An Analysis of Junior High School Students' Computational Thinking in Solving Bebras Task Problems: A Preliminary Study

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Abstract. Massive digitalization in education, particularly in mathematics, has made Computational Thinking (CT) as a critical skill for students to navigate and solve complex problems in a technology-driven world. Computational Thinking (CT), which enhances problem-solving abilities and fosters logical reasoning, algorithmic thinking, and creativity—essential skills for success in the digital age—was the focus of this study, aiming to investigate the CT concepts of junior high school students in Manggarai Regency, East Nusa Tenggara Province. Using a descriptive research approach, the study included two schools equipped with computer facilities. Eleven students were selected based on their math learning achievement using purposive sampling. Data collection involved testing students' CT concepts through Bebras task questions. The students' responses were qualitatively analyzed to examine their problem-solving approaches and specific indicators of computational thinking skills. This analysis provided an assessment of the students' CT abilities through their problem-solving strategies and thought processes. The findings indicated that the CT concepts of junior high school students require further development, highlighting the need to integrate CT practices into the mathematics curriculum.

Keywords: Bebras Task; Computational Thinking; Mathematics Education.

1 Introduction

The OECD in the PISA 2022 Framework explains the importance of math skills and mathematical thinking [1]. The mathematical thinking in question is not basic computational procedures, but reasoning (both deductive and inductive). The important role of reasoning needs greater emphasis in the education process when assessing mathematical literacy. Framework issued by PISA for Mathematical literacy, which initially engrossed on basic numeracy competency, was restated by the OECD considering rapid technological advancements. The PISA 2022 Framework highlights Computational Thinking (CT) as a crucial skill for students. It is believed that, in addition to problem-solving, mathematical literacy in the 21st century should encompass mathematical reasoning and aspects of CT. CT is a form of analytical

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thinking, which takes a method to answering problems, designing schemes, and understanding human activities that incorporates on basic computational ideas. The PISA 2022 Study Framework emphasizes the important role of technology in students' lives, so now mathematical literacy is not only limited to aspects of mathematical thinking but must be able to pay attention to synergy and reciprocal relationships with CT [1].

Computational Thinking (CT) is a thought process that involves formulating problems and finding solutions that can be represented in a form that can be effectively processed by information processing agents. [2]. CT involves taking a complex problem and breaking it down into a series of smaller, more manageable problems (decomposition). Each of these smaller problems can then be looked at individually, taking into account how similar problems have been solved before (pattern-recognition) and focusing only on the important details, ignoring irrelevant information (abstraction). Next, simple steps or rules to solve each smaller problem can be devised (algorithm). These are often referred to as the 4 *cornerstones* of Computational Thinking.

The PISA 2022 Framework has shown the importance of CT skills as part of mathematical literacy applied in solving mathematical problems along with the increasing role of computers in everyday life and in helping solve mathematical problems. CT, which is needed as a provision in facing the development of the 21st century, is important to grow early in students. [3], [4], [5], [6], [7]. The combination of mathematical thinking and CT skills is not only able to support the development of students' conceptual understanding of mathematics but is able to provide students with a view of how mathematics is applied in the real world so that it is expected to prepare students to choose careers in fields that emphasize CT skills. CT is currently one of the focuses tested in the PISA mathematical literacy test.

ICT integration in mathematics learning has a positive impact on students' CT [7], [8], [9]. Lewis Presser et al. (2023) stated that an intervention consisting of digital investigations and applications, facilitated preschool teachers and children in responding data-focused questions by taking part in each step of the DCA process to develop CT and also math skills and it was found that Children in classes that took part the intervention showed significantly higher scores at post-intervention compared to children in classes that did not take part the intervention. Then, Rodríguez-Martínez et al. (2020) present the outcomes of a quasi-experimental research study with sixth-grade students studying the contribution of using Scratch for the acquiring mathematical concepts, and on the advancement of computational thinking and with evidence indicating that Scratch can support the development of students' mathematical ideas and computational thinking. In line with that, the research conducted by Sezer (2022) aims to investigate how tools and concepts of computational thinking (CT) are useful to understand the Covid-19 outbreak better, and how the disease context can be used as a real-world setting to promote primary and secondary education. Employing a qualitative research approach, particularly content analysis, it was discovered that the instruction of mathematical modeling and computer programming is improved by detailing in specific contexts. This serves as a stepping stone to encourage students to tackle real-world issues and enhances their ability to use their knowledge and skills in making the right choices in future crises. Additionally, it explores the opportunities to motivate students by highlighting the value and relevance of CT and mathematics. Several studies have been conducted that serve as benchmarks for how CT contributes to students' academic achievement.

