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Exploring mathematics teachers' and lecturers' perceptions of algorithmic thinking

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Abstract

This study aims to explore teachers' and lecturers' perceptions of algorithmic thinking and strategies to develop students' algorithmic thinking skills. This study is a qualitative research using a phenomenological approach. Data were collected through a questionnaire and an interview. In the data analysis process, we used the first cycle and second cycle coding techniques with NVivo. The findings show that both teachers and lecturers perceive algorithmic thinking as the ability to think of procedures for solving problems algorithmically, logically, and systematically. Participants shared the same perception that algorithmic thinking helps students engage in solving mathematics-related problems in context-oriented and problem-based learning activities. Several efforts offered by participants to improve algorithmic thinking skills include optimizing problem-solving and contextual learning activities, and creating concept maps in teaching and learning activities. Participants also believed that algorithmic thinking encompasses cognitive thinking abilities, such as abstraction and decomposition, in addition to its advantages and applications. The theoretical contributions of the research include the concept of algorithmic thinking, its advantages and implications for daily activities and solving mathematical problems, and efforts to enhance algorithmic thinking abilities. In the future, there is an opportunity to conduct research related to exploring the aspects of algorithmic thinking.

Keywords: Algorithmic thinking, Mathematics problem-solving, Perceptions, Phenomenological approach.

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1. Introduction

Algorithmic thinking is regarded as a cognitive process that involves formulating problems and expressing a series of computational steps Katai [1]. Li et al. [2] emphasize that algorithmic thinking plays an important role in understanding and

analyzing problems through a series of steps to find solutions to the problems. Futschek [3] adds that algorithmic thinking, a type of mathematical thinking, may be regarded as an object, a sequence of steps to be executed, and thus may be presented as results on a flow chart. Li et al. [2] argue that the cultivation of algorithmic thinking should be taught at the primary and secondary levels of education to provide students with early algorithmic literacy that involves knowledge, skills, and attitudes. Hromkovič et al. [4] posit that algorithmic thinking effectively improves students' problem-solving strategies and helps students as they develop algorithmic concepts. In the context of mathematical learning, algorithmic thinking plays an important role in planning, analyzing, and solving problems to complete specific problem-solving tasks [5, 6]. Empirical evidence reported by Lockwood et al. [5] confirms that integrating algorithmic thinking into mathematics learning can help students improve their problem-solving skills and their ability to communicate mathematical ideas [5]. Thus, algorithmic thinking assists students in understanding mathematical concepts better and developing the ability to think logically and analytically, which are important skills in various aspects of life.

In the last ten years, there has been extensive literature discussing and documenting the concept and benefits of algorithmic thinking in the fields of mathematics and computer science [3, 7-9]. In the context of computational problem solving, algorithmic thinking, which is a part of computational thinking, is regarded as a skill limited to designing algorithms. Shute et al. point out that designing algorithms is one component of computational thinking skills [10]. However, algorithmic thinking is a different cognitive ability from computational thinking. What differentiates algorithmic thinking from computational thinking is that algorithmic thinking is concerned with the precise design and analysis of algorithms for specific tasks [11] while computational thinking is a more general problem-solving approach inspired by computer science principles [5, 12, 13].

Lockwood et al. [5] conducted a study by interviewing four professors in the mathematics department and an industrial worker with a master's degree in statistics [5]. The interviews were conducted to explore the role of algorithmic thinking in their areas of expertise. The findings of the interviews conclude that algorithmic thinking is very necessary in mathematical practice (e.g., problem solving). In line with Lockwood et al. [5], algorithmic thinking can also be used in the field of education as Dogan [14] explored 36 prospective primary school teachers' views on the benefits of algorithmic thinking. This study suggests that teachers with strong algorithmic thinking skills would conduct the teaching process systematically and be able to plan learning effectively and neatly. However, Mumcu and Yıldız [15] study provided poor results regarding students' algorithmic thinking abilities in completing assignments. They reported that the results of the algorithmic thinking test taken by 138 public secondary school students in Ordu Province showed that the average student score was 43% of the maximum score. This indicates that students' ability to complete algorithmic thinking tasks is still not optimal. However, this research has not yet investigated the factors that cause this condition.

By understanding the concept of algorithmic thinking, teachers and students can engage in algorithmic thinking to find solutions to mathematical problems. Despite the ubiquity of empirical evidence on algorithmic thinking in the area of education, there is still room for us as mathematics teacher educators to explore the perceptions of mathematics teachers and lecturers regarding the role of algorithmic thinking in mathematics learning at various levels of education. By exploring the perceptions of mathematics teachers and lecturers regarding the concept and application of algorithmic thinking, we hope that there will be an increase in understanding that algorithmic thinking has an important role in the process of solving everyday problems and mathematical problems. With this understanding, students and teachers have the motivation to make efforts to improve algorithmic thinking abilities in problem-solving activities in the classroom and daily activities. Thus, algorithmic thinking can contribute to the task/problem-solving process. The integration of algorithmic thinking in mathematics learning will contribute to the formation of a structured, systematic, and critical thinking pattern. This research also explores efforts that can be made to improve students' algorithmic thinking abilities.

RQ1: How do Mathematics Teachers and Lecturers perceive algorithmic thinking skills in solving problems of everyday life and mathematics learning activities?

