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Students' Profiles of Mathematical Reasoning Process: A Mathematics Anxiety Perspective

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Abstract: This study aims to describe in depth the mathematical reasoning process of students based on categories of mathematics anxiety. This research is qualitative study with a descriptive design. The data sources in this study are 34 eighth-grade students at a junior high school in Batam City, Riau Islands Province, who are classified into three categories of mathematics anxiety: cognitive, affective, and somatic. Data collection techniques in this study included a mathematics anxiety questionnaire, mathematical reasoning test, interviews, and documentation. Data analysis was conducted by describing the stages of mathematical reasoning that emerged based on the results of student work and in-depth interviews. The findings show that students with cognitive math anxiety exhibit the most representative reasoning processes. This can be seen in their ability to accurately identify information, formulate hypotheses through structured exploration, and produce valid generalizations supported by relevant mathematical justifications. The implication of this study is the need to design interventions that encourage exploration, hypothesis testing, and the formation of interrelationships between representations independently, thereby improving generalization and justification skills, especially among students who still rely on routine procedures.

Keywords: Anxiety, Mathematics, Reasoning Process, Cognitive Performance

1. Introduction

Mathematical reasoning is one of the essential competencies in mathematics education because it enables students to construct logical arguments, evaluate relationships between concepts, draw generalizations and conclusions at well-founded solutions. Reasoning in mathematics is the process of applying logical thinking to a situation in order to obtain the appropriate problem-solving strategy for a given question, and then using that method to develop and explain the solution (Baiduri, 2021). Mathematical reasoning refers to the ability to analyze mathematical situations and construct logical arguments. With the development of mathematical reasoning, students realize that mathematics is reasonable and understandable. Students learn how to evaluate situations, choose problem-solving strategies, draw logical conclusions, develop and describe solutions, and recognize how those solutions can be applied (Pengmanee, 2016).

The importance of developing mathematical reasoning is receiving increasing attention in mathematics education research. Reasoning not only determines students' success in solving mathematical problems, but also influences their ability to construct and communicate mathematical ideas (Ayal *et al.,* 2016). Evidence shows that who posses strong reasoning skills are better able to analyze problems, identify relevant information, and choose the right strategy to reach a solution (Khontee & Poonputta, 2025). This indicates the need for learning practices that emphasize the development of mathematical reasoning, a skill that provides opportunities for students to engage with mathematics at a deeper intellectual level and stimulate higher-order thinking (Mukuka *et al.,* 2023).

One affective factor that can cause students difficulty in solving mathematical reasoning problems is anxiety in learning mathematics. A negative relationship between mathematics anxiety and performance has been found in many empirical studies, indicating that math anxiety often leads to poor performance when dealing with mathematical reasoning or problem solving (Beilock & Willingham, 2014; Zhang *et al.,* 2019). This is consistent with the results of studies by Zivkovic *et al.* (2023) and Barroso et *al.* (2021), which show that there is a negative correlation between mathematics anxiety and students' mathematical reasoning abilities. Currently, mathematics anxiety is no longer viewed as a single construct but rather as a multidimensional phenomenon encompassing cognitive, affective, and somatic aspects. Therefore, it is important to understand the characteristics of each aspect of anxiety in order to develop more targeted learning strategies and interventions to improve students' mathematical reasoning skills.

Although various studies have explored students' mathematical reasoning, they still focus on cognitive aspects, while affective factors that influence activities in the mathematical reasoning process are often overlooked. Previous studies on mathematics anxiety have primarily highlighted the relationship between anxiety levels and learning outcomes, suggesting that high math anxiety hinders cognitive performance in problem solving, resulting in inaccurate answers (Hasan *et al.,* 2025; He *et al.,* 2025). However, these studies have not yet fully explained how the process of mathematical reasoning unfolds among students exhibiting different anxiety characteristics, particularly based on the cognitive, affective, and somatic dimensions. In other words, there remains a knowledge gap regarding how each dimension of anxiety influences students' activities in analyzing, making conjectures, generalizing, and providing mathematical justifications.

To fill this gap, this study aims to identify and characterize students' mathematical reasoning processes based on categories of mathematics anxiety. This study is expected not only to provide insight into the interaction between the affective and cognitive domains but also to offer practical implications for teachers in designing more effective learning strategies tailored to students' anxiety characteristics.

2. Literature Review

2.1 Mathematical Reasoning

Mathematical reasoning is a fundamental concept in mathematics teaching and learning, as it involves a series of interrelated intellectual processes that integrate knowledge, experience, and mental movements (Nhiry *et al.,* 2023). The concept of reasoning in mathematics learning is described as a process of thinking and reaching rational conclusions based on all relevant factors (Ilhan & Aslaner, 2021). It is a process of gradual change in guessing, generalizing, investigating reasons, and developing and evaluating arguments (Lannin *et al.,* 2011).

In mathematical reasoning, a higher-order thinking process that involves analyzing a problem or phenomenon to understand why and how, and making it meaningful (Erdem & Gurbuz, 2015). Mathematical reasoning includes various processes, such as formulating questions, formulating and testing hypotheses, and developing justifications (Ribeiro *et al.,* 2021). In addition to constructing arguments, it also involves transforming abstract concepts or ideas into observable and measurable phenomena (Smit *et al.,* 2024). According to Herbert *et al.,* (2022) the mathematical reasoning process is an activity consists of three main actions: analyzing, justifying, and generalizing. Several earlier studies related to the mathematical reasoning processes have been conducted, as shown in Table 1 below.

Table 1. Mathematical reasoning process

Rodrigues *et al.* (2021)	Mullis *et al.* (2021)	Davidson *et al.,* (2019)	Vale *et al.,* (2017)	Lannin *et al.,* (2011)
Generalizing	Analysing	Analysing	Comparing	Conjecturing
Justifying	Integrating	Generalizing	Contrasting	Generalizing
Exemplifying	Generalizing	Justifying	Generalizing	Investigating
Comparing	Justifying		Justifying	Developing
Classifying				Evaluating

Barnes (2021) stated that mathematical reasoning is a series of investigative processes aimed at producing statements and developing arguments with the goal of reaching and justifying a conclusion. It is related to reasoning as a means to extract new information, and link known ideas, based on evidence and logical rule, formulating and testing generalizations and other conjectures, and justifying them (Rodrigues *et al.,* 2021).

Furthermore, this form of reasoning is a crucial part of the mathematical thinking process that enables students to improve their mathematical skills. Therefore, this thinking skill can be considered as a guide that helps students understand mathematics (Askew, 2020). It also involves beliefs that arise when a person has arguments that can be justified and communicated to others (Brodie, 2010). Moreover, it includes additional processes such as calculating, solving, drawing, and measuring (Sokolowski, 2021).

Mathematical reasoning emerges as one of the skills that contribute significantly to students' overall critical thinking as it enables them to reason logically when faced with challenging tasks both inside and outside the classroom. This indicates the need for learning practices that emphasize the development of mathematical reasoning, a skill that provides opportunities for students to engage with mathematics at a deeper intellectual level and stimulate higher-order thinking (Mukuka *et al.,* 2023).

2.2 Mathematics anxiety

Anxiety is one of the emotional and psychological aspects of a person. Mayer (2008) defined anxiety as a state of irritability, foreboding, tension, and fear that arises from a real or perceived threat of danger. It is an affective aspect that involves emotions and includes physiological changes such as muscle tension, rapid heartbeat, increased sweating, and behavioral responses such as restlessness and pacing (Anderman *et al.,* 2024). Anxiety is a part of everyday life. However, it becomes problematic when it occupies most of a person's day or life. Anxiety can affect how a person thinks, behaves, feels, and relates to others (Elliot & Smith, 2006).

Huberty (2012) explained that there are several characteristics or symptoms of anxiety that a person may experience during the learning process, namely cognitive, behavioral symptoms, and physiological symptoms. Cognitive symptoms include difficulties with memory, concentration, problem solving, and attention. Behavioral symptoms are the most easily observable indicators of anxiety, such as lack of motivation, laziness, or disinterest in academic or social situations. Physiological symptoms are conditions that reflect high levels of excitement and distress, including headaches, rapid heartbeat, and muscle tension.

In school learning, especially in mathematics, anxiety when learning and solving mathematical problems is commonly referred to as math anxiety. According to Galiano et al. (2023) mathematics anxiety is a negative emotion, worry, or tension experienced by a person in situations involving mathematics. It is an emotional reaction to anything related to mathematics, which causes negative feelings that can interfere with one’s ability to manipulate numbers and solve mathematical problems in daily life (Jaggernauth & Charles, 2015).

Sousa (2015) described mathematics anxiety as a feeling of tension that interferes with the process of manipulating numbers and solving mathematical problems in academic and everyday situations. Similarly, Nolting (2012) characterize this condition as a state of panic, helplessness, paralysis, or mental chaos that occurs in some students when they are asked to solve mathematical problems. Therefore, this form of anxiety is a condition that should not be ignored, because if left unaddressed its intensity may not be able to work effectively (Sepehrianazar & Babaee, 2014).

