Computational thinking skills profile in solving mathematical problems based on computational thinking attitude

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ABSTRACT

The aim of this qualitative research is to describe the thinking process as a profile of students' mathematical computational thinking (CT) skills in terms of CT attitudes. The subjects in this study were 66 junior high school students in grade IX. There were three students taken by purposive sampling based on high, medium, and low CT attitude. The main research instrument was the researcher, while the auxiliary instruments were mathematical CT ability test and CT attitude scale questionnaire. Data analysis included 3 stages, namely data reduction, data presentation, and conclusion drawing. The data credibility test used triangulation techniques, namely tests and interviews. The results showed that subjects with high CT attitude were able to show all indicators of CT ability, namely abstraction, problem decomposition, algorithmic thinking and generalisation and pattern recognition. However, subjects with moderate and low CT attitudes were only able to show one of these indicators, namely abstraction. Based on the results of this study, researchers will create a mathematics learning model to develop CT skills, especially for number pattern material.

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1. INTRODUCTION

In today, problem-solving skills and technology have a significant contribution in dealing with various problems in the present and in the future [1]. Technological developments are increasingly massive, requiring every individual to be able to interact with technology, one of which is in the field of education [2]. The use of computer technology in learning can directly influence and guide students' thinking processes [3]. In parallel, students will know how to think computers (technology) in solving problems [4]. In this context, it is known as computational thinking (CT) [5]. CT is a collection of several problem-solving skills based on the basic principles of computer science [6].

Initially, CT was a term attached to computer science disciplines [7]. CT is an activity of thinking in problem-solving using technology (computer) assistance [8]. CT is also an approach through digital innovation to solve public and social problems [9]. In the last decade, a lot of attention has been paid to the ability of CT researchers, the reason being that CT can be widely accepted from various disciplines, such as mathematics, science, and humanities [10]. Like CT, mathematics is a scientific discipline that develops ways of thinking and reasoning through problem solving [11]. Both mathematical thinking and CT have the same characteristics, namely problem-solving skills [12].

Polya's four problem-solving steps, including understanding the problem, planning a strategy, implementing the strategy and evaluating [13]. Understanding the problem is related to problem decomposition and abstraction. Decomposition is a skill in dividing complex problems into smaller ones to propose appropriate solutions [14]. Planning a strategy is related to algorithmic thinking (algorithm) which focuses on problem structure and problem solutions by making a series of logical steps [15]. Implement strategies through pattern recognition, modeling, simulation and generalization [16]. Meanwhile, evaluation is decision making as a solution to a problem through testing the truth and the process as a whole [17]. Based on this relationship, CT skills in problem solving, especially mathematical problems include indicators of abstraction, decomposition, algorithmic thinking, pattern recognition, generalization and evaluation.

Abstraction is the ability to select important information from an object so that problems become easier to solve [16]. Problem decomposition is the activity of solving a problem into smaller sub-problems that make the problem easier to solve [15]. Algorithmic thinking is the ability to determine systematic strategies in the form of sequences, conditional conditions and repetitions to find solutions to problems [18]. Pattern recognition is the ability to look for structural similarities, patterns, or parallel differences between current and previous information found to help determine an efficient strategy [19]. Generalization is the ability to formulate solutions in general terms so that they can be applied to different problems [20]. Meanwhile, evaluation is the ability to identify the process as a whole, correct errors, and make decisions as the final solution to problems [17], [21].

CT skills are so important that CT is one of the skills needed in the 21st century [1], [22], [23]. CT skills have also become a framework for the Program for International Student Assessment (PISA) which is explicitly included in one of the aspects of mathematics literacy in PISA 2022. Therefore, this skill is very necessary to be developed in mathematics learning in the classroom. However, students especially in junior high schools have not been able to demonstrate CT skills well. The researchers conveyed the results of their research that students had difficulty showing indicators of abstraction and thinking algorithms in solving linear programming problems and algebra problems [24], [25].

This study also reveals the profile of junior high school students' CT skills in solving material problems of arithmetic sequences. This is an interesting study that links CT skills and CT attitudes. International studies have found that students' learning attitudes determine their learning achievement [26]–[28]. Based on this, we can hypothesize that CT attitudes can influence and determine CT skills. Therefore, this study reveals the relationship between CT skills and attitudes as well as students' CT skill profiles in the form of CT indicators that arise from students' thinking processes in solving problems. This research is expected to produce new findings as a reference for innovative learning research that can stimulate and develop CT skills and attitudes.