RQ2: How do teachers and lecturers improve students' algorithmic thinking skills?

2. Theoretical Framework

2.1. Algorithmic Thinking

Algorithmic thinking refers to logical and sequential processes that together create a desired result and is more focused on the design stage of problem-solving Blannin and Symons [16]. Stephens and Kadijevich [11] argued that algorithmic thinking is necessary whenever someone has to understand, test, improve, or design an algorithm. An algorithm is a routine procedure that can be applied and followed systematically until the conclusion. Algorithmic thinking not only focuses on the design stage of problem-solving but also involves the process of analyzing problems and implementing solutions. As Dogan [14] adds, algorithmic thinking is related to a logical way of thinking and involves a precise sequence of actions, which can be applied systematically, and leads to achieving goals.

Algorithmic thinking is a logical and organized way of thinking that is used to break down complex goals into a series of (ordered) steps using available tools [5, 6]. Algorithmic thinking is more than just the implementation of procedures or even the explanation of why procedures work the way they do. It also involves planning and designing steps, an overall understanding of what an algorithm can do, and having the details to implement the algorithm successfully. Thus, algorithmic thinking is the ability to solve problems and design solutions using algorithm-based approaches. This involves understanding the basic concepts of algorithms, such as the sequence of logical steps and details. Algorithmic thinking involves systematic problem-solving by decomposing complex problems into a series of clearly defined steps Stephens and Kadijevich [11]. Olkhova [17] adds that algorithmic thinking is also characterized by the ability to translate any abstract idea into an instruction that can be executed sequentially to realize that idea.

2.2. Algorithmic Thinking and Mathematical Problem Solving

Some mathematical problems involve an algorithm expressed in a clearly defined sequence of instructions. To deal with algorithms successfully, algorithmic thinking requires other cognitive abilities, including decomposition and abstraction. As Stephens and Kadijevich [11] revealed, to be successful in algorithmic cases, algorithmic thinking requires different cognitive abilities, including decomposition and abstraction. Decomposition and abstraction are cognitive abilities that are often involved in problem-solving. Decomposition means "breaking a problem into sub-problems." Abstractions are used to create general statements that summarize specific examples of underlying concepts, procedures, relationships, and models. This abstraction concept is related to the problem-solving approach. Polya [18] and Liljedahl et al. [19] emphasize that to reach the abstraction stage in problem-solving, problem solvers often use visualization and structuring tools, such as informative images, tables, and solution graphs. Thus, solving mathematical problems can involve algorithmic thinking abilities as well as other cognitive abilities, such as decomposition and abstraction.

As Stephens and Kadijevich [11] argued, the role of algorithmic thinking in the field of mathematics includes:

- Algorithmic thinking can be used in the process of solving mathematical problems and in generalizing solutions to such problems.
- Algorithmic thinking can be involved in the process of identifying mathematical structures.
- It is used to generate examples of problems where the algorithm works and also to generate examples of problems where the algorithm does not work.
- The iterative process in algorithmic design can be used in making mathematical conjectures and proofs.

Thus, algorithmic thinking can be involved in mathematically-oriented problem-solving activities, starting from identifying structures, algorithmic design, and iterative processes, to generalizing solutions.

3. Methodology

3.1. Research Context and Design

This qualitative study involved mathematics teachers from primary and secondary education levels in East Java, Indonesia. To complement the diversity of data, it also involved lecturers in the field of mathematics education in the Madura, Java, and Kalimantan regions of Indonesia. In this study, we explored mathematics teachers' and lecturers' perceptions of algorithmic thinking. Therefore, the phenomenological case study was adopted as an investigative strategy to examine the essence of the human experience of a phenomenon as described by participants [20].

3.2. Participants

Participants involved in this study came from several regions of East Java and from outside East Java, Indonesia. Several participants were fellow researchers during their undergraduate and postgraduate studies between 2001 and 2007, who had become teachers/lecturers. Several participants were acquaintances recommended by the school principal/other colleagues. Out of the 15 potential participants we contacted, only 12 participants (5 lecturers and 7 teachers) participated. The teacher participants came from various levels of education: elementary school teachers, junior high school teachers, and vocational high school teachers. Table 1 is the demographic information on the participants.

Table 1.
Demographic information on participants.

Participants	Gender	Age (year)	Origin (Indonesia)	Workplace	Years of Teaching
Teacher_01	Female	42	Sampang, Madura	Middle School A	15
Teacher_02	Male	41	Surabaya, Jawa Timur	Vocational School B	17
Teacher_03	Male	54	Surabaya, Jawa Timur	Vocational School B	20
Teacher_04	Male	38	Mojokerto, Jawa Timur	Primary School C	38
Teacher_05	Female	39	Mojokerto, Jawa Timur	Primary School C	14
Teacher_06	Female	42	Bangkalan, Madura	Vocational School D	14
Teacher_07	Male	52	Bangkalan, Madura	Vocational School D	25
Lecturer_01	Male	40	Banjarmasin, Kalimantan	University F	18
Lecturer_02	Male	37	Banten	University G	10
Lecturer_03	Female	45	Jakarta	University H	15
Lecturer_04	Male	32	Banten	University I	6,5
Lecturer_05	Female	36	Bangkalan, Madura	University J	12