3. Methodology

3.1 Research Design

This research used qualitative method with a descriptive design that aims to describe in depth mathematical reasoning process of students when solving problems. This approach refers to data that have been collected and analyzed during the research, consisting of processes, actions, or interactions found within it (Creswell & Guetterman, 2019). Data analysis was conducted by describing the stages of mathematical reasoning that emerged based on students’ work and in-depth interviews.

3.2 Subject and Data Collection

The data source in this study consisted of eighth-grade students at a junior high school in Batam City, Riau Islands Province, who acted as research subjects. The data collection techniques used in this study included: (1) a mathematics anxiety questionnaire developed based on conceptual definitions and consisting of 32 favorable and unfavorable statements; (2) a mathematical reasoning test comprising four main processes: analyzing, conjecturing, generalizing, and justifying; (3) interviews and documentation of students' work in completing the mathematical reasoning test. The research instruments used in data collection, specifically the mathematics anxiety questionnaire and the mathematical reasoning test, underwent a validation process by experts to ensure the appropriateness of their content and construct validity. Furthermore, the instruments were pilot-tested on a limited scale to assess construct validity and estimate internal reliability using Cronbach's alpha. The results of the validation and pilot testing indicated that the instruments met the criteria for acceptability, making them suitable and reliable for the research data collection process.

Table 2. Results of the Instrument Validation and Reliability Analysis

Instrument	Content Validity	Construct Validity	Reliability
Mathematics anxiety questionnaire	0.83	0.58	0.94
Mathematical reasoning test	0.82	0.87	0.89

Data collection began with administering a mathematics anxiety questionnaire to 34 students who were classified into three categories: cognitive, affective, and somatic. Next, the researcher selected research subjects in each category of mathematics anxiety to participate in a mathematical reasoning test and in-depth interviews to verify their mathematical reasoning processes. Research subjects in the cognitive anxiety category were coded as S1, those in the affective anxiety category as S2, and those in the somatic anxiety category as S3. The research subjects were chosen based on their ability to explain their mathematical reasoning processes clearly, systematically, and consistently while solving problems and during in-depth interviews. This consideration was made so that the data obtained could provide a more in-depth description of the subjects' mathematical reasoning processes and align with the research objectives.

3.3 Data of Analysis

The data obtained from the research were analyzed using a qualitative model procedure consisting of data collection, data selection, data separation, analogy creation, and hypothesis formation (Sukestiyarno, 2021). Research subjects from each category of mathematical anxiety were given a mathematical reasoning test with questions constructed based on the indicators of mathematical reasoning processes, as shown in Table 3 below.

Table 3. Mathematical reasoning process indicators

Mathematical Reasoning Process	Code	Description
Analysing	A1	Understanding the information provided in the question
	A2	Using the information provided to create illustrations to solve problems
Conjecturing	C1	Formulating the assumption clearly
	C2	Verifying the formulated assumptions by finding the correct reasoning
Generalizing	G1	Finding patterns in a problem
	G2	Using the identified patterns to solve problems
Justifying	J1	Verifying the accuracy of statements
	J2	Drawing valid conclusions

From the test results, the students' mathematical reasoning process was obtained. Then, to deepen the analysis of the students' mathematical reasoning aspects on the Pythagorean Theorem material, the researcher conducted in-depth interviews. The process of drawing conclusions was carried out by testing hypotheses through data collection. Triangulation was used to validate the data, which was a combination of mathematical reasoning tests, in-depth interviews, observations, and documentation. Data reduction was carried out to eliminate data that was not needed in the study.

4. Results and Findings

Based on the results of the mathematics anxiety questionnaire administered to all students, three categories of mathematics anxiety were identified, as shown in Table 4 below.

Table 4. Students' mathematics anxiety

Description	Categories of Mathematics Anxiety		
	Cognitive	Affective	Somatic
Average	43.79	42.32	36.03
Standard deviation	7.46	9.48	25.01
Highest possible score	180	180	180
The lowest possible score	36	36	36
Highest score achieved	57	59	57
The lowest score achieved	29	25	18
Number of Students	17	12	5

The research subjects were selected based on the results of the student's mathematics anxiety questionnaire in each category. Next, the researchers administered a mathematical reasoning test and conducted in-depth interviews related to the process of completing the mathematical reasoning test by the selected research subjects, who were given the codes S1, S2, and S3. The following are the results of the analysis for each research subject.

4.1 Mathematical Reasoning Process in Students with Cognitive Mathematics Anxiety Category (S1)

The analysis process in subject S1 was identified through the interview results. Subject S1 began the analysis activity by reading and understanding the information presented in the question. Next, subject S1 verbally identified the problem and was able to write down all the information that was known or asked. Subject S1 also made simple illustrations that helped to facilitate understanding and problem solving. At this stage, subject S1 recalled the concepts that had been learned previously to process all the information obtained into his own words, and then transformed it into mathematical language representation.

The S1 subjects also carried out coordination procedures through interview tracing activities to obtain more in-depth data. The following are the results of the coordination process.

Q1: How do you understand the information provided in the question?

S1: I read the question carefully first, sir, then find the things that are known and asked in the question.

Based on the mathematical reasoning process carried out by subject S1 as shown in Figure 1, it appears that subject S1 has a strong ability to understand and process information obtained from questions. At stage A1, subject S1 began by reading and understanding the rules that must be followed, then systematically writing down the information that was known and asked accurately. Next, subject S1 carefully identified each question to ensure the accuracy and appropriateness of their statements. In the concept recall stage, the identification process was carried out in writing, where the subject reorganized all the information using their own language and made analogies for each variable so that the variables could be understood and solved correctly.

In the A2 stage of mathematical reasoning, it appears that subject S1 is able to utilize the information obtained by classifying relevant relationships and patterns to answer questions, solve problems, and compile them into simple illustrations that help determine the appropriate solution. The following are the results of in-depth interviews related to the process carried out by subject S1 in creating simple illustrations.

Q2: How do you use the information provided to create illustrations to solve problems?

S1: I looked at the positions of the two cars when they were parked, then drew a path with perpendicular directions from the point where the two cars left the fountain. In addition, I adjusted the image I created myself based on the information and data provided in the question.

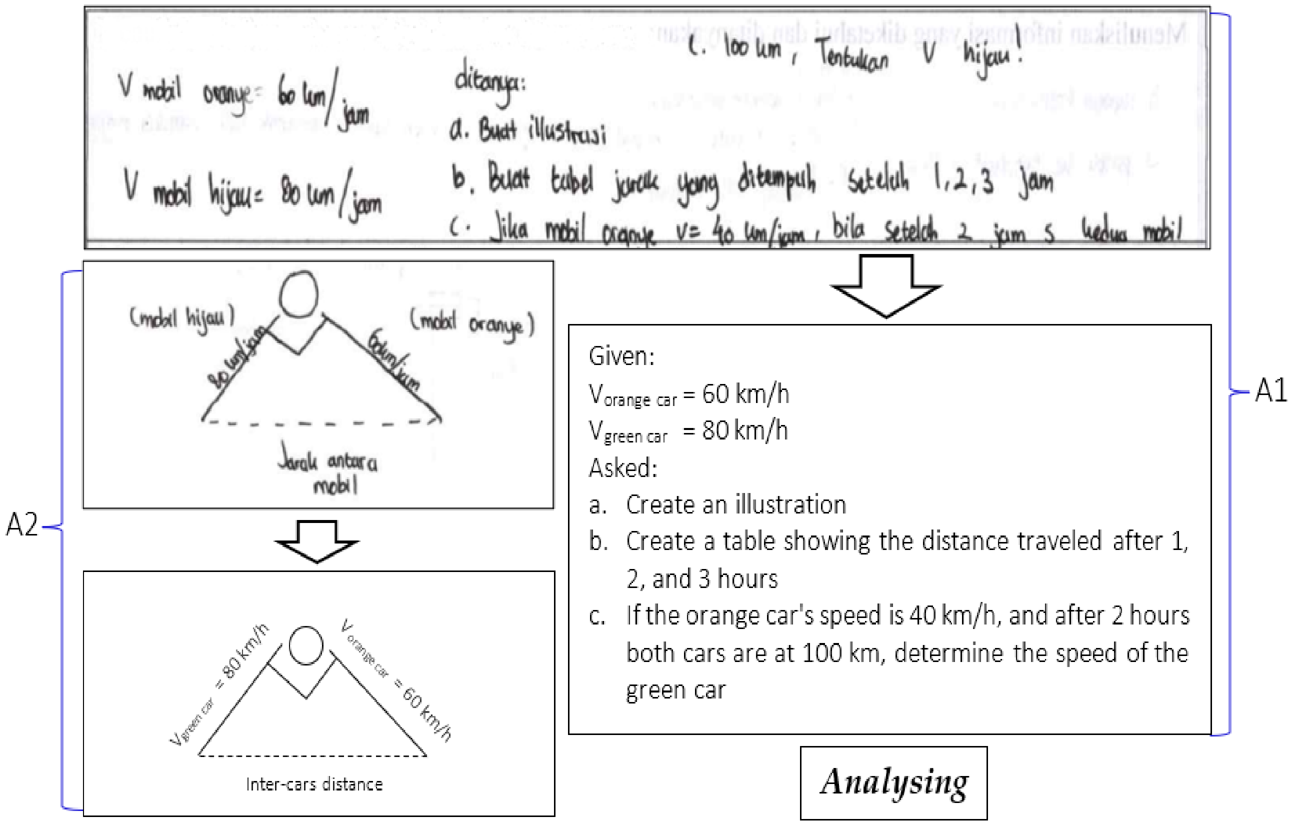

Figure 1. The mathematical reasoning process of S1 in understanding and using information.