According to PISA 2018, Indonesia's average math literacy score was 379, 52 points below the average for students in Southeast Asia. By proportion, 24% of students met or exceeded the minimum competency level. Over 70% of Indonesian students are under the minimum proficiency level in math and reading. A significant number of Indonesian students still struggle

to understand basic reading or utilize fundamental math concepts. Over the past decades or so, Indonesian students' PISA scores in reading and math have shown minimal improvement. This highlights a significant global disparity in the quality of learning between different regions and socio-economic groups. The results indicates that Indonesia needs to enhance students' mathematical literacy skills to meet the minimum PISA competency level. Another important consideration is the inclusion of Computational Thinking (CT) skills in the PISA mathematical literacy assessment. This competency needs to be enhanced starting from the basic education level to higher education.

In relation to CT, low Information and Computer Technology (ICT) skills are found in several regions, including in East Nusa Tenggara Province. Data from Badan Pusat Statistik (Badan Pusat Statistik, 2023) related to the proportion of adolescents and adults aged 15-59 years with information and computer technology (ICT) skills by province in 2020-2022 shows that the province of East Nusa Tenggara (NTT) occupies a low ICT usage subindex category for two consecutive years (2020 and 2021), and occupies a medium ICT skills subindex category in 2021. In addition, during 2020-2021, the province of East Nusa Tenggara (NTT) together with Papua occupied the low ICT Development Index category. This fact must be a challenge for the government and all Indonesian people.

Along with the increasing demand for mastery of Computational Thinking in students as part of 21st-century skills by utilizing ICT, researchers want to design a learning model to improve students' CT in NTT. This is urgent to do, despite the infrastructural limitations, so that students are equipped with CT skills that are claimed to be important for students' careers and futures. But before this is done, researchers need to know the initial condition of students' CT. For this reason, it is necessary to conduct research to measure students' CT concepts before this learning model is designed. The goal is that researchers have initial data on the initial ability of students' concept of CT so that it can be used as a basis for designing learning models with CT practice to optimize students' CT.

Thus, the purpose of this study is to investigate the initial condition of junior high school students' Computational Thinking (CT) concepts in Manggarai Regency, East Nusa Tenggara Province, as a foundation for designing a learning model aimed at enhancing CT skills. This research contributes to addressing the gap in CT competency among students in regions with limited ICT infrastructure, while also aligning with the global emphasis on integrating CT into mathematics education as highlighted in the PISA 2022 Framework. By understanding students' current CT abilities, this study aims to provide actionable insights for developing targeted interventions that can improve mathematical literacy and CT skills, ultimately preparing students for the demands of the 21st century. This goal is achieved by answering the following question: What are the current levels of Computational Thinking concepts among junior high school students in Manggarai Regency, and how can these findings inform the design of an effective CT-integrated learning model?

2 Method and Materials

This research was conducted using descriptive research since descriptive research provides knowledge about the status quo, which is often the first step in improving educational practice and also identifies characteristics of a group at one time or changes in these characteristics over time, but it does not look at cause-and-effect relationships associated with these characteristics [10]. The choice of descriptive research is also based on the consideration that the results of the

research findings can reveal the prevalence of problems, opinions, computational thinking concepts' achievement, and other computational thinking phenomena related to the entire specified population as a first step to determine and design what is the solution to improve computational thinking in school.