3.3. Data Collection

Data were collected through a questionnaire and an interview. We designed a questionnaire that consisted of questions to explore participants' perceptions of algorithmic thinking (see Table 2). The written questionnaire consisted of open-ended questions to which the participants freely wrote responses, feelings, or opinions. As Creswell [20] suggested, questions are probing and open-ended. After obtaining consent from the participants, we asked them to fill out a questionnaire, followed by an interview based on their responses. To explore participants' experiences and perceptions of

algorithmic thinking, we conducted in-depth interviews using the same main questions as those in the written questionnaire. Through these interviews, we further reconfirmed the participants' opinions and answers expressed in the questionnaire. Overall, data collection through questionnaires and interviews was carried out in 2023-2024. After completing the questionnaire, interviews were scheduled according to the participants' availability. The interviews were conducted online in Indonesian. The duration of each interview ranged from 2 to 2.5 hours per participant. Table 2 below presents the themes and examples of questions asked, both in the questionnaire instrument and during in-depth interviews.

Table 2.
Theme and Example of Question.

Theme	Example of a Questionnaire and Interview Question
Theme 1: The Concept of Algorithmic Thinking	Have you ever heard the term "algorithmic thinking" before? (If "Yes," please explain it according to your understanding!)
Theme 2: The Advantages and Implications of Algorithmic Thinking in Daily Activities	Algorithmic thinking is related to a way of thinking that involves a precise sequence of actions that can be applied systematically and lead to achieving goals. So, in your opinion, is this kind of thinking useful in everyday life? (Explain and give examples!)
	Can this algorithmic thinking be applied to solving everyday life problems?
Theme 3: The Advantages and Implications of Algorithmic Thinking for Learning and Solving Mathematical Problems	Can algorithmic thinking also be useful in mathematics learning activities? Please explain and give examples of the benefits.
	Can this algorithmic thinking be applied in solving mathematics-related problems for your students?
Theme 4: Improving Algorithmic Thinking Abilities	What can be done to enhance one's ability to think algorithmically?

3.3. Data Analysis

We used a phenomenological approach. As a participant-oriented method, the phenomenological analysis allowed participants to express themselves and their "lived experience" stories as they wished, without being constrained. As Alase [21] emphasized, the essence of using the phenomenological approach in qualitative research was to explore the "lived experiences" of participants and enable them to share their lived experiences freely.

All the interview data were then transcribed and sorted for further analysis. We followed Widodo [22] interview data analysis steps: listening to spoken data, forming spoken data, communicating spoken data with interpretative intent, reproducing or reconstructing spoken data, and establishing data credibility or validating data [22]. After the participants completed the written questionnaire, we interviewed them based on their answers to the questionnaire questions. We asked them to elaborate on some of the answers they had written, especially those that were still ambiguous. Subsequently, we transcribed the interview data in Indonesian and translated the transcriptions into English. Our focus was on capturing the essence of the data for more detailed analysis and interpretation.

In processing the data, we use first-cycle and second-cycle coding techniques with the help of NVivo software. The data coding process will produce several themes and sub-themes. First-cycle and second-cycle coding are the two main stages of coding [23]. The codes originally allocated to the data chunks are known as first-cycle coding schemes. The resulting First Cycle codes are typically used with Second Cycle coding techniques.

We also conducted triangulation and member checks to ensure data credibility. This type of research triangulation is known as method triangulation. The triangulation process involved comparing data collected through questionnaires and interview methods [24, 25]. Member checking allowed the participants to comment on the accuracy of how the spoken data was presented and interpreted [22].

4. Results and Discussion

Drawing on the interview data analysis, we identified four themes: (a) teachers' and lecturers' perceptions of the concept of algorithmic thinking, (b) teachers' and lecturers' perceptions of the advantages and implications of algorithmic thinking in daily activities, (c) teachers' and lecturers' perceptions of the advantages and implications of algorithmic thinking for learning and solving mathematical problems, and (d) teachers' and lecturers' perceptions of how to improve algorithmic thinking abilities.

Theme 1. Teachers' and Lecturers' Perceptions of the Concept of Algorithmic Thinking.

Most participants reported that the concept of algorithmic thinking is related to logical steps in solving a problem. For example, Teacher 01 reported that.

> *Algorithmic thinking is a way to get solutions through logical steps that are arranged systematically so that the problem-solving process is more efficient. So, we need algorithmic thinking because in reality, when doing anything, we will think algorithmically even without realizing it.*

Teacher 04 added that algorithmic thinking is a thinking process used to find a solution to a problem through systematic steps, making the solution easier. Teacher 05 opined that algorithmic thinking is a step-by-step procedure for solving a problem. A total of seven participants argued that algorithmic thinking involves sequential or systematic steps (see Figure 1). They added that the ability to think algorithmically is related to logical steps in completing a job, task, or

problem at hand. These findings provide empirical evidence that participants' perceptions of the concept of algorithmic thinking are in line with Dogan [14] that algorithmic thinking is a way of thinking logically and involves a precise sequence of actions, which can be applied systematically, and leads to achieving goals.

Other participants also contended that decomposition capabilities are part of the algorithmic thought process. Decomposition capabilities are used to break down large problems into sub-problems. Lecturer 01 exemplified that.