The conjecturing process in subject S1 was carried out by trying to interpreting the relationship between the elements in the question through connections with previously acquired knowledge. At stage C1, subject S1 made an initial conjecture based on observations of apparent patterns or regularities. Subject S1 estimated that the longer the travel time, the greater the distance between the two cars, before formally proving this. This activity can be seen in Figure 2, where subject S1 determined the change in distance between the two cars after a certain period of time. This finding is reinforced by the interview results, which show the consistency of subject S1 reasoning in developing the conjecture.

Q1: How do you formulate hypotheses in problem solving?

S1: I will create several formulas that I know, sir, and if there is a suitable formula, I will prove it by performing a simple calculation.

Meanwhile, at stage C2, subject S1 tested the validity of the hypothesis through an exploratory process involving simple calculations and table creation. The consistency of the results obtained with the initial hypothesis strengthened subject S1 belief in its validity. The results of the analysis were also validated through interview.

Q2: How do you verify the hypothesis that has been formulated?

S1: I did a simple calculation, sir, using the Pythagorean Triple concept to see the relationship between time and distance traveled.

The generalization process for subject S1 was carried out by observing several examples of right-angled triangles with different side lengths, then trying to find patterns that emerged between the lengths of the right angles and the hypotenuse. However, based on Figure 3 at stage G1, subject S1 repeated the calculation procedure for each case and thus had not yet demonstrated the ability to conceptually generalize patterns.

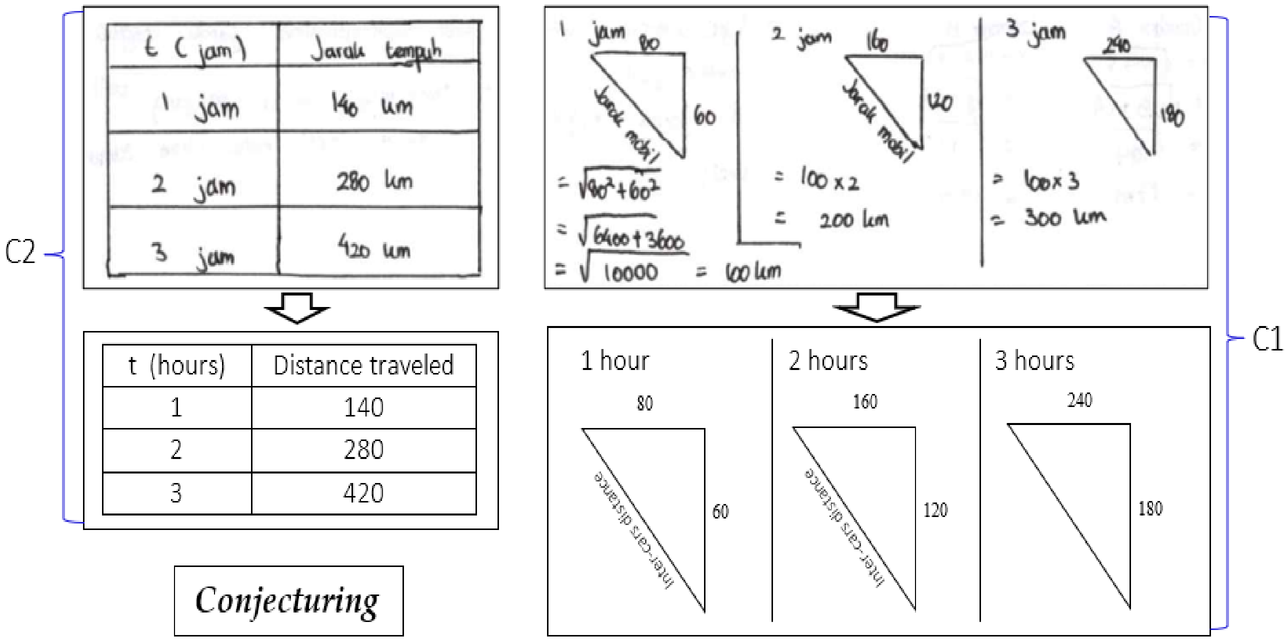

Figure 2. The mathematical reasoning process of S1 in formulating and verifying assumptions.

Therefore, this stage is more appropriately viewed as a process of pattern exploration rather than full generalization. Signs of generalization began to appear in stage G2 when S1 used previously recognized relationships to solve subsequent problems by applying the Pythagorean Theorem and the relationship between distance, speed, and time. This indicates that the previously identified patterns were no longer treated as isolated calculation results but were being used as principles applicable to other contexts. This analysis is also reinforced by the following interview results.

Q1: How do you find patterns in a given problem?

S1: I saw the illustration I made, sir. Then, from the simple calculations I did when checking my assumptions, it showed that the concepts I should use were the Pythagorean Theorem and the formulas for distance, speed, and time.

Q2: How do you use the patterns you have learned to solve problems?

S1: I substitute the known information into the formula that Sir will use.

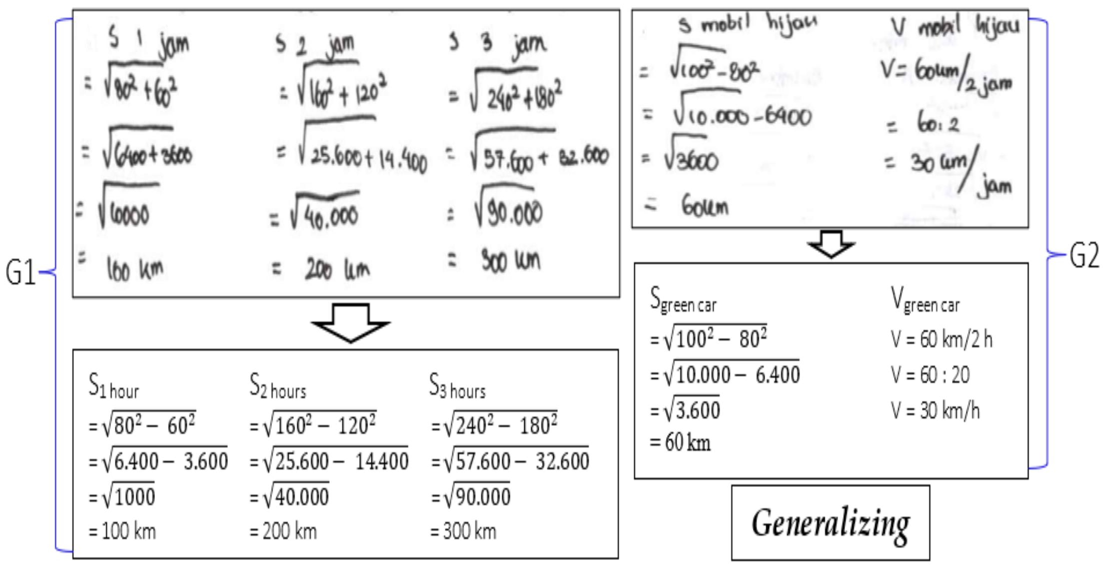

Figure 3. The mathematical reasoning process of S1 in finding and using patterns.

The Justifying process carried out by subject S1 in Figure 4 shows that at stage J1, subject S1 used the Pythagorean Theorem equation to determine the distance between the two cars after a certain time. This step shows that subject S1 not only performed calculations, but also explained the reason why the formula was used, namely because the movement of the two cars could be represented in the form of a right-angled triangle. Meanwhile, at stage J2, subject S1 compared the results with the previously obtained data on the speed and distance between the cars. Based on this comparison, subject S1 attempted to justify their findings by examining the consistency between the relationship of time, distance, and speed. This process shows that subject S1 did not just stop at obtaining the calculation results, but also sought to ensure that the results were in accordance with the underlying mathematical principles. This finding is also reinforced by the following interview results.

Q1: How do you verify the accuracy of the statements obtained?

S1: I am double-checking whether my calculations using the Pythagorean Theorem formula are correct, sir.

Q2: How do you draw valid conclusions??

S1: I wrote down the final answer that best described the essence of all of your questions.