In this study, researchers involved 3 schools in Kabupaten Manggarai that have computer facilities. The selection of research subjects was carried out with the criteria of involving students with good academic ability to see how good the initial condition of CT students in that school was, and to what extent CT ability could be further developed. Fifteen students were selected to work on problems adapted from the Bebras Task Contest to see the concept of CT. Bebras is an extra-curricular activity that educates problem-solving skills in informatics. Bebras organizes competitions known as Bebras tasks. Bebras tasks are presented in the form of problem descriptions equipped with attractive images so that students can more easily understand the problems. The problems can be answered without the need to learn informatics first, but the problems presented are related to certain concepts in informatics and computational thinking.

The steps in this research are choosing the problem to be studied, conducting a literature study, formulating the problem, determining the focus of the research, choosing the research method, collecting data (selection of questions on the Bebras contest), interviewing teachers, analyzing data in the form of student answers and teacher responses, and formulating research results.

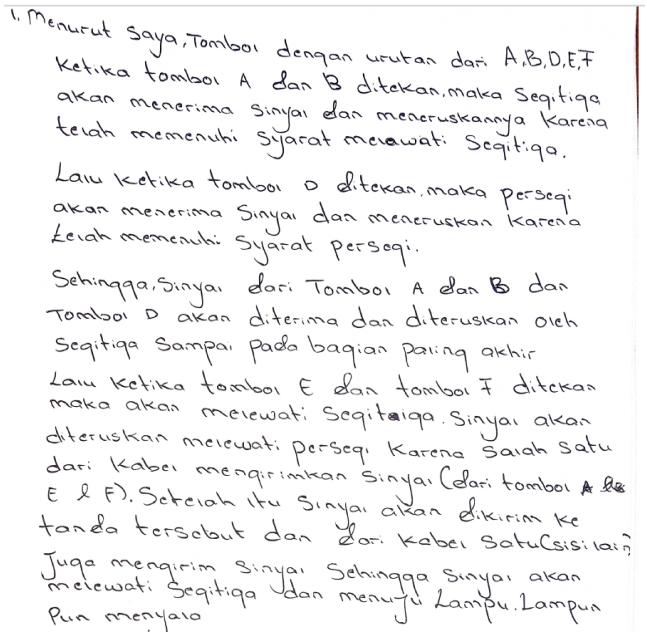
In this research, Bebras Task questions were tested on 2-5 students in 2 school to see the readability of Bebras questions. At this stage, students were not only required to write the answers but also to explain their reasoning by detailing the steps they took to solve the problem. This allows researchers to understand the students' thought processes during problem-solving. Students are given the opportunity to solve 5 problems within 60 - 90 minutes. Students are given the opportunity to really think about solving the questions.

3 Results and Discussion

3.1 Results

The students selected to work on the problems were students with high abilities. From the students' answers, it can be seen that students already have CT Concepts and understand the problems given. Students are able to provide reasons and lines of thought in the selection of answers.

In question number 1, students are given the context of playing a game entitled "The Lights Are On". The game has 8 buttons to press. When a button is pressed it will send a signal through the cable. The cable will pass through the triangle or square which will turn on the light. A triangle will send a signal if both wires entering the mark send a signal. A square will send a signal if only one of the wires entering the square is sending a signal. Students are given the challenge of choosing which button to press to turn on the light.


1. Menurut Saya, Tombol dengan urutan dari A,B,D,E,F
Ketika tombol A dan B ditekan, maka Segitiga
akan menerima sinyal dan meneruskannya karena
telah memenuhi Syarat melewati Segitiga.

Lalu ketika tombol D ditekan, maka persegi
akan menerima Sinyal dan meneruskan karena
telah memenuhi Syarat persegi.