2. METHOD

This study uses a descriptive qualitative approach. Creswell states that research that aims to analyze, convey and describe facts or individual events in a particular activity process is called descriptive qualitative [29]. This study aims to obtain a profile of junior high school students' CT skills in solving mathematical problems in terms of CT attitudes. To answer the research objectives, subjects were given mathematical problems related to number patterns. Through this problem, researchers analyzed the results of students' answers based on indicators of CT skills.

The subjects of this study were taken from grade 9 junior high schools, totaling 66 students at a private school in the city of Yogyakarta, Indonesia. The subject was given a CT attitude questionnaire with the aim of grouping the subject into 3 categories namely high, medium and low. Subjects were also given a math problem test related to arithmetic sequence material to determine CT skills. Furthermore, the research subjects selected one sample from each category of CT attitudes by using a purposive sampling technique. This technique is a way of taking samples from data sources based on certain considerations [30]. The sample was selected based on considerations including the completeness of the answers to the test questions, willingness to be interviewed face to face, and having active communication to make it easier for researchers to gather information. Subject grouping and sample determination are presented in Table 1.

The questionnaire and test instruments used have been tested for validity and reliability. The questionnaire used refers to a questionnaire that has been developed by Korkmaz and Xuemei [31]. Cronbach's alpha reliability coefficient for the scale in the original study was 0.822. While in this study, the Cronbach alpha reliability coefficient was 0.779. While the test instrument for math problems is 1 question, related to the material for arithmetic sequences. The instrument has been tested for content validity by experts. The results of the validity of the instrument test for math problems are shown in the Table 2.

Table 1. Determination of research samples based on CT attitudes

No	Grading scale		Subject	
	Score	Criteria	Informant	Selected sample
1	Score $> \bar{x} + \frac{1}{2}s$	High	10	1
2	$\bar{x} - \frac{1}{2}s \leq$ score $\leq \bar{x} + \frac{1}{2}s$	Moderate	47	1
3	Score $< \bar{x} - \frac{1}{2}s$	Low	9	1
	Total		66	3

$\bar{x} = means\ ; s = standard\ deviation$

Table 2. Content validity test results mathematics problem test

Aiken validity indeks	Validity
0.875	Valid (Hight)

The data from this research are in the form of answer sheets from test results and recorded interviews with respondents. The interview aims to clarify and clarify the results of student test answers. The results of the test answers and the results of the interviews were analyzed to obtain a profile description of students' CT skills.

Data analysis in this study includes 3 stages, namely data reduction, data presentation, and drawing conclusions [32]. Data reduction is done by selecting important data and information and eliminating data that is deemed unnecessary or unimportant. Data presentation was carried out by processing, grouping and interpreting the profile description data of students' CT skills in solving math problems based on CT attitudes with high, medium and low categories. While the conclusion is a CT profile based on the indicators shown by each group of students based on CT attitudes. The method triangulation technique was used to ensure the validity of the data through interviews and tests with three students based on the CT attitude category. In-depth interviews were conducted with the aim of confirming and digging up more detailed information on student test answer

3. RESULTS AND DISCUSSION

The CT skills profile was obtained based on the results of a math problem test, interviews with 3 informants, and documentation of the informants' worksheets. The informants were RH, FS, and RB who were taken from a group of students with high, medium and low CT attitude categories. Furthermore, there are three indicators used to measure CT skills, namely abstraction, problem decomposition, algorithmic thinking, pattern recognition and generalization. Test to measure students' CT skills is shown in Figure 1.

Toni has a hobby of collecting rubik's cubes. "Rubiks Toys" is Toni's regular shop for buying rubiks. In the first week, Toni bought 2 Rubik's cubes and stored them in the first small cardboard box. In the second week he bought 6 more Rubik's cubes and stored them in the second small cardboard box. In the third week he bought another 10 rubik's cubes and put them in the third small cardboard box. In the fourth week he bought another 14 Rubik's cubes and stored them in the fourth small box. If Toni buys rubiks every week with the same pattern and puts them in different small boxes according to the order, how many rubiks are in the 100th small box?