> *When we are faced with various problems, the right step in solving the problem is to first outline the possible solutions. Next, map the priority of each solution step that has been created previously.*

This perception is in line with the concept of algorithmic thinking by Stephens and Kadijevich [11]. The process of implementing algorithmic thinking requires different cognitive abilities to be successful in handling algorithms. Other cognitive abilities involved are decomposition and abstraction. Figure 1 is the distribution of finding sub-themes of Theme 1 (The Concept of Algorithmic Thinking).

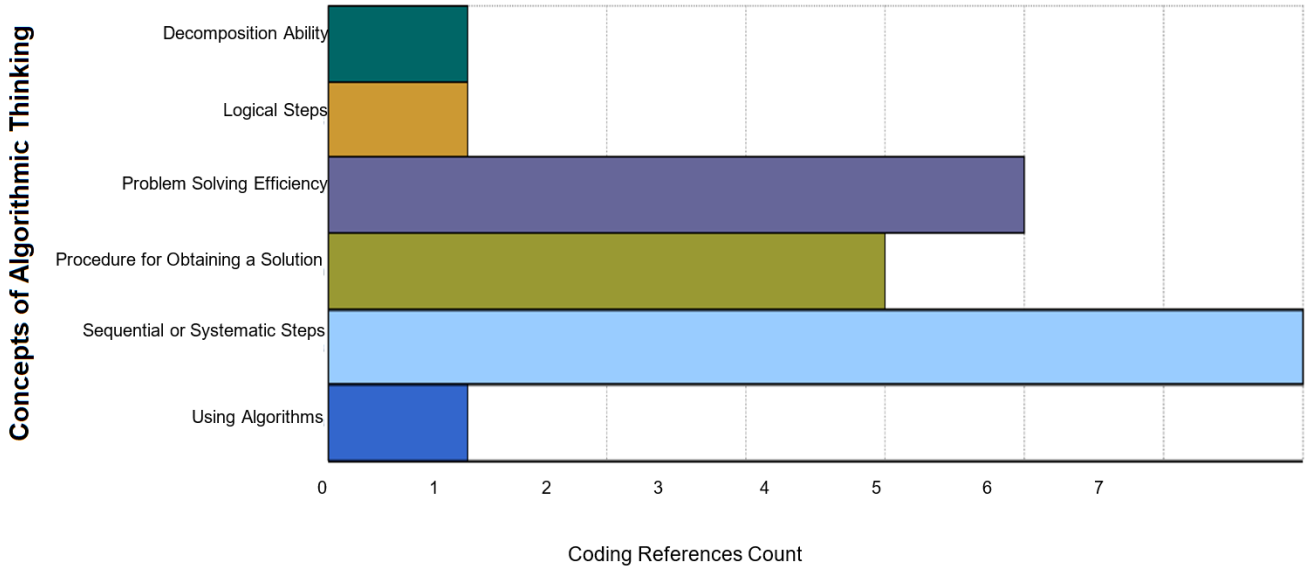


Figure 1.
The Distribution of Finding Sub-Themes of Theme 1 (The Concept of Algorithmic Thinking).
Source: The researcher's data analysis (coding in NVIVO 12).

Based on what the teachers and lecturers reported, it can be concluded that the concept of algorithmic thinking involves the following capabilities: procedures for obtaining solutions to problems, the use of algorithms, sequential/systematic and logical steps, decomposition capabilities, and the efficiency of solving a problem.

Theme 2: Teachers' and Lecturers' Perceptions of the Advantages and Implications of Algorithmic Thinking for Daily Activities.

Contextual problem-solving abilities are among the benefits of applying algorithmic thinking. The contextual problems in question can be daily issues. Teacher 04 highlighted that algorithmic thinking could make it easier for him to solve problems, as well as provide examples of the problems in question.

> *In my opinion, algorithmic thinking is very useful in everyday life because it makes it easier for me to solve existing problems, such as reducing the problem of household waste. The algorithm that I do: understand the types of waste through reading sources, prepare several containers according to the types of waste, choose the type of organic waste and put it in the container for organic waste, choose the type of plastic waste and put it in the container for plastic waste, choose the type of paper waste and put it in a container for paper waste, reprocess organic waste into fertilizer, hand over plastic waste containers and paper waste to the waste bank to be recycled again* (Teacher 04).

The interview excerpt also provides an example of the sequential steps used in solving a problem. This is also included in other benefits of algorithmic thinking: algorithmic thinking can improve and train the ability to solve problems systematically. Algorithmic thinking can also help individuals make decisions and carry out efficient problem-solving steps. The following is an example of an excerpt from the results of the questionnaire and interview:

> *It is very useful, of course, by involving the correct sequence of actions to achieve the goal, making the resolution process more efficient so that there is no need to waste time and energy solving problems. A simple example, is when we go to work via the Mojopahit highway, but it turns out there are road repairs on the road, of course, we have to look for an alternative way to get to work, accurately and wisely determining which road to take, so that time and energy becomes more efficient and we can arrive at work on time* (Teacher 05).