Sehingga, Sinyal dari Tombol A dan B dan
Tombol D akan diterima dan diteruskan oleh
Segitiga Sampai pada bagian paling akhir
Lalu ketika tombol E dan tombol F ditekan
maka akan melewati Segitaiga. Sinyal akan
diteruskan melewati persegi karena salah satu
dari kabel mengirimkan sinyal (dari tombol A &
E & F). Setelah itu Sinyal akan dikirim ke
tanda tersebut dan dari kabel satuCsisi lain?
Juga mengirim Sinyal Sehingga Sinyal akan
melewati Segitiga dan menuju Lampu. Lampun
Pun menyala

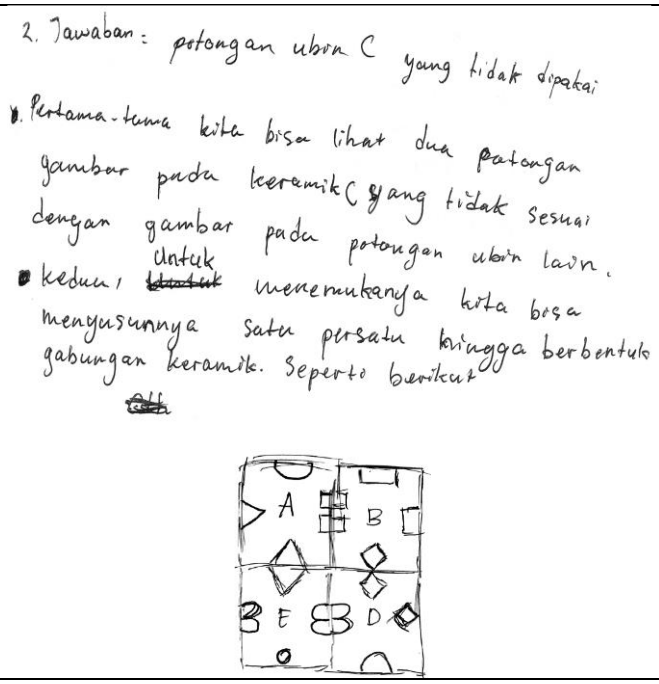
Translation:
In my opinion, the buttons with the order of A, B, D, E, F will be received.
When buttons A and B are pressed, then the Triangle will receive the signal and forward it because it has met the requirements through the Triangle.
Then when button D is pressed, then the Square will receive the signal and forward it because it has met the requirements of the square.
Thus, the signals from buttons A and B and button D will be received and forwarded by the Triangle until the very end.

Then when buttons E and F are pressed, then it will pass through the Triangle. The signal will be forwarded through the Square because one of the cables sends the signal (from button A/ E & F). After that, the signal will be sent to that sign and from one of the cables (other side?).
Also sending a signal so that the signal will go through the Triangle and go to the lights. The lights also turn on

Fig. 1. Student's Answer.

The text in the image, written in Indonesian, outlines a sequence of actions involving buttons labeled A, B, D, E, and F. Initially, when buttons A and B are pressed, the triangle receives a signal and passes it on because it meets the triangle's requirements. When button D is pressed, the square receives a signal and also passes it on as it meets the square's requirements. The signal flow from buttons A and B, along with button D, is received and passed on by the triangle to part of the square. When buttons E and F are pressed, the square receives a signal since both conditions for the square are met. Consequently, signals from buttons A, B, D, E, and F are sent to the solution cable. This sequence of signals also causes the triangle to receive a signal, which lights up the lamp. The explanation appears to describe a logic circuit or process involving signal flow between different components (triangle and square) based on button presses.

In problem number 2, students are asked to arrange four tile pieces into a 2×2 square based on the rule: the side of the tile piece that touches another tile must have the same symbol. Then five pieces of tile are given and students are asked to arrange the pieces of tile into a 2×2 square that meets the rules mentioned. Students are given the challenge to determine which pieces are not used.

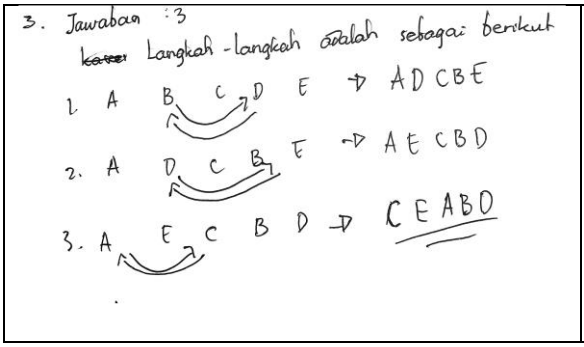


Translation:
2. Answer: tile section C which is not used.
First of all, we can see two pieces of the image on the ceramic (which does not match the image on other tile pieces). Secondly, to find it, we can arrange them one by one so that they form a combination of ceramics. Like the following.

