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Learning obstacles of high school students in computational thinking on two-variable linear inequality system

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Abstract

Computational thinking skills are systematic ways of thinking that involve formulating a problem, deconstructing the problem, and communicating the solution. The development of students' computational thinking ability is significant; therefore, knowing the obstacles is essential. The purpose of this research is to find out students' learning obstacles in computational thinking. This qualitative research uses a phenomenological approach that describes the meaning of certain concepts related to life experiences for some individuals. The population in this study is one of the high school class XI in Bulukumba district. The subjects in this study were three students in the high, medium, and low categories. Data collection techniques in this study used the following instruments: 1) math test question instrument, 2) interview. The results of this study are (1) ontogenical obstacle in the form of students having difficulty in making models (abstraction stage) because they are wrong in capturing information and do not understand in making mathematical models, (2) epistemological obstacle in the form of students having difficulty in solving problems because the problems given have never been encountered, and (3) didactical obstacle in the form of not understanding the correct writing of permissiveness, this is due to the absence of emphasis on correct permissiveness during learning. This research is expected to help teachers overcome students' computational thinking obstacles.

Keywords: learning obstacles; computational thinking; two-variable linear inequality system

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I. Introduction

Learning mathematics can train students to think critically and develop problem-solving skills and abilities needed to face the 21st century. Through learning mathematics and mastering its skills, students are expected to achieve multiple achievements in solving problems optimally and play an active role in monitoring development and changes that occur. What can be done to train students to develop their problem-solving skills is through habituation of problem-solving and paying attention to how teachers teach concepts to students (Prabawanto, 2023). That helps students find solutions, train process acceleration, and solve problems. Computational thinking is one skill that supports and trains students' problem-solving skills.

Computational thinking (CT) is one of a person's thinking abilities that resembles how a computer thinks. In this era of technological development, students need to have the ability to think computationally because it will be used in solving the problems they face. Wing (2008) states that computational thinking can be interpreted as an approach to solving problems, designing systems, and understanding human behavior that refers to the basic concepts of computing. Furthermore, Mailund (2021) explains, "Computational thinking is what you do when you take a problem and formalize it when you distill it into something where you can objectively determine if something is a solution to it or not." CT capabilities require various cognitive aptitudes: elaboration and abstraction processes, algorithms, pattern recognition, iterative thinking, transformation, problem reduction, error prevention, defense, and intuitive reasoning (Subramaniam, Maat & Mahmud, 2022).

The thinking process in CT has four stages: decomposition, pattern recognition, abstraction and Generalization, and algorithms (Hasanah, Susilowati & Haryadi, 2022; Thalhah, Angriani, Nur & Kusumayanti, 2021; Pei, Weintrop & Wilensky, 2018; Qian & Choi, 2023; Whitney-Smith, 2023). Decomposition is the ability to break a more complex problem into simpler parts, in addition to knowing whether or not the information is sufficient to answer the problem. Pattern recognition is finding patterns or similarities between problems and within the problem, for example, knowing when shading approaches 0 and moves away from 0. Abstraction and Generalization is the process of turning problems into mathematical models and being able to generalize them. Then, the algorithm builds the steps to solve the given problem. The four indicators in computational thinking are critical to be developed in students, and they will be used to solve problems requiring higher-order thinking skills. However, in reality, students' computational thinking skills still need attention. This aligns with what Supiarmo & Susanti (2021) stated, that students' computational thinking skills are still in the low category. Therefore, it needs to be considered in learning how to develop it. The two-variable linear inequality system is one of the materials that can train students in computational thinking.

A two-variable linear inequality system is one of the materials taught at the high school level. This material is essential to pay attention to the level of success in learning because this material is the initial concept that students in linear program material will use. However, in the implementation of learning, students often need help solving problems related to the two-variable linear inequality system. Based on the results of research conducted by Muchsin, Hairun & Jalal (2019) stated that the errors that often occur in students when solving two-variable linear inequality systems are where students do not understand the concept of variables, coefficients, and determining the point of the solution area on the graph. In addition, Siagian, Suryadi, Nurlaelah, & Prabawanto, (2022) stated that students experience epistemological obstacles; namely, students need help to apply the concept of linear variable inequality to different problems. Therefore, paying attention to students' learning obstacles is essential to anticipate the obstacles in further learning. A learning obstacle is when students gain knowledge during the learning process that runs not smoothly or slowly, causing difficulty in understanding the material (Brousseau, 2002; Suryadi, 2019).

