by 43.3%, question number 18 by 43.3%. The lowest score is in the question number 7 that has score 23.3%. The question of number 7 is “Slide the slider b on position b > 1 (position of slider a, c, d still fixed). What happens to the graph when b > 1?”. The right answer is “The transformation of the graph is the wave of the graph is getting narrower, and this new graph narrower than the previous graph when $0 < b < 1$”. Almost all students could not answer correctly, even there were a student with no answer. One of students that could not answer the question of number 7 is MID who classified as high ability students. His answer is “The wave of the new graph is almost as big as the green color graph (the green color graph means graph of $g(x) = a\sin(bx + c)° + d$)”. It can be concluded that students cannot communicate the transformation of the graph or have cognitive obstacles in question number 7. This is in accordance with the statement by Zhou et al. (2023), cognitive load or misunderstanding of parametric transformations could cause errors. Furthermore, at the interview stage, the following is a list of questions asked and answers with the method of questions answered by students together.

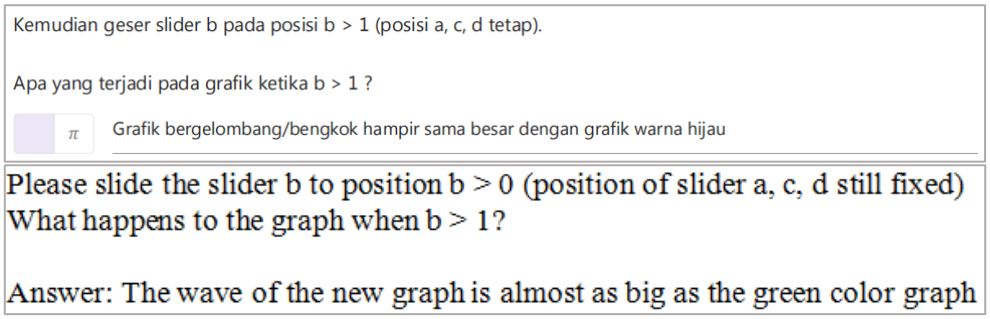

Figure 4. The answer of question number 7 by MID

The model problem given to students is trigonometry material. Trigonometric function is one of the things studied in trigonometry. Trigonometric functions include trigonometric function sentences and trigonometric function graphs. Examples of basic trigonometric function sentences include $f(x) = \sin(x)$; $f(x) = \cos(x)$; $f(x) = \tan(x)$, with x in radians. While the graph of trigonometric functions is a graphical representation of these functions. In trigonometric material, there are differences between $f(x) = \sin(x)$ function graphs and $f(x) =$

$\sin(x - 30)$ function graphs. So students need to understand how the graphs of the two trigonometric functions differ and the graphs of other trigonometric functions.

Table 3. List of Question and Answer of Interview as benchmark for Oral Mathematical Communication Skills

Question	Answer
Given: g(x) = a sin (bx + c) + d	
How do you think the graph changes if there is a change in the value of a as a moves away from 0?	Some students answered that the waves widened, some answered that they could become straight, and some answered that the waves narrowed.
How do you think the graph changes if there is a change in the value of b as the value of b moves away from 0?	Some students answered that the waves became bigger, some answered that they became straight, and some answered that the waves widened.
How do you think the graph changes if there is a change in the value of c as the value of c moves away from 0?	Some answered that it had no effect, some answered that it moved horizontally, and some answered that the graph became straight.
How do you think the graph changes if there is a change in the value of d as the value of d moves away from 0?	Some answered that the graph can go down and up, while others said that it moves vertically.
Is there any difference in the shape or position of the graph of g(x) = sin (x) and the graph of g(x) = sin (x + 30)? Explain your opinion and why.	Some answered that the shape of the graph remained but shifted slightly to the left, while others answered that it did not change.