Fig. 2. Student's Answer.

The student's response shows a clear and logical approach to solving the tile arrangement problem. The student first identified the tile piece that did not fit the rule, which was tile C. They noticed that tile C did not have matching symbols with the other tile pieces. After eliminating tile C, the student proceeded to try arranging the remaining tile pieces to form a 2×2 square according to the given rule. By attempting different combinations, they successfully found the correct arrangement. The student then verified their solution by ensuring that the sides of the tiles touching each other had matching symbols. Through this systematic process of elimination and verification, the student confidently determined that tile C was the piece not used in the final arrangement. This approach demonstrates the student's ability to apply logical reasoning and problem-solving skills effectively.

In question number 3, students are asked to solve a sorting problem. It is illustrated that Toko Bebras has ordered 5 tiger dolls to celebrate Chinese New Year (Chinese New Year). The dolls are stored randomly on a long shelf. Then, the dolls are rearranged with the rules that they must be arranged from shortest to tallest and can only swap 2 dolls at the same time. Students are asked to determine how many times to swap 2 dolls to make the dolls arrange themselves in the requested order.

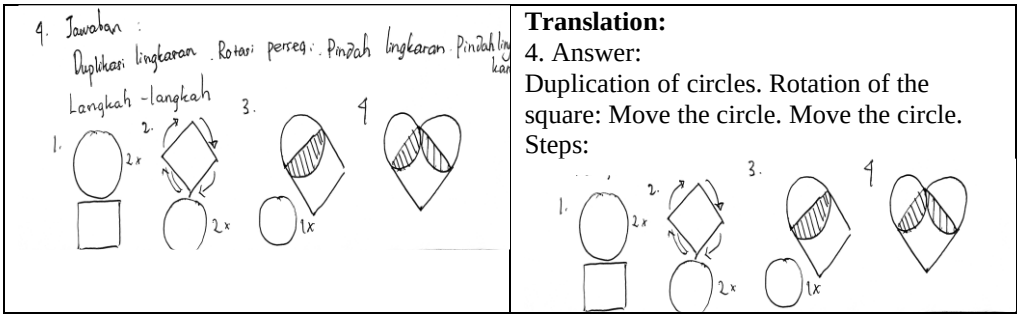


Translation:
Answer: 3
The steps are as follows:
1. A B C D E -> ADCBE
2. A D C B E -> AECBD
3. A E C B D -> CEABO

Fig. 3. Student's Answer

The student's solution demonstrates a logical approach to the problem of rearranging the five tiger dolls at Toko Bebras. Initially, the student observed the random arrangement of the dolls on the shelf, which is crucial for identifying the necessary swaps to achieve the required order. They recognized that the dolls needed to be swapped in pairs to arrange them from shortest to tallest. Analyzing the current positions, the student identified and planned the necessary swaps. They executed the swaps step-by-step: first, swapping two dolls to bring the arrangement closer to the desired order, then performing another swap to further arrange the dolls, and finally completing the last swap to ensure all dolls were in the correct order. After performing these swaps, the student verified the final arrangement to ensure it met the criteria of being from shortest to tallest. Through this methodical approach, the student determined that a total of three swaps were needed to achieve the correct order. This systematic solution highlights their ability to apply logical reasoning and problem-solving skills effectively

In question number 4, a circle and a rectangle are given to draw a heart. The operations that can be used for a shape are: 1) rotation: rotate the shape any amount in another direction; 2) move: move the shape to another location; 3) duplication: creating a copy of the same shape at the same location. Students are asked to determine the order of commands used.