Various previous studies have examined computational thinking in mathematics. Many of them emphasize the exploration of computational thinking ability through ICT-based learning media and examine, in general, related to students' computational thinking ability (Çiftçi & Topçu, 2023; Misirli & Komis, 2023; Zhang & Gary, 2023). More specifically, previous studies have researched to examine computational thinking skills through story problems (Lestari & Roesdiana, 2023; Xu, Geng & Wang, 2022). Furthermore, some studies have focused on creating learning designs to develop computational thinking skills (Presser et al., 2023; Zhao, Liu, Wang & Su, 2022). However, no research examines students' learning obstacles in computational thinking. This becomes one of the foundations for studying students' learning obstacles. Learning obstacles referred to in this study are epistemological obstacles (limited student understanding), didactical obstacles (stages and sequence of material presentation), and ontogenic obstacles (student readiness and maturity). Based on the description of the problems that have been revealed, the researcher will reveal student learning obstacles from 3 aspects (epistemology, didactic, and ontogenic) in computational thinking on the material of a two-variable linear inequality system.

II. Research Method

This research is qualitative and uses a phenomenological approach to describe the meaning for some individuals related to their life experiences about certain concepts; in this study, the concept is a two-variable linear inequality system. This research will focus on assessing students' learning obstacles in computational thinking based on a two-variable linear inequality system. The subjects of this research are students of class XI of State Senior High School in Bulukumba.

Data collection in this research is done by collecting various sources that support this research through student work, interviews to explore students' experiences obtaining knowledge, and reviewing teaching materials up to the textbooks used. In addition to the researcher as the main instrument, this study used test and non-test instruments. The test instrument is the question of two variables' linear inequality, and the non-test instrument is the interview guide. To test the validity of the data, researchers used stages, namely credibility, transferability, dependability, and confirmability tests.

The data analysis technique in this study was carried out through several stages, starting from data reduction, namely filtering and sorting out important data obtained from test results, interviews, student work, and textbook reviews, which are relevant to the focus of the research. Namely, student learning barriers in computational thinking on the material of two-variable linear inequality systems. The reduced data were then presented as narratives and tables based on Computational Thinking (CT) indicators, namely Decomposition, Pattern Recognition, Abstraction and Generalization, and Algorithms, to map students' learning barriers based on high, medium, and low categories. After that, conclusions and verification were drawn through data triangulation from various sources to gain an in-depth understanding of the student learning experience.

The indicators used to analyze students' computational thinking skills are as follows:

Table 1. Indicators of computational thinking ability

CT Indicators	Sub-Indicators
Decomposition	Students can write the known components in the given problem
Patter Recognition	The ability to recognize patterns of problems allows students to apply problems in different contexts. For example, they can make x and y equations in different cases and determine the sign of inequality.
Abstraction and Generalization	Students can build models by looking at known components and writing conclusions.
Algorithm	Students write the steps related to the given problem.

Furthermore, to find out all types of student learning obstacles, researchers analyzed textbooks and SPtLDV questions. The questions used are as follows:

Ria has Rp100,000 that she will use to buy books at the school cooperative. Book A costs Rp5,000, and book B costs Rp4,000. The number of books Ria must buy is at most 20 books. If the number of books A to be bought is not more than 15 books, then determine:

a. Mathematical model
b. The solution area

III. Results and Discussion

Result

Student Work Review

The following presents the analysis of students' computational thinking barriers based on the level of students' work.