Figure 1. Instrument test of CT

The results of the tests and interviews were then compared and analyzed to get an overview of the CT ability profile. The results of tests and interviews with informants are described as follows.

3.1. Result

3.1.1. Student of high attitude CT category (RH)

The initial activity carried out by the RH subject on the problem is to write down the information that has been understood. Based on the answer results, subject RH is able to understand and take important information as a basis for solving problems. In other words, subject RH was able to show indicators of abstraction. The results of students' answers are shown in Figure 2

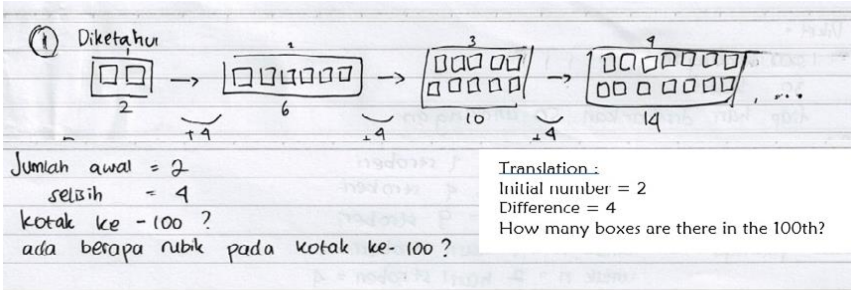


Figure 2. Abstraction thinking of subject RH

More detailed information on the RH subject's answers, the following interviews were conducted:

R : Can you explain the initial information that you understand from the problem?
RH : Ok sir, the first box contains 2 rubiks, and every week it increases by 4. So, the second box has 6 rubiks, the third box has 10 rubiks, the fourteenth box has 14 rubiks, and so on until the 100th box. The number of rubik in the 100th box is the answer to the problem

In the next stage, the RH subject wrote a description of the stages of completion so he could find the answer. The results of students' answers are shown in Figure 3.

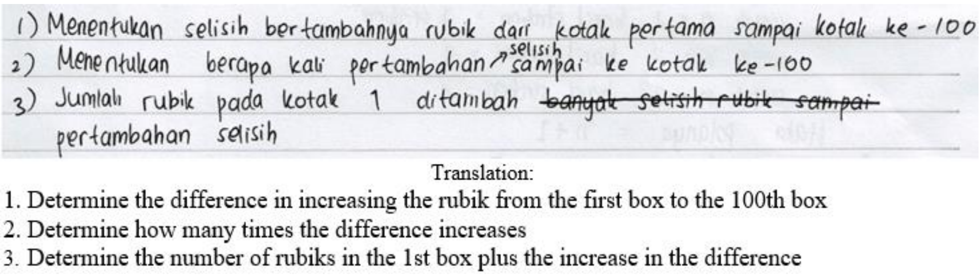


Figure 3. Decompotition thinking of subject RH

Based on the answer in Figure 3, subject RH was able to show decomposition indicators. RH subjects can break down the problem into 3 sub-problems so that the problem is easy to understand and can be solved. However, researchers need to explore the meaning of the third sub-problem, so researchers conducted interviews with RH subjects:

R : Can you explain, the purpose of the third step?
RH : After we know the value of the difference and the number of increases in the value of the difference up to the hundredth box, then the number of cubes in box 1 is added to the product of the value of the difference and the number of increases in the value of the difference

The next step, subject RH answered 3 sub-problems that had been determined previously. This activity is related to algorithmic thinking abilities. Subject RH was able to determine the value of the difference in the number of rubiks starting from the second box onwards, namely 4. In addition, subject RH was able to determine the number of differences starting from the first box to the hundredth box, namely 99 times. This number is the difference value between 100 and 1. In this context, subject RH has demonstrated pattern recognition abilities. It can be seen that subject RH has found the same pattern based on increasing 4 rubiks in each box starting from the second box to the hundredth box. With this pattern recognition ability, RH subjects can determine efficient strategies for answering questions. With the ability to understand the structure of patterns in problems, RH subjects are able to fulfill the elements of generalization. At this stage, the subject was asked to check the answers as a whole before ensuring that the number of rubiks in the 100th box was 398 rubiks. The results of students' answers are shown in Figure 4.