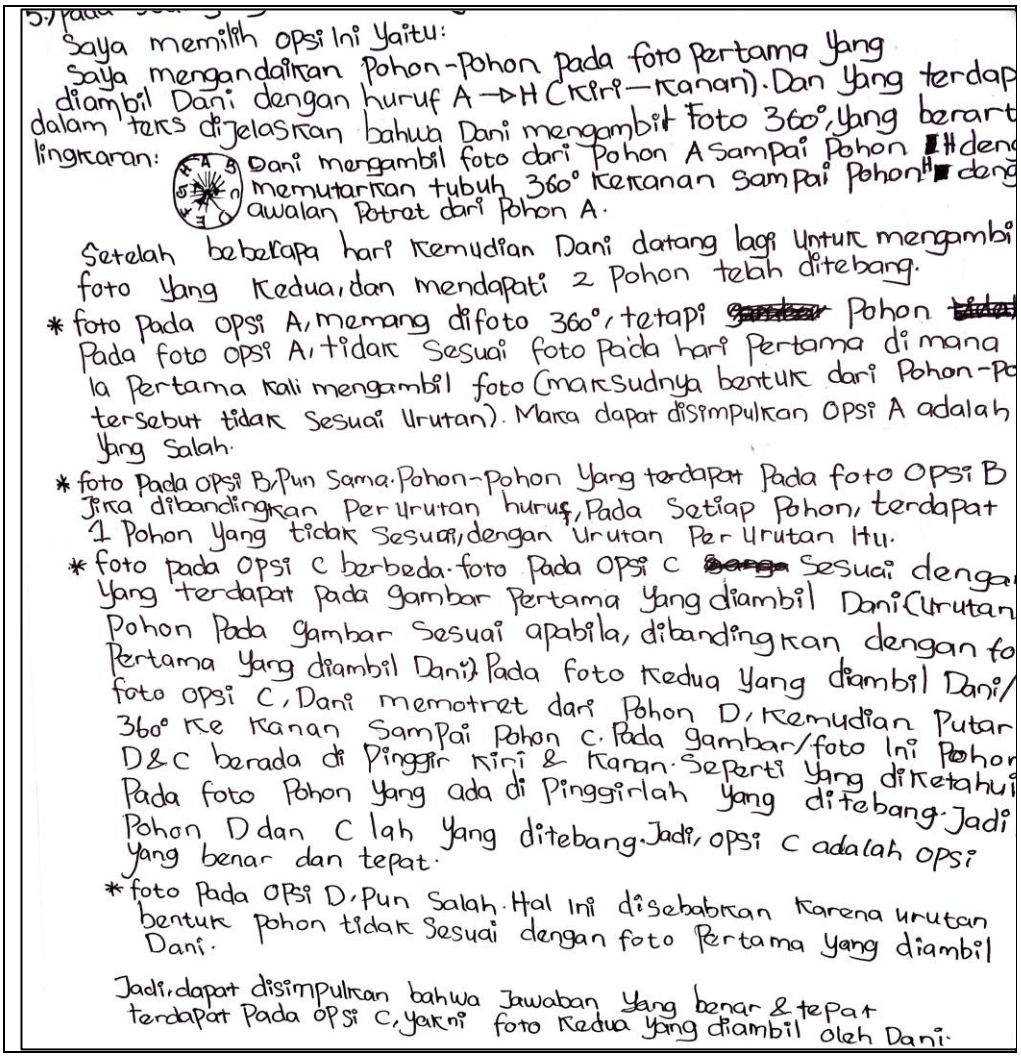
Translation:
4. Answer:
Duplication of circles. Rotation of the square: Move the circle. Move the circle.
Steps:

Fig. 4. Student's Answer

The student's answer to question number 4 demonstrates a systematic approach to drawing a heart using a circle and a rectangle. They began by duplicating the circle, resulting in two circles. Next, they rotated the rectangle to a different orientation, preparing it for alignment with the circles. The student then moved one of the circles to a new location where it would contribute

to forming the heart shape. Finally, they moved the second circle to overlap with the first circle and the rotated rectangle, thus forming the heart shape. Through these steps, the student illustrated their understanding of how to manipulate shapes using the given operations of rotation, movement, and duplication. Their methodical process of transforming the initial shapes into a heart shape demonstrates their ability to apply logical reasoning and spatial understanding effectively. The illustrations provided in the image help visualize the transition from the initial shapes to the final heart shape, showcasing each step clearly.