Based on Table 3, students' ability in oral mathematical communication is described in the answers to oral questions number 1 to 5. From some of these answers, at least in each question there are several students who answer or communicate mathematically correctly. The analysis of errors is found in the analysis test of mathematical communication skills in writing on item number 7, 8, 9, and 13 for high, medium, and low ability students. Almost all students could not answer the question, or if they could answer, the answer was not correct. So that students cannot communicate how the graph changes mathematically. This can be seen based on the percentage of students' ability to communicate answers mathematically in number 7 amounting to 23.3%, and numbers 8, 9, and 13 have a percentage of 36.7%. The comparison of the level of accuracy of the analysis of mathematical communication skills in writing compared to orally, the results are more accurate in writing. This is because students get more opportunities to think first and then write down the results of their thinking, while students' oral mathematical communication tests tend to be more spontaneous than written communication tests.

According to Ningsih et al. (2020), trigonometry is one of the important materials learned by students. The things that students learn in trigonometry material are trigonometric comparisons, triangle formulas in trigonometry, trigonometric functions, sine or cosine subtraction addition operations, sine cosine multiplication, double angles, and the sum of the difference of two angles. Trigonometry can be used in problem solving. Students' mathematical abilities are needed to master trigonometry material. Through communication, it has an important role in discussion activities between students, where in the discussion activities carried out students can explain, describe, state to ask and respond to a discussion based on the analysis they have done.

Indicators that can be applied to analyze students' mathematical communication on trigonometric function graph material are (1) students can interpret answers, (2) students can convey ideas or opinions, and (3) students can state conclusions in writing (Andriono et al., 2021). In the indicator "students can interpret answers", emphasizes the ability of students to understand and explain the meaning of the results of trigonometric calculations. Based on the test results, some students were able to state what the sine, cosine, or tangent values meant in the context of the problem. However, there are still students who only give numerical answers and have not been able to relate to contextual situations. Based on this, it is known that trigonometric material is still implemented in the calculation process and has not been realized in the form of meaning.

In the second indicator, namely “students can convey ideas or opinions”, students are tested to convey opinions or strategies for solving trigonometric problems. The results show that students with good concept mastery are able to explain why they use certain formulas, such as trigonometric identity or sine rule. In the third indicator, namely “students can state conclusions in writing”, some students were able to write the final conclusion well. However, there are also those who only write the final result without narration, or even without mentioning units, which shows that written mathematical communication still needs to be improved. Stating conclusions is not only listing the results, but also showing a coherent thinking process.

The results of the study are in line with Barus & Hakim (2020) who explained that mastery of mathematics is a must where it is non-negotiable because it is related to decision making and structuring reasoning in an increasingly competitive global era. It is impossible for someone to carry out life without the slightest involvement of mathematics. Therefore, it is important for educators to apply innovative and active mathematics learning models to make it easier for students to understand mathematics learning.

CONCLUSION

The conclusion drawn through the results of the research conducted is that mathematical communication on the material of trigonometric function graphs is low, both in writing and orally. This is based on the percentage in the analysis test of mathematical communication skills in writing more are below 50% compared to above 50%. With the activities aided by geogebrabook, we know how capable students are in communicating how graph transformations are concretely, for example on point 7 has score percentage 23.3%, while almost all students could not answer correctly, even there were a student with no answer. Meanwhile, the analysis test of mathematical communication skills by orally there are still misconceptions in each question asked.

RECOMMENDATION

Based on this research, the following suggestions for teaching and learning activities and further research, to high school students and the equivalent need to be trained or guided specifically in mathematical communication skills, maybe by the method of group-based Geogebra exploration or by teacher-led modelling, especially in the material of trigonometric function graphs. Student’s mathematical communication skills could be analyzed aided by Geogebrabook. We get to know how much the student's ability to communicate the extent to which they understand the material, especially in the material of transformation of function graphs. The students studied about how the transformation of function graph aided by the slider on the graph so they can communicate their extent of understanding the transformation of the graph, and the teacher can analyzed how far the students can understand the transformation of the graph. Suggestions are also addressed to further research related to the analysis of mathematical communication skills on the material of graphs of trigonometric functions, students are expected to be able to write more fully and in detail related to graph transformation. Recommendations also conveyed to readers or the wider community to explore further

knowledge or information related to topics that are in accordance with the research conducted, so that the knowledge / information obtained is broader.

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