In this quote, Teacher 05 argued that when solving problems through algorithmic thinking, individuals gain alternative knowledge to achieve their goals. Moreover, the participant noted that the benefit of algorithmic thinking is to enhance comprehensive understanding in problem-solving. The following is a snapshot of another lecturer participant:

Several important aspects of algorithmic thinking include understanding comprehensive methods to solve problems, recognizing alternative approaches to achieve objectives, knowing how to overcome errors that occur during the process, combining multiple methods into a new approach when necessary, and creating a complete flow of problem-solving, such as in a flowchart or other formats. The highest level involves solving problems in everyday life (contextually) (Lecturer 04).

The participant added that it is also necessary to create a problem-solving flow that can be presented in the form of a diagram or algorithm. Thus, solving problems involving algorithmic thinking will be more comprehensive. The responses from 12 participants regarding the benefits of algorithmic thinking in daily life activities can be presented in Figure 2.

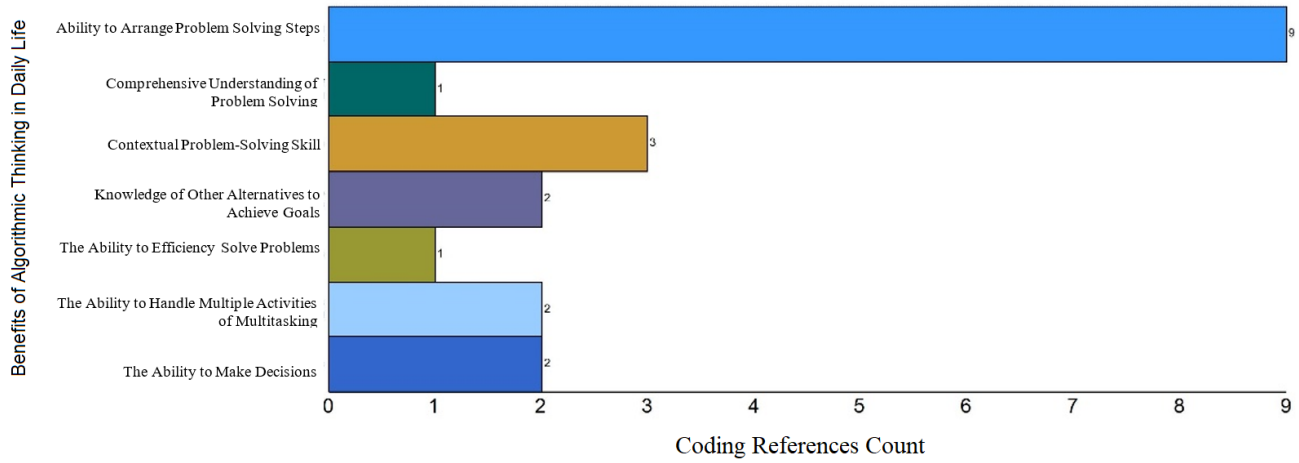


Figure 2.
The Distribution of finding sub-themes for "The Advantages of Algorithmic Thinking in Daily Life".
Source: The researcher's data analysis (coding in NVIVO 12).

The data in Figure 2 indicate that algorithmic thinking is useful in improving "the ability to organize stages of problem-solving," as nine participants reported. The participants also noted that there are several other advantages that a person can get by involving algorithmic thinking, including:

- Improve contextual problem-solving skills.
- Have the ability to make decisions.
- Have the ability to efficiently solve problems.
- Increase the ability to handle multiple activities or multitasking.
- Knowing other alternatives that can be used to achieve the goal.
- Have a comprehensive understanding of problem-solving.

In addition to exploring the benefits of algorithmic thinking in daily activities, we also asked the following question: *Can algorithmic thinking be applied to solving problems in everyday life in general?* The participants provided various answers with examples of applying algorithmic thinking in everyday life. The following includes several excerpts from participant responses regarding the application of algorithmic thinking in "Application of Application Installation".

Algorithmic thinking is very applicable in solving problems in everyday life, in general, because algorithmic thinking is a process of logical steps that are arranged systematically to solve a problem. In other words, algorithms are used to achieve a certain goal. An example of algorithmic thinking applied in solving problems in everyday life, in general, is installing Android applications via the Play Store. The following is an example of the ordered steps (algorithm) that can be carried out:
1. Start
2. Enter the Play Store application
3. Search for the application in the search engine in the header (top)
4. The system displays a list of applications according to the keywords searched
5. Select the desired application
6. Click the download button
7. The download process is running
8. If it fails, the download message will appear again; if successful, the install button will appear
9. Click the install button
10. Wait until the installation is complete
11. Done
(Teacher 01).

This excerpt demonstrates that the steps taken are systematic and logical, which is essential for the successful installation of the application. This indicates the importance of algorithmic thinking involvement.

The participant also exemplified the application of algorithmic thinking in daily activities, such as washing clothes and making a cup of coffee. The following is what participants reported regarding the application of algorithmic thinking in washing clothes.

Algorithmic thinking is very necessary in everyday life. For example, when washing clothes, it starts with the following steps: 1) Separate clothes according to how dirty they are; 2) soak them in soapy water; 3) check the clothes until they are clean; 4) rinse the clothes that have been washed twice with running water; and 5) dry the clothes. If this process is carried out out of sequence, the clothes will not be clean, for example, drying them immediately in the sun after washing, or rinsing first and then washing (Lecturer 05).