In problem number 5, students are faced with a problem where someone stands in the middle of a circle consisting of 8 trees and takes a 360^0 photo. After a few days, when he returned to the place, he again took photos and observed that 2 trees had been cut down. Students are asked to determine the second photo taken.


5.) pada
Saya memilih opsi ini yaitu:
Saya mengandaikan pohon-pohon pada foto pertama yang diambil Dani dengan huruf A → H (kiri—kanan). Dan yang terdap dalam teks dijelaskan bahwa Dani mengambil foto 360°, yang berart lingkaran:

Dani mengambil foto dari pohon A sampai pohon [redacted] deng memutarkan tubuh 360° kekanan sampai pohon [redacted] deng awalan potret dari pohon A.

Setelah beberapa hari kemudian Dani datang lagi untuk mengambi foto yang kedua, dan mendapati 2 pohon telah ditebang.

* foto pada opsi A, memang difoto 360°, tetapi [redacted] pohon [redacted] Pada foto opsi A, tidak sesuai foto pada hari pertama di mana la pertama kali mengambil foto (maksudnya bentuk dari pohon-po tersebut tidak sesuai urutan). Maka dapat disimpulkan opsi A adalah yang salah.
* foto pada opsi B, pun sama. pohon-pohon yang terdapat pada foto opsi B jika dibandingkan per urutan huruf, pada setiap pohon, terdapat 1 pohon yang tidak sesuai, dengan urutan per urutan itu.
* foto pada opsi C berbeda. foto pada opsi C [redacted] sesuai dengan yang terdapat pada gambar pertama yang diambil Dani (urutan pohon pada gambar sesuai apabila, dibandingkan dengan fo pertama yang diambil Dani). pada foto kedua yang diambil Dani/ foto opsi C, Dani memotret dari pohon D, kemudian putar 360° ke kanan sampai pohon C. pada gambar/foto ini pohon D & C berada di pinggir kiri & kanan. seperti yang diketahui pada foto pohon yang ada di pinggirlah yang ditebang. jadi pohon D dan C lah yang ditebang. Jadi, opsi C adalah opsi yang benar dan tepat.
* foto pada opsi D, pun salah. hal ini disebabkan karena urutan bentuk pohon tidak sesuai dengan foto pertama yang diambil Dani.

Jadi, dapat disimpulkan bahwa jawaban yang benar & tepat terdapat pada opsi C, yakni foto kedua yang diambil oleh Dani.

Translation:
I choose this option, which is:
I assume the trees in the first photo were taken by Dani with the letters A to H (left to right). And as explained in the text, Dani took a 360° photo, meaning in a circle:
[Illustration of someone taking a photo around trees]
Dani took a photo from tree A to tree H, rotating his body 360° to the right until tree A, with the initial portrait of tree A.

After a few days, Dani came again to take a second photo and found that 2 trees had been cut down.

*Photo in option A, it was indeed taken at 360°, but the tree drawing is not right. In photo option A, it does not match the photo from the first day when he first took the photo (meaning the shape of the trees is not in the correct order). So, it can be concluded that option A is wrong.

*Photo in option B is also the same. The trees in photo option B, if compared by letter order, in each tree, there is 1 tree that does not match, with the order per order.

*The photo in option C is different - photo in option C is very similar to what is in the first picture taken by Dani (the tree order in the picture is correct if compared to the first photo taken by Dani). In the second photo taken by Dani/photo option C, Dani photographed from tree D, then rotated 360° to the right until tree C. In this picture/photo, trees D & C are on the left & right edges. As is known, in the photo, the trees on the edges are the ones that were cut down. So, trees D and C are the ones that were cut down. So, option C is the correct and precise option.