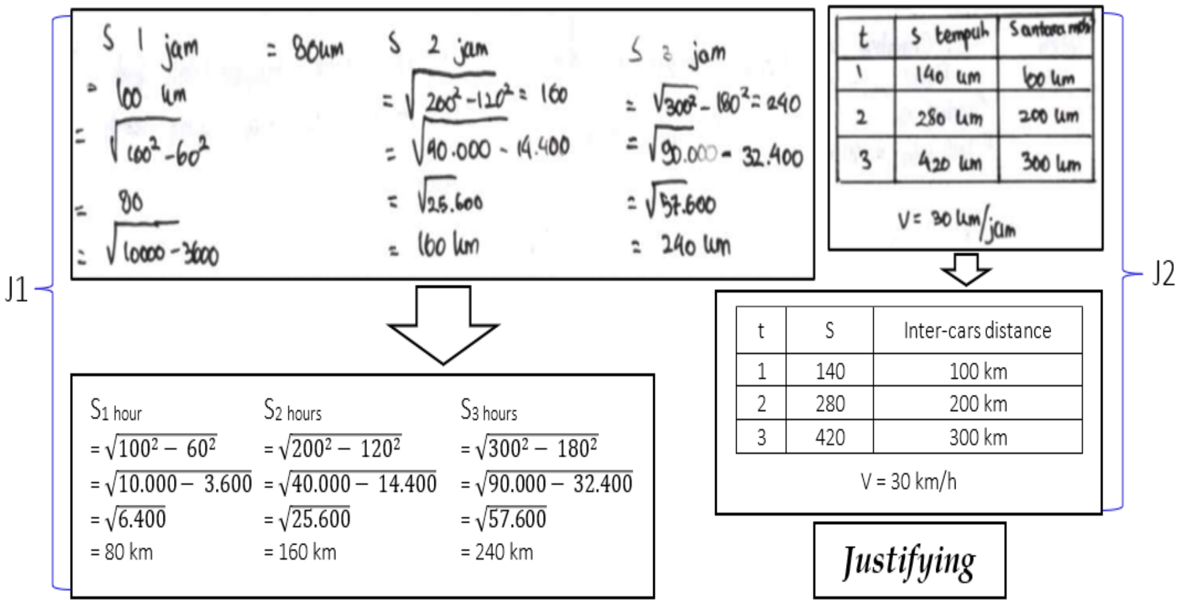

Figure 4. The mathematical reasoning process of S1 in checking the truth of statements and drawing valid conclusions.

Based on the analysis of all answers and in-depth interviews conducted with subject S1, it was found that subject S1 had a coherent train of thought and was able to combine conceptual and procedural understanding in constructing logical mathematical arguments. The summary of the mathematical reasoning process in students with cognitive mathematical anxiety is shown in Table 5 below.

Table 5. Summary of mathematical reasoning processes in S1 subjects

Mathematical Reasoning Process	Code	Description
Analysing	A1	Write down all the information that is known and asked, and represent it in a specific variable form
	A2	Illustrations can help in understanding the problem
Conjecturing	C1	Preliminary assumptions based on observation results
	C2	The truth of the assumption is obtained through an exploration process by performing simple calculations
Generalizing	G1	The pattern used still focuses on procedural calculations
	G2	Results can be obtained from the patterns found
Justifying	J1	Checking the consistency of the results obtained with mathematical principles
	J2	The conclusion reached is correct

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4.2 Mathematical reasoning process in students with affective mathematics anxiety category (S2)

The analysis process carried out by subject S2 in Figure 5 shows that at stage A1, subject S2 was able to identify the known and unknown information from the question, namely the speed of each car and the travel time, which were the variables used for comparison, even though they were not represented in the form of specific variables. Meanwhile, in stage A2, subject S2 demonstrated the ability to connect the information obtained with geometric concepts, specifically the Pythagorean Theorem, in determining the distance between the two cars. Subject S2 realized that the trajectories of the two cars formed a right triangle, where each perpendicular side represented the distance traveled by the two cars, and the slanted side represented the distance between them. It can be said that subject S2 is able to interpret the quantitative relationship between time, speed, and distance in the appropriate spatial context. This process shows that subject S2 not only understands numerical data but can also utilize the interrelationship between variables in a more complex mathematical reasoning context. The following are interview results that support the description of the process carried out by subject S2 in performing the analyzing process.

Q1: How do you understand the information provided in the question?

S2: I read the entire text, sir, then I looked for and wrote down what was known and what was being asked.

Q2: How do you use the information provided to create illustrations to solve problems?

S2: I followed the picture provided in the question and adjusted it based on the information I obtained, sir.

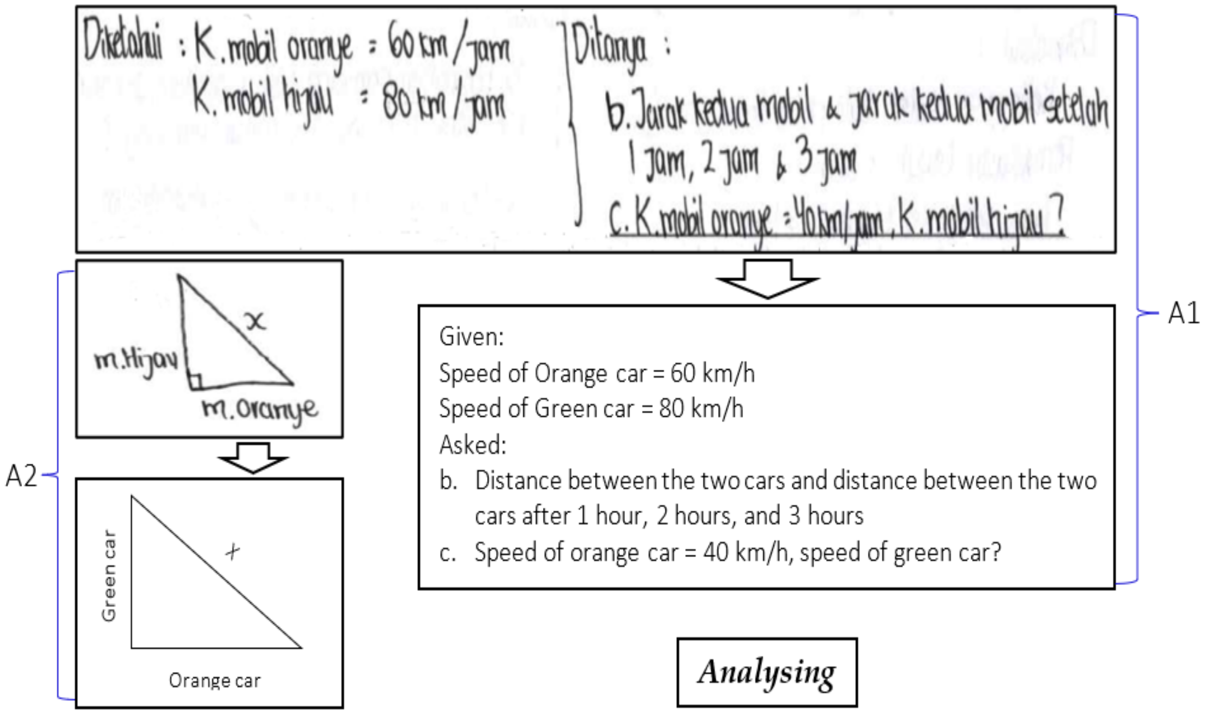

Figure 5. The mathematical reasoning process of S2 in understanding and using information.

The conjecturing process carried out by subject S2 in Figure 6 shows that at stage C1, subject S2 was able to demonstrate systematic thinking in formulating conjectures related to the relationship between speed, time, and distance traveled by two cars moving in perpendicular directions. Furthermore, these conjectures were presented in tabular form to illustrate the pattern of change in the distance traveled by the two cars. This process indicates that subject S2 attempted to form a general pattern based on repeated calculations, leading to the conjecture that the total distance between the two cars increased proportionally to the travel time. Meanwhile, in stage C2, subject S2 attempts to test the validity of the formulated relationship by applying the Pythagorean theorem to calculate the distance between the two cars after a certain time, since they are moving perpendicular to each other. This verification step demonstrates subject S2 ability to integrate geometric concepts with the concepts of speed and distance and to prove the consistency of the results with the initial hypothesis.

However, there is a conceptual error in the calculation process in stage C2. Subject S2 assumes that the distance between the two cars can be obtained by adding the product of each car's speed and time, then directly multiplying the total result without considering the quadratic relationship between the distance components. In some parts, it appears that subject S2 did not consistently use the Pythagorean theorem equation for each time condition, but instead added the linear distances without considering the mutually perpendicular directions of motion. This error indicates a misconception in the interpretation of the meaning of the distance between the two cars, in which subject S2 equated the total distance traveled with the distance between positions. This occurs because subject S2 conceptual understanding is not yet mature at the initial stage of mathematical modeling and there are limitations in understanding the vector relationship between speed and direction of motion, so that their spatial reasoning is not yet completely accurate even though the mathematical structure used is correct. This analysis is also reinforced by the following interview results.