Table 2. Student learning barriers for each category

Category	Obstacles
High	Pattern recognition
Medium	Decomposition, Pattern Recognition, Abstraction and Generalization, and Algorithm
Low	Decomposition, Pattern Recognition, Abstraction and Generalization, and Algorithm

Based on Table 2, each category of students still experiences obstacles in computational thinking. The following presents the results of student work with the analysis that the researcher has done:

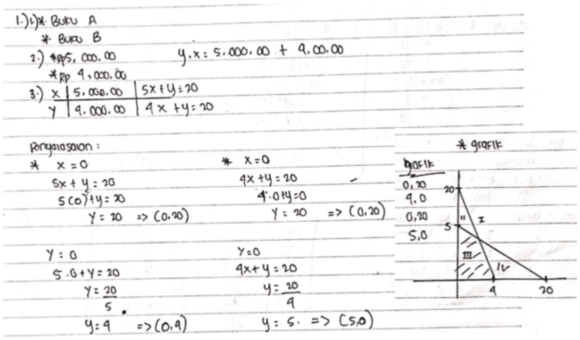

Figure 1. Work of low-category students (S1)

Based on Figure 1, student S1 did not write down the known components in the problem given (decomposition), did not write the permissiveness correctly (pattern recognition), and did not make a complete mathematical model (abstraction). More stages of work needed to be completed in the modeling section (Algorithm). Then, the obstacles that occurred through interviews were further explored.

Q : Do you understand what this question means? If yes, try to explain it in your own language.

S1 : Yes sir, got it. Ria has Rp100,000.00 which she will use to buy 2 types of books, book A costs Rp5,000.00 and book B costs Rp4,000.00. Then the number of books Ria has to buy is not more than 20 with the number of book A not more than 15.

Q : Is the information in question sufficient?

S1 : That's enough sir.

Q : Why don't you write down the known things?

S1 : It's a habit sir

Q : When in class, do you write down the known things in the example problems?

S1 : Yes, sir, write it down.

Q : Did you find this problem difficult?

S1 : Yes sir, because problems like this I rarely encounter in class exercises. Like the information about the number of books A should buy is not more than 15. I don't know what it is used for.

Q : Okay, on your answer sheet what does this mean?

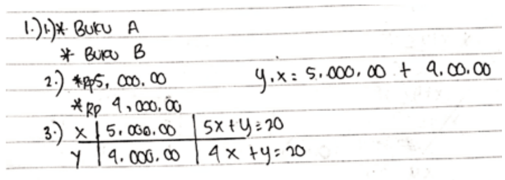

Figure 2. Student answer (S1)

S1 : It is actually Book A =x and Book B =y. because it is 50000, it is simplified to 5x and 4000 to 4x.

Q : What's your next step?

S1 : Determining the point that will be used to draw the graph, sir.

Q : Oh yeah, it is (5.0) or (0.5).

S1 : Hemm, it seems like a rush; it should be (0.5).

Q : So which settlement area is it?

S1 : Region 3 because it is the thickest area.

Based on the interview excerpt above, it can be seen that S1 students have understood the problem given but still experience many mistakes in the process. Students have understood what is known about the problem and state that these components are sufficient to answer the existing problems (decomposition). After further investigation, the student had difficulty working on the problem because the problem had never been encountered in the usual problems in class (epistemic barriers). In addition, in abstraction and Generalization, students still experience obstacles in making mathematical models; as seen in Figure 1, student S1 still experiences errors in making models because they are wrong in capturing information and do not understand how to make mathematical models (ontogenic obstacles). So, students in the low category still have not achieved the indicators of computational thinking ability.

Furthermore, the results of their work can be seen in the picture below for students in the medium category.

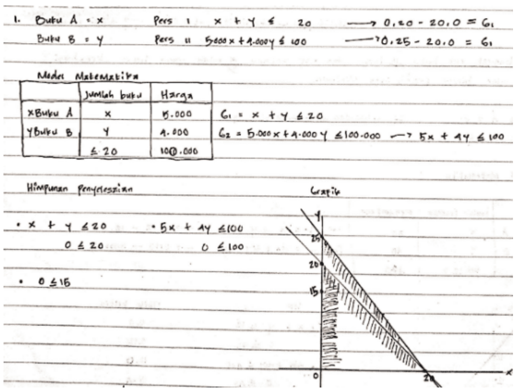
Figure 3. Work of medium category students (S2)

Based on Figure 3., it can be seen that S2 students did not write down the known components in the given problem (decomposition), did not write the permissiveness correctly (pattern recognition), did not make a complete mathematical model (abstraction), and there were unclear working steps (Algorithm). Then, the obstacles that occurred through interviews were further explored.