Another participant exemplified the application of algorithmic thinking in making a cup of coffee as follows.

This algorithmic thinking can be applied to our everyday lives. For example, when we determine procedures for making an object or minimum standard procedures for quality services. In the procedure for making something, we need stages in the process that are followed, for example: the algorithm for making a cup of coffee: 1) prepare a cup, 2) add coffee, 3) pour hot water, 4) add sugar, 5) stir and taste the coffee, 6) if it's not sweet enough, go back to point 4, and 7) if it's just right, then the coffee is ready (Teacher 05).

The participants demonstrated the application of algorithmic thinking in routine activities that involved a systematic and logical sequence of steps. This logical and systematic stage is one of the factors for achieving success in reaching activity goals. Just like the installation process of a computer program, this activity requires certain stages (which we usually call a programming algorithm) to guarantee the success of the installation process. Algorithmic thinking will make it easier for someone to achieve the desired goal. Starting with examining the logical steps required to arrange them into systematic steps to achieve the goal. The next most important thing is how to train algorithmic thinking skills, starting from simple problems to complex problems.

Theme 3: Teachers' and Lecturers' Perceptions of the Advantages and Implications of Algorithmic Thinking for Learning and Solving Mathematical Problems

When asked about the advantages of algorithmic thinking in mathematics learning experienced by teachers and lecturers, a total of 12 participants provided different responses. Participants believed that algorithmic thinking was useful for teachers or students in finding solutions to mathematical problems. For example, Participant 06 stated that we need algorithmic thinking when working on geometric problems. Teacher 06 then demonstrated the application of algorithmic thinking in solving geometric problems, as seen in Figure 3.

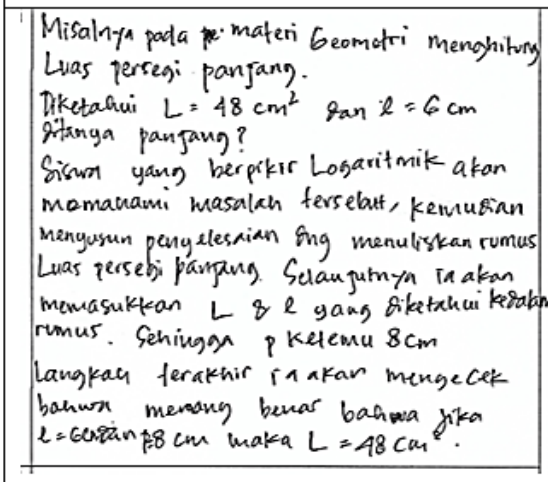
Participant Answers in Indonesian	Translation in English
 Misalnya pada pe. materi Geometri menghitung Luas persegi panjang. Diketahui L = 48 cm² dan l = 6 cm Ditanya panjang? Siswa yang berpikir Logaritmik akan memahami masalah tersebut, kemudian menyusun penyelesaian dng menuliskan rumus Luas persegi panjang. Selanjutnya ia akan memasukkan L & l yang diketahui kedalam rumus. Sehingga p ketemu 8cm Langkah terakhir ia akan mengecek bahwa memang benar bahwa jika l = diketahui 8 cm maka L = 48 cm².	For example, in geometry material to, calculate the area of a rectangle. It is known that L = 48 cm² and l = 6 cm. Question: Length? Students who apply algorithmic thinking will understand the problem, then arrange a solution by writing the formula for the area of a square. Next, he will substitute the known values of L and l into the area formula. So it will be obtained 8 cm. In the last step, He will check whether it is true that if the value l = 6 cm, p = 8 cm, then L = 48 cm²

Figure 3.
An Illustration of the Application of Algorithmic Thinking to Geometric Problem Solving.
Source: Obtained from the questionnaire's responses.

In finding a solution to the geometry problem (see Figure 3), students first needed to understand the problem. They had to identify what information was known and asked about. Afterward, the students used their previous knowledge to develop systematic and logical solution steps. In this example, the algorithmic thinking process was realized starting from the stage where students were able to identify what things were needed, formulate a solution, and systematically apply the principles of a rectangular area.

Lecture 04 opined that algorithmic thinking was useful not merely in finding solutions to mathematical problems, but also in implementing the steps of the teaching process or delivering lesson material.

At the beginning of the chapter, teachers should explain the learning material comprehensively in the form of a tree diagram or similar, so that students can know what they will learn. Then the teacher can also show the flow of problem solving for a problem, and then students are asked to create a flow for another problem. That way, students will learn to think systematically. A wrong solution path can also be given to give rise to cognitive conflict so that students can recognize how systems are unsystematic and illogical (Lecturer 04).

The excerpt also emphasizes the provision of examples of problem-solving pathways in teaching activities and asking students to develop problem-solving pathways for other problems. This is in line with Stephens [26], who pointed out that the explicit use of algorithmic thinking in school mathematics will help students expand their problem-solving techniques, as well as being useful for explaining and justifying students' mathematical reasoning.