Q1: How do you formulate hypotheses in problem solving?

S2: I'm just trying things out, sir. Which answer matches the calculation results.

Q2: How do you verify the hypothesis that has been formulated?

S2: I did the calculations using the formula for distance, speed, and time, sir.

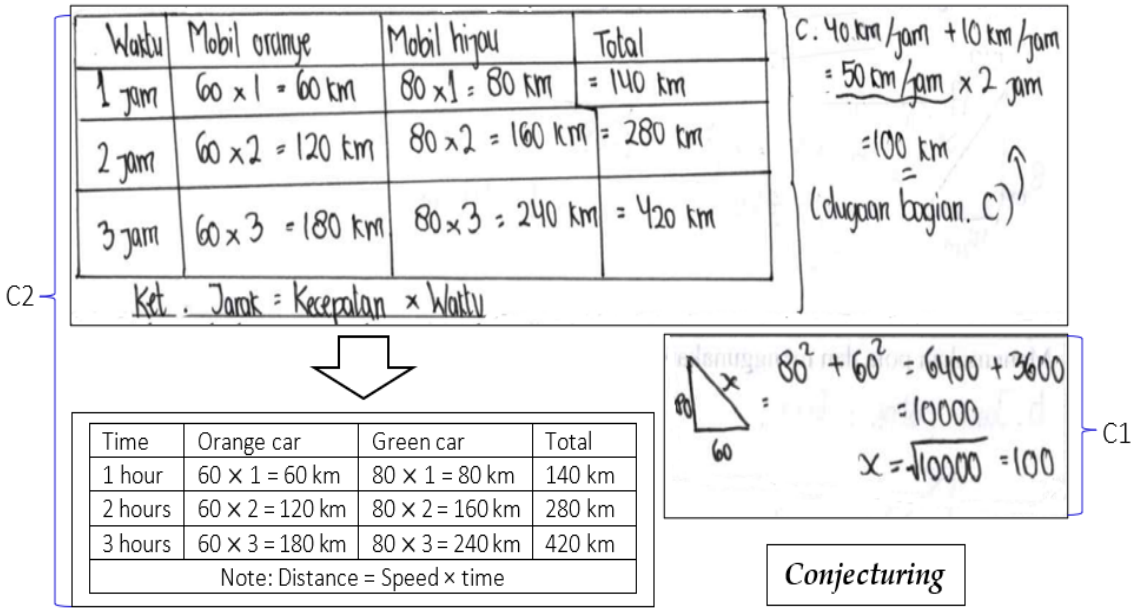

Figure 6. The mathematical reasoning process of S2 in formulating and verifying assumptions.

The generalization process carried out by subject S2 in Figure 7 shows that in stage G1, subject S2 attempted to determine the relationship between travel time and distance traveled by two cars with different speeds moving perpendicular to each other. The student tried to generalize the pattern of distance change based on travel time using the basic formula for the relationship between distance, speed, and time. However, in this process, subject S2 made a conceptual error in interpreting the relationship between the relative speeds of the two cars, so that the distance between them could not be determined simply by adding the product of each speed and time, but should have used the Pythagorean theorem to calculate the actual distance between the two cars.

Furthermore, in stage G2, it appears that subject S2 generalized the findings by writing down the relationship between distance, speed, and time and interpreting the results as a basis for finding the speed of one of the cars. Although this step shows an effort to reflect and use the patterns obtained to solve new problems, the generalization structure used is still mathematically inaccurate. Subject S2 did not integrate geometric understanding into the mathematical model used, so that the reasoning process stopped at the arithmetic stage without involving the geometric relationship that should have appeared in the context of a two-way, mutually perpendicular problem. This finding was also reinforced by the following interview results.

Q1: How do you find patterns in a given problem?

S2: I looked at the picture I had drawn, sir, and then my hypothesis led me to the formula for distance, speed, and time. However, I forgot, sir, that there is also the Pythagorean theorem formula that I should have used because the picture I drew was in the shape of a right triangle.

Q2: How do you use the patterns you have learned to solve problems?

S2: I entered the numbers I obtained into the formula, sir

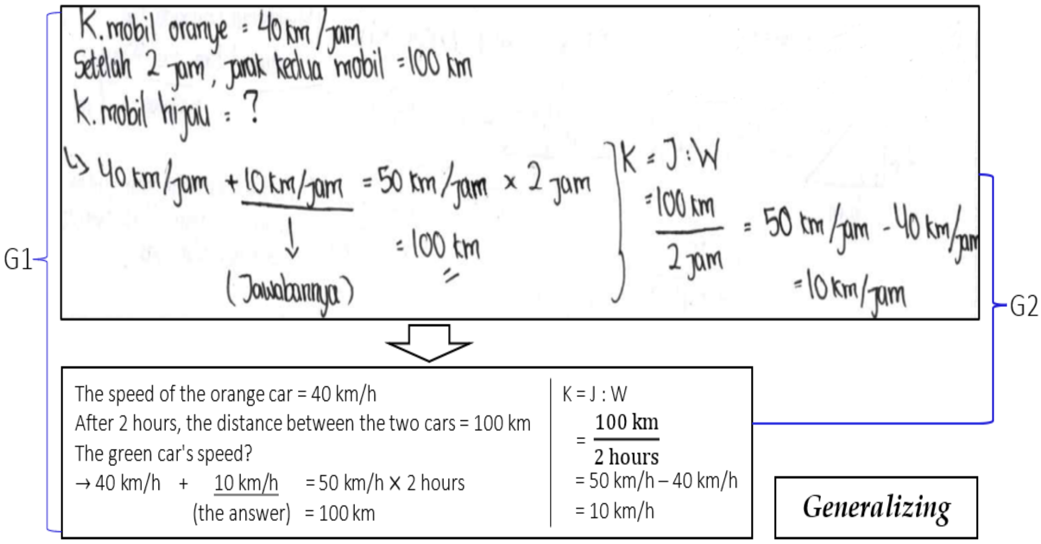

Figure 7. The mathematical reasoning process of S2 in finding and using patterns.

The justification process carried out by subject S2 in Figure 8 shows that at stage J1, subject S2 attempted to examine the statement by writing down mathematical operations involving the speeds of the two cars. This statement indicates that subject S2 understood the need to combine the speed values to obtain the total distance traveled, but the approach used was conceptually incorrect. The error arises because subject S2 did not recognize that the two cars were moving in mutually perpendicular directions; therefore, the distance between the cars could not be obtained by adding their respective distances traveled, but rather represented the hypotenuse of the right triangle formed by the paths of the two cars. As the result, the mathematical model constructed by subject S2 did not match the conditions of the problem, so the calculated speed of the green car was incorrect.

Meanwhile, in stage J2, subject S2 attempted to draw a conclusion by stating that the speed of the green car was 10 km/h and the distance traveled by both cars was 100 km. This conclusion shows that Subject S2 attempted to justify their calculation using values they considered logical, but their justification was not supported by proper mathematical reasoning. Subject S2's main error did not lie in the arithmetic operations but rather in the problem representation and modeling stage. Subject S2 ignored the fact that the paths of the two cars were perpendicular to each other, leading to the use of a velocity addition model that was inappropriate for the problem context. As a result, the student concluded that the green car's speed was 10 km/h. In fact, based on the correct mathematical model, the green car's speed should be 30 km/h, using the equation $100^2 = (80)^2 + (2v)^2$. This indicates a misconception in understanding the initial information and an error in checking the validity of the statement, which directly impacts the drawing of invalid conclusions. The following are the interview results that support this finding in describing the process carried out by subject S2 in the justifying process.

Q1: How do you verify the accuracy of the statements obtained?

S2: I double-checked the calculations I had done earlier, sir.

Q2: How do you draw valid conclusions?

S2: I wrote down the answer to the last question, sir, because I think that question represents all the questions given in the test.

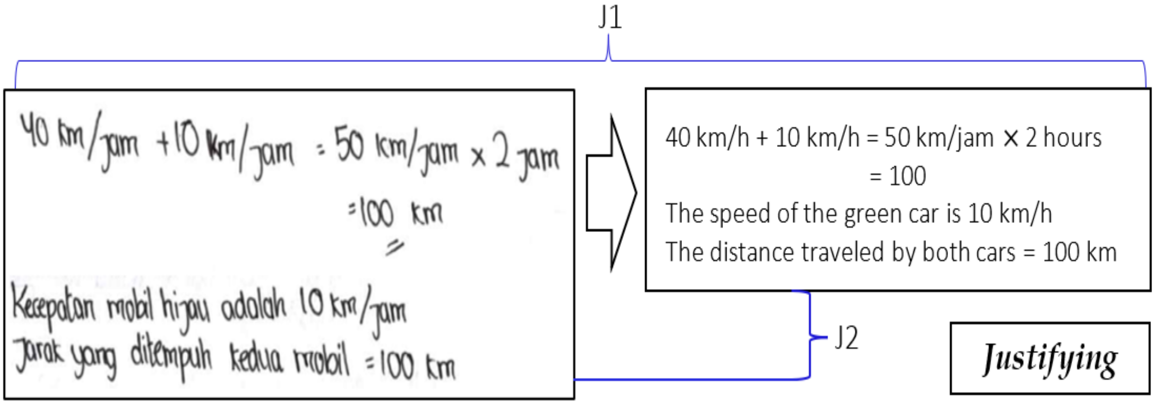

Figure 8. The mathematical reasoning process of S2 in checking the truth of statements and drawing valid conclusions.