Q : Do you understand problem number 1? Try to explain to me what you understand about the problem given.
S2 : Yes, sir, I understand. In question number 1, Ria has money of Rp100,000.00 to buy 2 types of books, namely book A for Rp5,000.00 and book B for Rp4,000.00. The number of books Ria buys is not more than 20, and many books A are not more than 15.
Q : Okay good, why in question number 1 did you not write the known?
S2 : I understand the problem, sir, so I'll go straight to the next step.
Q : What does it mean that book A = x and book B = y?
S2 : The type of book sir
Q : Is it possible that many books A and B bought by Ria are negative?
S2 : No, sir.
Q : So, what is there to add?
S2 : Hemm (silence)
Q : Why is the sign with ≤?
S2 : Because in the question, there is the word no more than.
Q : Ehh what does this mean 0.20-0.20 and so on?
S2 : For the line drawing sir
Q : What's the name?
S2 : Point of intersection sir
Q : The writing is like this?
S2 : I don't think so, sir.
Q : So what?
S2 : Don't know sir.
Q : Are you sure the drawing is just 2 lines?
S2 : Yes Sir
Q : What are these 15 questions?
S2 : Now that sir, I don't know what to do, because the questions that are usually done are not like this.
Q : Why not make a conclusion?
S2 : In a hurry sir.

Based on the interview excerpt above, S2 understands the meaning of the problem because he can explain the meaning of the problem using his language, but there are still errors in his work. After the interview, it turned out that the student knew the known things in the problem, but S2 was used to working on problems rather than writing down the known things. In addition, related to the error of permissiveness, S2 does not know the actual permissiveness (pattern recognition); this is due to the absence of specific explanations related to the permissiveness used (didactic obstacles). Regarding the incomplete model error, S2

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understands that the number of books cannot be harmful but cannot turn it into an inequality. Furthermore, students have difficulty making a complete model because students have never encountered a problem like this (epistemic and ontogenic barriers). In addition, students also need help writing coordinate points correctly (ontogenic barriers) because the previous material was taught online, so the concept is not understood. Based on the explanation above, it is found that students with moderate mathematics ability are sufficient to think computationally, but there are still shortcomings at each stage.

Furthermore, the results of their work can be seen in the picture below for students in the medium category.

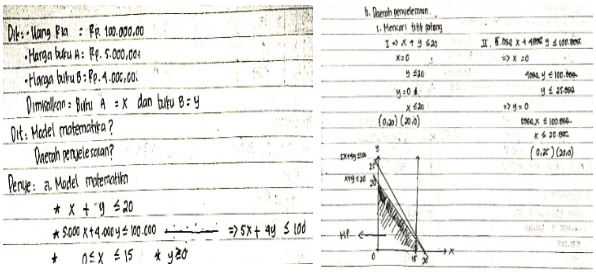


Figure 4. Work of medium category students (S3)

Figure 4. shows that S3 can work on problem number 1 nicely. However, there are still areas for improvement in the pattern recognition process, namely errors in generalizing and the generalization process in the form of needing to write the conclusion in the answer. Then, it was further traced to discover the obstacles through interviews.