In the previous discussion, we explained the benefits of algorithmic thinking in mathematics learning according to the perceptions of teachers and lecturers. In this section, we present the results of a deeper exploration of how the application of algorithmic thinking in mathematics learning aligns with the perceptions and experiences of participants at various levels of education. The participants provided various examples of the application of algorithmic thinking in mathematics teaching and learning activities. Participant Teacher 01 believes that algorithmic thinking is used in solving multiplication mathematical problems. This indicates that numeracy skills are supported by an algorithmic thinking process. Teacher 01 provided the following opinion and example:

> *This algorithmic thinking can be applied in solving mathematics-related problems for my students. An example of algorithmic thinking in solving mathematics-related problems for my students is Multiplication 3,546 times 5. The algorithm for this problem is the addition of the same numbers repeatedly, and can be explained as follows:*
> *What is 3546 plus 3546? 7092*
> *What is 7092 plus 3546? 10638*
> *What is 10638 plus 3546? 14184*
> *What is 14184 plus 3546? 17730*
> *So 3,546 times 5 is 17730.*
> (Teacher 01).

Not only related to numeracy skills, participant Teacher 05 revealed that algorithmic thinking can also be applied in solving simple and complex mathematical problems. Then, participant Teacher 05 gave an example of applying algorithmic thinking in determining how long it takes to travel from city A to city Z. Participants suggested several stages that need to be carried out in determining the solution to the problem, including determining what the problem is (understanding the problem), analyzing the situation or context of the problem (looking for any information that is known), and carrying out calculations to obtain a solution (using mathematical formulas appropriate to the context of the problem). This is in line with Olkhova [17] that algorithmic thinking is characterized by logic, clarity, and the ability to translate any abstract idea into an instruction, the sequential execution of which will realize the idea in providing a solution to the problem. Here is an example of several stages needed to find a solution to a problem (see Figure 4).

Participant Answers in Indonesian	Translation in English
Contohnya: Jarak antara kota A dan Z adalah **360 Km**, jika ditempuh menggunakan sepeda motor dg kecepatan **90 Km/jam**, maka berapa lama perjalan yang ditempuh? Salah satu algoritma penyelesaian dari soal di atas: 1. Tentukan masalah yang harus diselesaikan (lama perjalanan/waktu) 2. Lakukan analisis (cari data yang diketahui yaitu Jarak = 360 km dan Kecepatan 90 km/jam) 3. Hitung Waktu (dengan cara membagi Jarak dengan kecepatan) 4. Selesai	For example: The distance between cities A and Z is 360 km. If reached using a motorcycle with a 90 km/hour speed. so how long will the trip take? One of the solving algorithms for the above problem: 1. Determine the problem to be solved (travel time/time) 2. Perform analysis (find known data, namely distance = 360 km and speed of 90 km/hour) 3. Calculate time (by dividing distance by speed) 4. Done

Figure 4.
Application of Algorithmic Thinking in Solving Mathematical Problems.
Source: Obtained from the questionnaire's responses

In addition to numerical skills and mathematical problem solving, participants Teacher 02 and Teacher 07 both believed that teachers could utilize algorithmic thinking to organize the stages of teaching and learning, starting from the preparation stage to evaluating teaching and learning activities. As illustrated in the following excerpt:

> *Thinking like this is also carried out in your duties as a teacher to achieve learning in the classroom, starting from lesson planning, learning implementation, to learning evaluation (Teacher 02).*
> *For example, if we want to start a lesson, we have to prepare the stages first: we have to prepare the material, know to what extent the lesson has been applied, prepare questions, prepare student activity sheets, and prepare assessments* (Teacher 07).

Theme 4: Teachers' and Lecturers' Perceptions of Improving Algorithmic Thinking Abilities

In addition to the perceptions of teachers and lecturers regarding the benefits of algorithmic thinking and its implementation, we also explored efforts to improve or train algorithmic thinking skills. Fifty percent of participants believed that problem-solving activities in learning sessions could enhance the ability to think algorithmically. The following is an excerpt of participant responses.

> *Improving students' algorithmic thinking can be achieved by providing simple examples of daily activities that involve algorithmic thinking, such as how to buy goods at the supermarket. Then, pose simple questions related to how to think about algorithms that students can solve collaboratively (classical/group), and reflect on these together. Subsequently, encourage students to try independently and to think about algorithms by giving them problems to solve. Draw conclusions about a line of thinking that can be mutually agreed upon based on their competence, so that they are capable and confident in selecting and understanding algorithms* (Teacher 05).

The use of a contextual approach in mathematics learning activities has also been proposed as an effort to improve algorithmic thinking, as in the following excerpt:

> *In my opinion, the way to improve students' algorithmic thinking is to get students used to using a contextual learning approach (contextual-based learning), so that by actually involving students in real life, algorithmic thinking patterns can be formed effectively, as well as increasing the number of practice questions/problems both in daily life and mathematics-based problems* (Teacher 01).

The activity of creating concept maps is also an alternative method for enhancing algorithmic thinking skills. This activity should be complemented with additional activities, such as developing a flowchart or a simple solution sequence network. This aligns with the opinions of Lecturer 04 participants:

> *Giving examples, providing ways to create a plot in the form of a flowchart, providing cognitive conflict, discussing and brainstorming, and being given questions with a higher level of thinking ability are activities to train algorithmic thinking skills* (Lecturer 04).

Lecture 04 also revealed that in the process of solving problems, teachers and lecturers can provide examples of inappropriate problem-solving flows. This approach is useful for encouraging criticism from students, enabling them to develop the ability to think not only logically and systematically but also critically.