Based on an analysis of all the results of in-depth interviews conducted with subject S2, it was found that subject S2 has basic abilities in understanding information, making illustrations, and performing calculations using relevant formulas. However, their reasoning is still procedural and relies on a trial-and-error approach, without fully considering the relationships between the concepts underlying the problem. The failure to identify the use of the Pythagorean theorem indicates that the subject has not fully integrated visual representations with the appropriate mathematical principles. A summary of the mathematical reasoning process in students with affective math anxiety is shown in Table 6 below.

Table 6. Summary of mathematical reasoning processes in S2 subjects

Mathematical Reasoning Process	Code	Description
Analysing	A1	The information that is known and asked is correct, but it has not been represented in a specific variable form
	A2	Illustrations can help in solving problems
Conjecturing	C1	Preliminary assumptions based on the results of mathematical modeling
	C2	There are conceptual errors in the calculation process, as well as misconceptions in the interpretation of meaning
Generalizing	G1	Experiencing a fundamental error because the formula used is incorrect
	G2	Not yet able to integrate geometric understanding into the mathematical models used
Justifying	J1	Simply rewrite the results of the generalization process
	J2	Just rewrite the results of the generalization process

4.3 Mathematical reasoning process in students with somatic mathematics anxiety category (S3)

The analysis process carried out by subject S3 in Figure 9 shows that at stage A1, subject S3 was able to identify the important elements of the problem. This reflects the student's ability to extract relevant information from the question and represent it mathematically through known and unknown statements. Meanwhile, in stage A2, subject S3 attempted to illustrate the situation through a schematic drawing of two cars moving perpendicular to the center point of the fountain. This illustration shows subject S3 ability to connect verbal representations to visual representations, which is an important step in the mathematical modeling process, even though the resulting drawing does not accurately represent a right triangle. Subject S3 also wrote down the speed of each car in the direction of its movement, which indicates an effort to integrate numerical data into a spatial context. This analysis is also reinforced by the following interview results.

Q1: How do you understand the information provided in the question?

S3: I read the question carefully and identified the main components that appeared in the problem, sir, then differentiated between known, assumed, and asked information, so that the structure of the problem became clearer.

Q2: How do you use the information provided to create illustrations to solve problems?

S3: First, I imagine the picture in my mind, sir, then I redraw it based on the picture and information obtained from the question.

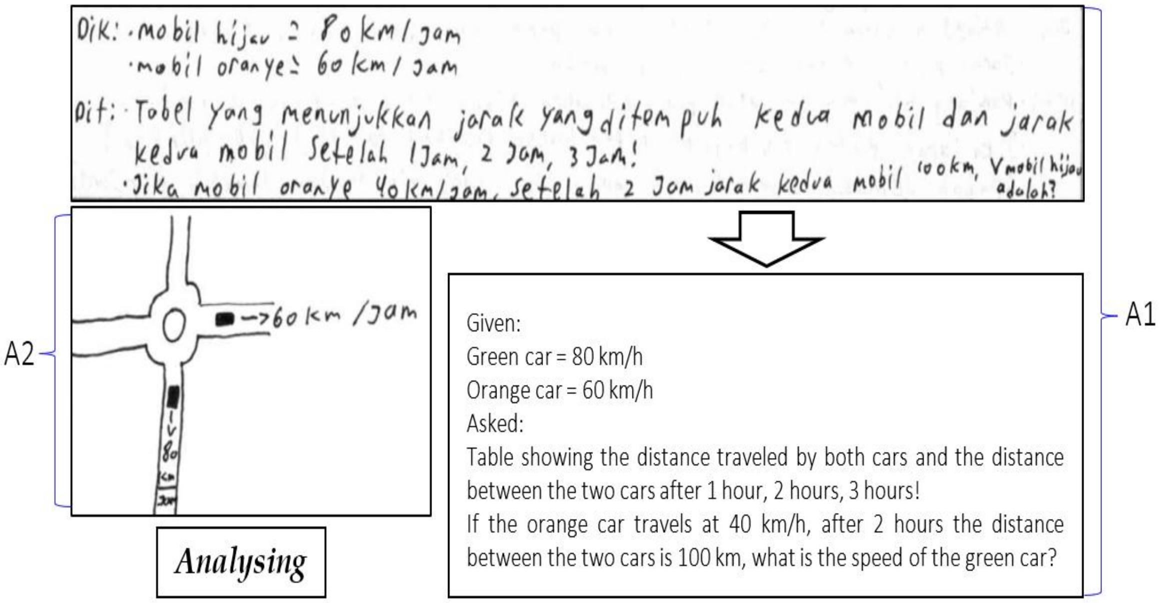

Figure 9. The mathematical reasoning process of S3 in understanding and using information.

The conjecturing process carried out by subject S3 in Figure 10 shows that at stage C1, subject S3 was able to understand the contextual situation correctly. This can be seen from their ability to interpret the narrative of the problem into mathematical representations using illustrations and geometric relationships between the distances of the two cars. Subject S3 conjectured that the relationship between the distances traveled by the two cars could be expressed using the Pythagorean theorem. This process indicates that subject S3 had discovered the perpendicular relationship between the directions of movement of the two cars and understood that the distance between them was the hypotenuse of a right triangle.

Meanwhile, at stage C2, subject S3 conducts a testing process on the hypothesis that has been formulated through systematic calculations over a certain period of time to demonstrate consistency between the initial hypothesis and the verification results. Subject S3 also complements their thought process by presenting data in tabular form, demonstrating their ability to organize numerical information in a structured manner as a form of justification for their initial hypothesis. However, there are minor errors in the reasoning process. These errors were not in the main concepts, but rather in the symbolic and procedural writing, which was not very neat, such as the use of root signs and simplification steps that were not fully written explicitly. The lack of clarity in the transition between calculation lines has the potential to cause ambiguity in the interpretation of the thought process, even though the final value obtained is still correct. These findings are also reinforced by the following interview results.

Q1: How do you formulate hypotheses in problem solving?

S3: I looked back at the picture I drew. If you connect the distance between the two cars, it forms a right triangle, so the Pythagorean theorem applies.

Q2: How do you verify the hypothesis that has been formulated??

S3: I performed mathematical calculations to determine the distance traveled by both cars and the distance between the two cars over a certain period of time using the formula I derived from my assumptions, sir.

However, looking back at my answer, I realize that there are some incorrect mathematical operations and procedures.

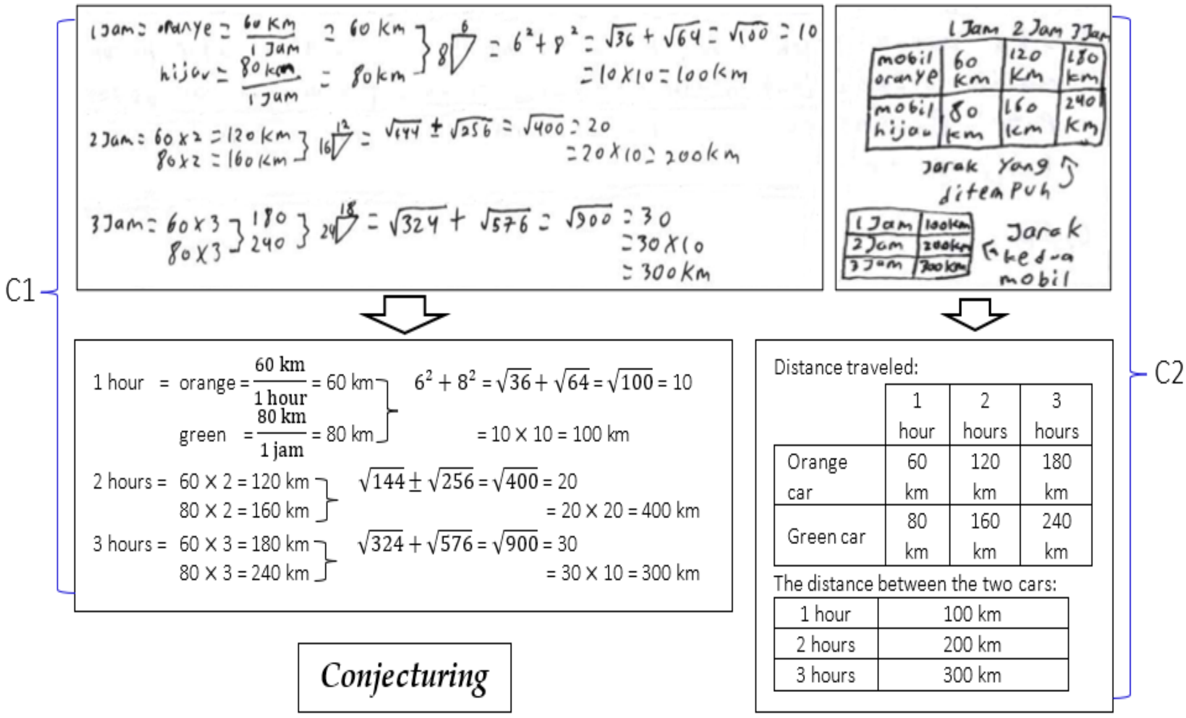

Figure 10. The mathematical reasoning process of S3 in formulating and verifying assumptions.