Q : Do you understand what this question means? If yes, try to explain it in your own language.
S3 : Yes sir, I understand. In this problem Ria has Rp100,000.00 which she will use to buy 2 types of books, namely book A at Rp5,000.00 and book B at Rp4,000.00. Then the number of books Ria has to buy is no more than 20 with the number of books A no more than 15.
Q : Okay good, next what does it mean that x = open A and y = book B?
S3 : That book sir...
Q : Yes Book, what does that mean?
S3 : Hemm …
Q : When you were learning in class, did you explain the complete model?
S3 : Directly the object under discussion sir
Q : Okay, then in the model you made why use the sign ≤, are there any signs from the problem?
S3 : Yes sir, there is. Because in the question there is the word no more than
Q : Why do you have $x \geq 0$, $y \geq 0$ in your model?
S3 : Since the number of books A and B cannot be negative sir, it needs to be limited.
Q : Why is that the way to determine the intersection point? Why not make the = inequality sign first?
S3 : That's what you were taught, sir.
Q : Why aren't all the lines shaded? Or is it just a piece that is shaded?
S3 : No sir, actually all the lines are shaded, but I only shaded the completion area sir, so that there are not too many scribbles and that's what I usually do when doing assignments sir and you are right.
Q : Okay lastly, why don't you write down the conclusion?
S3 : Hemm yes sir, forgot...

Based on the interview excerpt above, it can be seen that S3 understands the meaning of the problem given because it can explain the meaning of the problem using its language, but there are still a few things that could be improved in the process. After the interview, it turned out that S3 students did not know the actual permissiveness (pattern recognition) because there was no particular explanation for the permissiveness used (didactic obstacles). The mistake of not writing the conclusion was due to the haste in answering. Based on the explanation above, it is found that students with high mathematics ability have been able to apply the stages of computational thinking even though there are still a few problems at the pattern recognition stage.

Overview of Student Teaching Materials

After reviewing the learning design made by the teacher, it can be seen that the stages of learning are sound, but there are still gaps that cause students to experience obstacles in their learning. The stages not included in the learning are that the teacher needs to remind the material of equations and inequalities, even though it is the basis for solving the inequality system. In addition, some of the obstacles that occur are also caused by the learning resources students use. The textbook students use is the mathematics book / Ministry of Education and Culture, Revised edition Jakarta: Ministry of Education and Culture, 2017. In the book, several things trigger students to make mistakes and not export the types that have different levels of problems. One of the author's suspicions about the emergence of student obstacles in learning is the use of questions that are not varied.

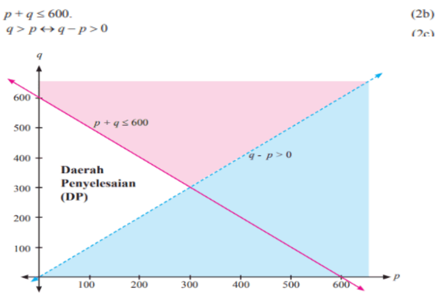
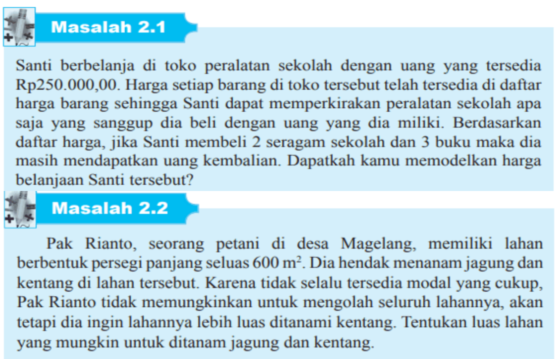


Figure 5. Sample problem

The problem above is a complete two-variable inequality (does not contain a form that x = 0 or y = 0), so when students face a different type of problem, they often need help with the model.



Masalah 2.1

Santi berbelanja di toko peralatan sekolah dengan uang yang tersedia Rp250.000,00. Harga setiap barang di toko tersebut telah tersedia di daftar harga barang sehingga Santi dapat memperkirakan peralatan sekolah apa saja yang sanggup dia beli dengan uang yang dia miliki. Berdasarkan daftar harga, jika Santi membeli 2 seragam sekolah dan 3 buku maka dia masih mendapatkan uang kembalian. Dapatkah kamu memodelkan harga belanjaan Santi tersebut?

Masalah 2.2

Pak Rianto, seorang petani di desa Magelang, memiliki lahan berbentuk persegi panjang seluas 600 m^2. Dia hendak menanam jagung dan kentang di lahan tersebut. Karena tidak selalu tersedia modal yang cukup, Pak Rianto tidak memungkinkan untuk mengolah seluruh lahannya, akan tetapi dia ingin lahannya lebih luas ditanami kentang. Tentukan luas lahan yang mungkin untuk ditanam jagung dan kentang.