In the teaching and learning process, educators also serve as role models for students in solving problems or completing assignments. As shown in the following excerpt from participants' responses.

> *The way to improve algorithmic thinking is by providing examples of behaviors that exemplify algorithmic thinking, and then by encouraging its practice in mathematics learning. In this way, our students will become accustomed to algorithmic thinking both in mathematics and in everyday life* (Teacher 06).

As role models, teachers can provide examples of how to approach or solve simple or complex learning problems by incorporating algorithmic thinking skills into the classroom.

As a result of the coding process in data analysis, Figure 5 below presents a mapping between participants and the efforts to improve algorithmic thinking that have been described. Figure 5 shows the components of efforts that can be made to improve algorithmic thinking abilities and the participants who provide these opinions. From this figure, many participants revealed that improving algorithmic thinking skills was carried out through problem-solving activities in learning activities at school.

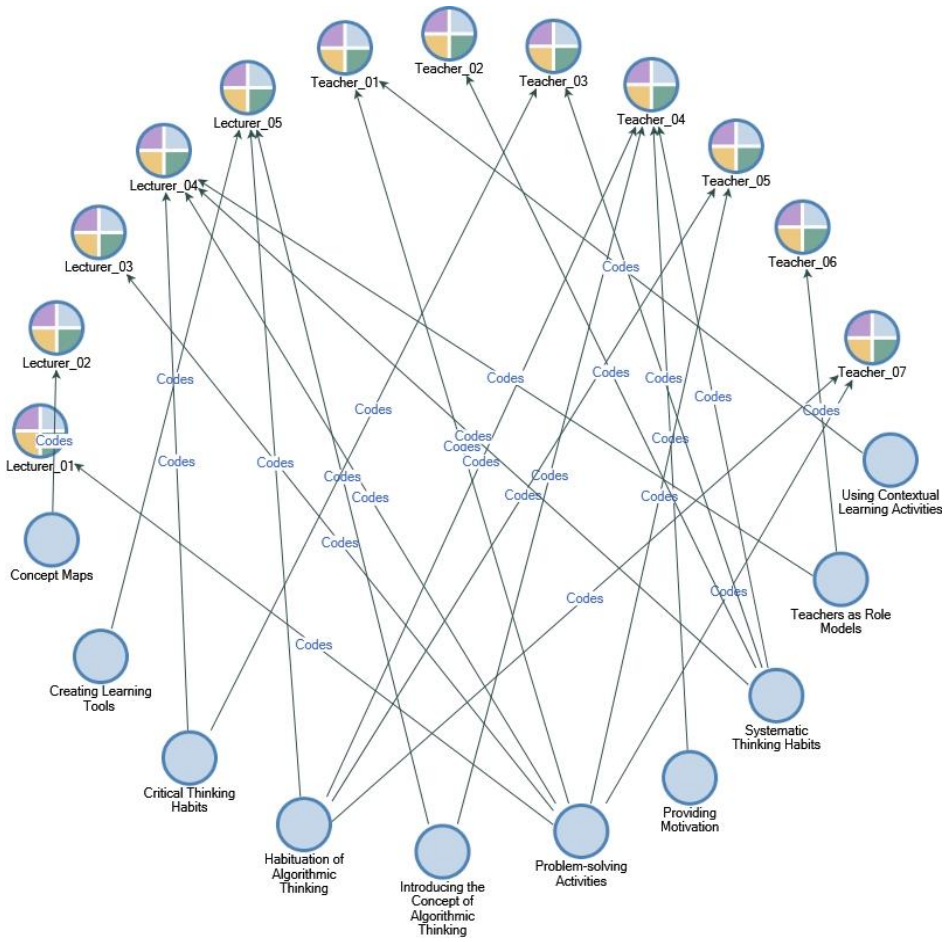


Figure 5.
Mapping of Participants and Sub-theme of Theme 4 (Attempts to Improve Algorithmic Thinking Abilities).
Source: The researcher's data analysis (Project Map of coding in NVIVO 12).

Thus, from several participant responses regarding efforts to improve algorithmic thinking abilities, several important points were obtained as follows:

- There is a need to optimize problem-solving and contextual learning activities in teaching and learning processes.
- The habit of using algorithmic thinking in problem-solving activities.
- There are activities in class that also support thinking systematically, logically, and critically.
- There are activities for making concept maps and flow diagrams in student learning activities.

5. Conclusions

Participants perceive that algorithmic thinking is related to systematic and rational/logical steps (another term is called an algorithm) to obtain a solution or solutions to a problem. Algorithmic thinking contributes to the process of completing tasks or solving problems, both in daily activities and in teaching and learning mathematics. They noted that by involving algorithmic thinking in mathematics learning activities, students are expected to develop a structured, systematic, and critical mindset. They suggested that optimizing problem-solving and contextual learning activities in teaching and learning, as well as activities for creating concept maps and flow diagrams, are some efforts that teachers can undertake to train students' algorithmic thinking abilities. The findings of other thinking abilities that support algorithmic thinking, explicitly reported by participants, include algorithm decomposition and compilation, but participants did not reveal other aspects or components of abilities related to algorithmic thinking. This could be an opportunity for future research.

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