The generalizing process carried out by subject S3 in Figure 11 shows that in stage G1, subject S3 attempted to generalize the relationship between distance, speed, and time by drawing a triangle diagram. In addition, subject S3 also extracted geometric patterns from the Pythagorean theorem to describe the distance between the two cars moving perpendicular to each other. Subject S3 understands the need to identify relevant mathematical structures to represent the given contextual situation. However, subject S3 generalization process is still not systematic. Subject S3 tends to present various forms of representation without explaining how these patterns arise from the context of the problem. This indicates that the student's ability to formulate patterns explicitly is still limited. The representations displayed are fragmentary and do not yet show the logical relationships between concepts that are actually needed in constructing patterns in a structured manner.

Next, in stage G2, subject S3 applied the pattern found to calculate the distance traveled by each car and the distance between them at a certain time. Subject S3 applied the Pythagorean theorem in determining the distance between cars. This shows that subject S3 understood how to use generalized mathematical patterns to solve the given problems. However, in the calculation section, there were indications of procedural errors, such as errors in interpreting the square root results, which led to illogical final results. In addition, errors in the division operation between distance and time indicated errors in using the pattern of relationships between variables that had been found previously. This analysis was also reinforced by the following interview results.

Q1: How do you find patterns in a given problem?

S3: I looked at the pictures that had been made and analyzed the questions that were given, sir.

Q2: How do you use the patterns you have learned to solve problems?

S3: I put all the known information into the formula, sir, then performed mathematical calculations to find the answer to the given question.

The justification process carried out by subject S3 in Figure 12 shows that at stage J1, subject S3 attempted to verify the information provided using the basic formula for the relationship between distance, speed, and time. In addition, subject S3 also tried to recheck the calculations in determining the travel time. This effort indicates that subject S3 understands the need to validate the relationship between variables before proceeding to the next stage of reasoning.

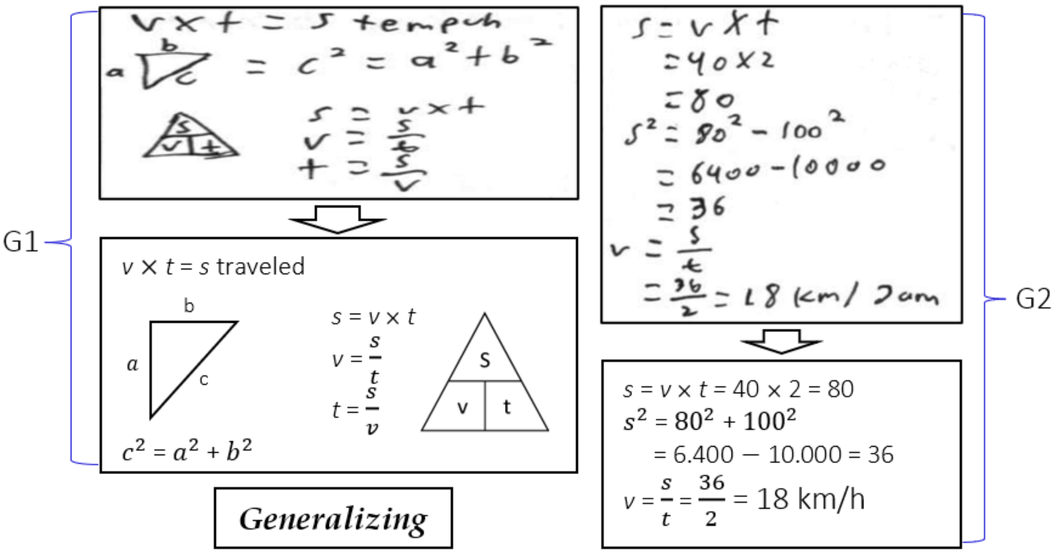

Figure 11. The mathematical reasoning process of S3 in finding and using patterns.

However, there is an error, where subject S3 entered values that were not relevant to the context of the question. This activity shows that subject S3 was not consistent in relating the data in the question to the verification procedure performed, so that the examination process was only procedural, not based on an understanding of the context.

Meanwhile, at stage J2, subject S3 demonstrated the ability to integrate geometric concepts with the concept of uniform linear motion, as well as drawing conclusions based on logical relationships between variables. This process indicates that subject S3 has combined the information provided to produce a coherent and conceptually valid mathematical argument. However, there is an error in that subject S3 has not provided a complete numerical justification for the application of the Pythagorean theorem to obtain the actual distance between the cars after a certain time. Subject S3 understands the relationship between concepts, but has not completed the inference process to produce a complete numerical answer. In addition, the use of notation and argument structure is still not systematic, thereby affecting the clarity and accuracy of mathematical reasoning. The following are the results of interviews that support these findings in describing the process carried out by subject S3 in the justifying process.

Q1: How do you verify the accuracy of the statements obtained?

S3: I double-checked the formula and calculations, sir. Are there still errors in the mathematical operations.

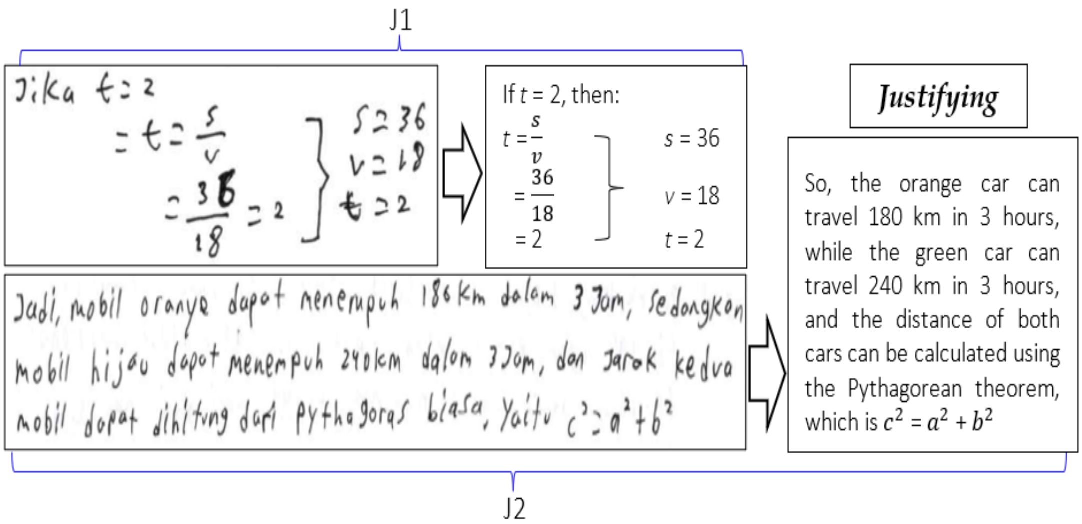

Figure 12. The mathematical reasoning process of S3 in checking the truth of statements and drawing valid conclusions

Q2: How do you draw valid conclusions?

S3: I took the answer from the proven results of the guess, sir.

Based on the analysis of all answers and in-depth interviews conducted with subject S3, it was found that subject S3 had good abilities in understanding problems, making assumptions, and reflecting on mistakes, but still needed improvement in calculation accuracy and the use of correct mathematical procedures. The summary of the mathematical reasoning process in students with somatic mathematical anxiety is shown in Table 7 below.