*Photo in option D is also wrong. This is because the order of the tree shapes does not match the first photo taken by Dani.

Therefore, it can be concluded that the correct and precise answer is in option C, which is the second photo taken by Dani."

Fig. 5. Student's Answer

The student's response to question number 5 involves a problem where someone, Dani, stands in the middle of a circle of 8 trees and takes a 360-degree photo. After a few days, Dani returns to the same spot and takes another photo, noticing that 2 trees have been cut down. The student's task is to determine which photo Dani took the second time. The student first considered each tree's position by labeling them from A to H. They explained that in the initial 360-degree photo, Dani captured all trees from A to H. When Dani returned to take a second photo, they observed that two trees had been cut down. The student then analyzed the given options for the second photo. They determined that option A was incorrect because the arrangement of the trees did not match the original photo's order. Similarly, option B was dismissed due to inconsistencies in the tree order. In contrast, option C matched the original photo's arrangement. The student noted that in the second photo, Dani captured the trees from D to C, with trees D and C being on the outer edges, indicating that these were the trees cut down. Finally, the student confirmed that option D was also incorrect due to discrepancies in the tree order. Therefore, the student

concluded that the correct second photo Dani took was option C. This thorough and systematic approach showcases the student's ability to apply logical reasoning and spatial analysis effectively.

3.2 Discussions

This study aimed to investigate students' Computational Thinking (CT) concepts developed through the learning process and life experiences, as outlined by Brennan & Resnick (2012). Brennan & Resnick (2012) proposed one of the most influential CT frameworks for K-12 education consisting of three dimensions: computational thinking concepts, computational thinking practices, and computational thinking perspectives. This study is focused only on investigating students' CT concepts developed through the learning process and life experiences and not through learning that is particularly designed by integrating CT Practices.

CT concepts described by Brennan and Resnick (2012) based on the analysis of existing research: a) Variable: An entity that can "store, retrieve, and update values"; b) Conditionals: An instruction that performs an action or not, according to a given condition; c) Loops: A control structure that allows to repeat one or more sequences multiple times; d) Sequences: A sequence or structure of instructions that must be followed to accomplish a goal or "a series of individual steps or instructions that must be executed by the computer; e) Events (handling): Handling one thing that causes another thing to happen" and instructions that make it possible to interact with objects in the programming environment; f) Subroutines: A procedure that can be called inside another procedure; g) Operators: Provide support for mathematical, logical, and string expressions.

CT practices include the ability to recognize patterns, designing and using abstractions, pattern decomposition, determining which computational tools (if any) can be used in analyzing or solving problems, and defining algorithms as part of a detailed solution . Computational thinking, a cognitive or thinking process involving logical reasoning by which problems are solved and artifacts, procedures, and systems are better understood, includes 1) the ability to think algorithmically; 2) the ability to think in terms of decomposition; 3) the ability to think in generalizations, identifying and utilizing patterns; 4) the ability to think abstractly, choosing good representations; and 5) the ability to think in relation to evaluation [6], [12], [13], [14], [15].

CT Perspectives reflects how students view the world around them and their own abilities. CT Perspectives further enriched the analysis with three critical elements: Expressing, Connecting, and Questioning. By framing it this way, the researchers emphasize the students' understanding and self-awareness in relation to computational thinking. By analyzing student responses, the researcher can connect their problem-solving approaches with the three dimensions of CT: computational thinking concepts, computational thinking practices, and computational thinking perspectives.

4 Conclusion

This research was carried out by taking questions from the Bebras Task. Bebras tasks are presented in the form of problem descriptions equipped with attractive images, so that students can more easily understand the problems. The problems can be answered without the need to learn informatics first, but the problems presented are related to certain concepts in informatics and computational thinking. It was found that students already have CT concepts and the questions given can be solved if given enough time. This research can be used as a basis for

designing a learning model containing CT Practices that can optimize student CT. Specifically, further research is intended to design a mathematics learning model to promote computational thinking by linking it to mathematical materials.

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