Figure 6. Exercise problem solving

The figure above shows that the image of the inequality system is restricted to the positive x and positive y axes. However, the model does not introduce p ≥ 0 and q ≥ 0. So, when students are asked about it, they do not understand its meaning.

Discussion

Based on the research results that have been presented in the previous section. Students' computational thinking skills still need to be considered in their development. Students' computational thinking ability will be an assessment point in the upcoming PISA. This study found that students with low ability still need to understand each stage of computational thinking well. This aligns with research conducted by Lestari & Roesdiana (2023) and Tran (2019), which state that students with low categories are dominant in needing help to achieve the stages of computational thinking well. This is because the problems given in class during learning could be more diverse (epistemic and didactic barriers), or in other words, students with low abilities are less likely to work on different problems. This aligns with research by Islami, Rahmawati & Kusuma (2019), which states that students need more practice problems to work on mathematical problems. Another cause is that students with low abilities must understand how to make models (ontogenic obstacles).

Students in the medium category are quite capable of achieving the stages of computational thinking skills, but there are still some obstacles. This aligns with research conducted by Kamil (2021), which found that students with mathematical abilities in the moderate category are pretty capable of computational thinking. However, there are still shortcomings in its areas for improvement. The obstacles in computational thinking that occur in students in the medium category are difficulties in making permissiveness correctly because students need to learn how to make the correct permissiveness of each problem (ontogenic obstacles). The other cause is that there needs to be more emphasis on correct permissiveness (didactic obstacles) in class. Like students in the low category, students in the medium category also experienced difficulties because the problems given in class during learning were not diverse (epistemic and didactic barriers). In other words, students with low abilities did not work on different problems. In addition, moderate students experience obstacles in needing help understanding the prerequisite material needed in this material because the learning in that material is done online. This is in line with research conducted by Yusuf, Titat & Yuliawati (2017), which states that one of the causes of student learning obstacles is a lack of understanding of prerequisite material.

Furthermore, students in the high category have achieved the stages of computational thinking skills. This is in line with the research conducted by Budiarti, Wibowo & Nugraheni (2022) and Richardo et al. (2025), who stated that the mathematical ability of students in the high group was well able to apply the stages of computational thinking ability. Although there are still obstacles in solving the problem in the form of difficulty in making permissiveness correctly due to students not knowing how to make the correct permissiveness of each problem (ontogenic obstacles), in general, students in the high category have been able to achieve the stages of computational thinking.

The obstacles that occur to students are caused by the students and the learning resources or textbooks used in the classroom. The textbooks used examples of problems that could be more varied or varied. So that when students are found with different problems, they have difficulty. This is in line with research conducted by Baweleng, Tilaar & Sumarauw (2023), Cai & Rott (2024), and Radiamoda (2024), who stated that students have difficulty doing math problems if the problems given are different from the practice problems. In addition, the textbook used also needs to present the complete method of solving the problem in the example given.

IV. Conclusion

Based on the research findings and discussion that have been described, it is concluded that, in general, there are learning obstacles in students' computational thinking on the material of two-variable linear inequality systems, including ontogenical, epistemological, and didactical obstacles. The obstacles that occur in each obstacle are as follows:

1. Ontogenical obstacles identified in the two-variable linear inequality system material are students having difficulty making models (abstraction stage) because they are wrong in capturing information and do not understand how to make mathematical models. Students also still need to understand the prerequisite material related to writing coordinate points.
2. Epistemological obstacles identified in the two-variable linear inequality system material are students' difficulties in solving problems with different contexts due to limited context in solving problems (in the pattern recognition, abstraction, and generalization section) in the form of students having difficulty solving problems because the problems given have never been encountered.
3. Didactical obstacles identified in computational thinking on the material of two-variable linear inequality systems are pattern recognition, namely, still needing to understand the correct writing of permissiveness due to the absence of emphasis on correct permissiveness during learning. In addition, the cause of student errors is the need for students to be directed to export different problems so that students have difficulty when faced with different problems in class.

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