Table 7. Summary of mathematical reasoning processes in S3 subjects

Mathematical Reasoning Process	Code	Description
Analysing	A1	Write down the main information that appears in the form of known and asked statements, but has not yet been converted into specific variables
	A2	The illustrations produced do not accurately represent the images or information provided
Conjecturing	C1	Preliminary assumptions based on the results of understanding the contextual situation
	C2	Used systematic calculations to demonstrate consistency between initial assumptions and verification results, but encountered procedural errors
Generalizing	G1	The pattern used is still fragmentary and does not yet show a logical relationship between concepts
	G2	Using the pattern obtained to solve the problem, but there are indications of procedural errors
Justifying	J1	Verification is only procedural, not yet based on contextual understanding
	J2	Has not yet provided a complete numerical justification

5. Discussion

Based on the results of research in students' mathematical reasoning processes from the perspective of mathematical anxiety, it was found that subjects in each category of mathematical anxiety were able to fulfill the indicators of mathematical reasoning processes, which included analyzing, guessing, generalizing, and justifying activities. These findings indicate that math anxiety does not completely inhibit students' ability to carry out mathematical reasoning components, although the quality, accuracy, and depth of the thinking processes demonstrated by each subject appear to vary. In other words, the influence of math anxiety is more evident in the way and consistency with which students manage information and construct mathematical arguments, rather than in the presence or absence of reasoning ability itself.

In this context, the mathematical reasoning process in subject S1 shows a relatively complete line of reasoning, in which subject S1 does not only rely on mechanical calculations but also attempts to reason the relationship between illustrations and relevant mathematical concepts. In other words, subject S1 has mature analytical skills in the process of understanding the problems given. Analyzing is a process of determining, remembering, repeating, sequencing, classifying (Davidson *et al.,* 2019) or using information, concepts, relationships, and patterns relevant to answering questions and solving problems (Mullis *et al.,* 2021) and involves providing examples, namely creating specific examples that meet the necessary conditions (Vale *et al.,* 2017).

However, it was found that the conceptual arguments developed by subject S1 were still limited, especially in explaining the logical reasons behind the use of the formulas or principles applied. These findings indicate that subject S1's mathematical reasoning ability was in a transitional stage from procedural thinking to conceptual thinking. This means that subject S1 has been able to link visual, symbolic, and numerical information, but has not yet fully expressed a deep understanding of the relationships between concepts. These limitations are believed to be related to the influence of cognitive anxiety, which can hinder the development of students' conceptual thinking processes (Ng & Lee, 2016). When cognitive anxiety arises, students' attention tends to focus on quickly completing procedures, thereby reducing opportunities to explore the reasons, relationships, and meanings behind a concept. Therefore, this situation underscores the importance of learning strategies that emphasize the exploration of ideas, verification, and reflection on logical truths, so that students' thinking processes do not stop at the application of formulas but develop toward a deeper conceptual understanding.

Conversely, subjects in S2 exhibit strong procedural ability, although their conceptual reasoning process has not developed optimally. When solving problems, S2 subjects tend to rely on routine calculation procedures rather than constructing mathematical arguments based on conceptual understanding. This tendency helps explain why certain stages of reasoning, such as connecting identified patterns to fundamental concepts, for example, the Pythagorean theorem, do not consistently appear in their thought processes. Therefore, S2 can be categorized as subjects with strong procedural reasoning abilities but with limitations in conceptual reasoning and mathematical generalization.

Generalization is the process of making statements that can represent relationships in more general terms and can be applied broadly (Mullis *et al.,* 2021). This process also involves identifying similarities across problems (Lannin *et al.,* 2011) and drawing conclusions about a set of objects or the relationships between them (Jeannotte & Kieran, 2017). The conditions observed in S2 are believed to be related to the effects of the affective anxiety they experienced. When experiencing affective anxiety, students tend to avoid problem-solving strategies they perceive as risky, opt for the simplest approach, and are reluctant to explore alternative solutions for fear of making mistakes. As the result, their ability to identify patterns and make generalizations becomes underdeveloped (Ramirez, Shaw, & Maloney, 2018). These findings emphasize the importance of learning interventions that emphasize understanding concepts and relationships between representations, rather than just applying mathematical procedures.

In comparison, the S3 subject demonstrated solid conceptual understanding, especially in recognizing relationships between concepts, understanding information, and using visual representations to aid mathematical thinking. However, their inferential and verificative abilities still need to be developed. Inconsistencies in the use of formulas, weaknesses in checking the accuracy of results, and a lack of confidence in the thinking process indicate that S3 is not yet fully capable of constructing complete and logical mathematical arguments.

Although S3 has shown strong mathematical reasoning potential from a conceptual perspective, reinforcement is still needed in the aspects of logical validation and justification so that the reasoning process produces conclusions that are accurate, consistent, and mathematically accountable. Research shows that somatic anxiety can hinder the process of evaluating evidence and considering alternatives before a decision is validated or justified (Fan *et al.,* 2023). In the context of mathematical reasoning, justification is a process carried out by providing logical arguments based on understood ideas (Lannin *et al.,* 2011). The justification process consists of checking the truth of statements, using known facts to verify that statements, general properties, or rules of a pattern apply to every case, and using counterexamples to refute a statement (Davidson *et al.,* 2019).

The process of mathematical reasoning in students serves as an important indicator in understanding how mathematical knowledge is internalized, organized, and applied in the context of problem solving. In other words, the quality of students' reasoning reflects the integration of cognitive understanding, representational skills, and metacognitive reflection, which form the basis of higher-level mathematical thinking skills. Therefore, mathematical reasoning is an important part of students' mathematical experiences, and students need to work together to formulate and explore their conjectures and to listen to and understand different interpretations, giving them the opportunity to discuss and modify or reinforce their arguments and ideas (Fraihat *et al.,* 2022). Encouraging students to engage in a constructive process while learning mathematical reasoning can have a lasting learning effect on brain activation, regardless of cognitive ability (Wirebring *et al.,* 2022).

Overall, an analysis of these research findings suggests that the development of mathematical reasoning skills cannot be achieved through a one-size-fits-all teaching approach for all students. Differences in the characteristics of math anxiety indicate that each group of students requires a different form of support during the learning process. Students with cognitive anxiety need activities that encourage them to explain the reasoning behind each procedure, such as mathematical discussions, simple proofs, and reflective questions, so that their conceptual abilities can develop more effectively. Meanwhile, students with affective anxiety require a learning environment that provides a sense of security to try various problem-solving strategies without fear of making mistakes. Teachers can facilitate this through collaborative learning, constructive feedback, and open-ended tasks that allow for more than one solution strategy. Students with somatic anxiety, on the other hand, need support in the form of exercises that emphasize the processes of validation and justification, for example, by reviewing their work, comparing different solutions, and providing reasons for every mathematical decision they make. Thus, mathematics learning is not only oriented toward arriving at the correct answer but also toward developing the quality of reasoning in accordance with students' psychological characteristics.

6. Conclusion

Based on the results of the description, data analysis, and discussion in this study, it can be concluded that students in the cognitive math anxiety category demonstrate the most representative reasoning process. This can be seen from their ability to identify information accurately, formulate hypotheses through structured exploration, and produce valid generalizations supported by relevant mathematical justifications. The mathematical reasoning process in students with cognitive math anxiety has a systematic line of thinking and is able to combine conceptual and procedural understanding in constructing logical mathematical arguments, but the pattern used in the generalization process still focuses on procedural calculations. In contrast, the reasoning process in students with affective math anxiety shows that their reasoning is still procedural and dependent on iterative processes, without fully considering the relationships between the concepts underlying the problem. Thus, the justification and generalization processes have not fully integrated visual representations with appropriate mathematical principles.

At last, the mathematical reasoning process in students with somatic math anxiety shows strong mathematical reasoning potential from a conceptual perspective, especially in understanding information, recognizing relationships between concepts, and using visual representations to aid mathematical thinking. However, strengthening is still needed in the aspects of logical validation and justification so that the reasoning process produces accurate, consistent, and mathematically accountable conclusions. These findings indicate that math anxiety does not eliminate students' mathematical reasoning abilities but does influence the characteristics of the reasoning processes they exhibit. Therefore, teachers need to consider students' math anxiety profiles when designing instruction. Instructional strategies that emphasize conceptual exploration, mathematical discussions, collaborative problem-solving, and reflection and justification activities can be tailored to students' anxiety profiles. Such an approach is expected not only to help mitigate the impact of math anxiety but also to support the optimal development of mathematical reasoning.

7. Recommendations

Further research should involve a larger number of participants so that mathematical reasoning patterns in various categories of anxiety can be understood more comprehensively. In addition, further studies need to explore how the use of real-world contexts and mathematization processes can support the transition from procedural reasoning to conceptual reasoning. Furthermore, future research should also design interventions that encourage exploration, hypothesis testing, and the formation of interrelationships between representations independently, thereby improving generalization and justification skills, especially among students who still rely on routine procedures.

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Author Contribution Statement

Habibullah: Conceptualization, Methodology, Investigation, Formal Analysis, Visualization, Writing - Original Draft. Stevanus Budi Waluya: Supervision, Validation, Funding acquisition, Writing - Review & Editing. Masrukan: Supervision, Validation, Writing - Review & Editing. Iqbal Kharisudin: Supervision, Validation, Writing - Review & Editing. All the authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors have no conflicts of interest to declare. There is also no financial interest to report. The author certifies that the submission is original work and is not under review at any other publication.

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