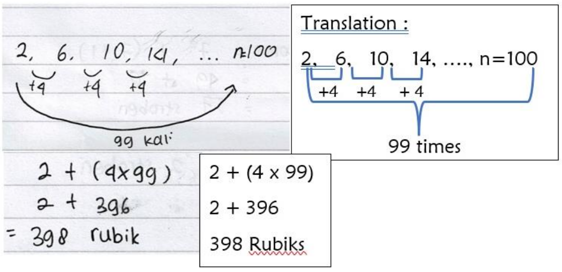


Figure 4. Algorithmic thinking and pattern recognition of subject RH

3.1.2. Student of moderate attitude CT category (FS)

FS subjects were able to understand the important information contained in the questions. Based on the results of the answers, the FS subject described it in the form of illustrations that were easier to understand. This shows that the FS subject is able to show indicators of abstraction. The results of students' answers are shown in Figure 5.

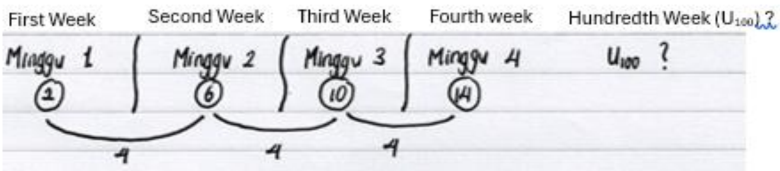


Figure 5. Abstraction thinking of subject FS

Based on Figure 5, Subject FS wrote that in week 1 (first week) there were 2 rubik pieces, week 2 (second week) there were 6 rubik pieces, week 3 (third week) there were 10 rubik pieces and week 4 (fourth week) there were 14 rubik pieces. There are an additional 4 rubik in each week. Furthermore, on the right side of the worksheet the FS subject wrote "U_{100}?" meaning how many rubiks are in the 100th week. The following is the result of the researcher's interview confirmation of the FS subject's answer:

R : Can you explain the illustration?
FS : Alright sir, in the first week there are 2 rubik's, and 4 more rubik's for each following week. Thus, the second week of rubik is 6 pieces, the third week 10 pieces and the fourth week 14 pieces. Next, we are asked to answer the question, how many rubik's cubes will there be in the 100th week?

The next stage, the FS subject wrote down the method or strategy for making patterns until he could find the answer. Even though this strategy does not lead to finding a pattern, the formula is found. The results of students' answers are shown in Figure 6.

Based on the answer in Figure 6, subject FS performed different techniques, namely (i) Sorting the numbers into ten terms; (ii) The number line is written 10 times in sequence from top to bottom. Based on the results of the researcher's interview, subject FS was unable to show the ability to decompose in detail, the answer tended to lead to algorithmic thinking skills, but was not in accordance with the concept of algorithmic thinking. The following are the results of the researcher's interview with subject FS.

R : Can you explain the meaning of this answer?
FS : To find out the number of Rubik's Rubik's Week 100, I have to write down the number up to 100 times, with the initial number 2 and the next number being a multiple of 4. So, the easy way is for me to sort each of the 10 terms by 10 lines?
R : OK, but in lines 4 to 10, you only wrote the last term, why is that?
FS : Because, in the 10th row there is the 100th term whose number is a fixed addition pattern in each last term starting from the first, second and so on, which is increased by 40. So, the 20th term is the number in the 10th term plus 40. Then it's the same, so that the 100th term is the number 398.

Based on the results of the interview, it is known that FS does not yet have the ability to think algorithmically correctly, even though he has obtained the correct answer. In addition, FS subjects have also not been able to demonstrate skills in determining efficient patterns and generalisations.

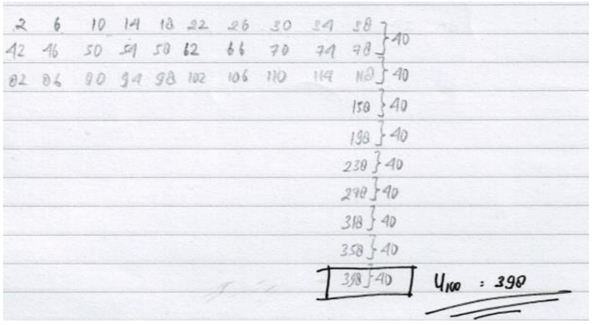
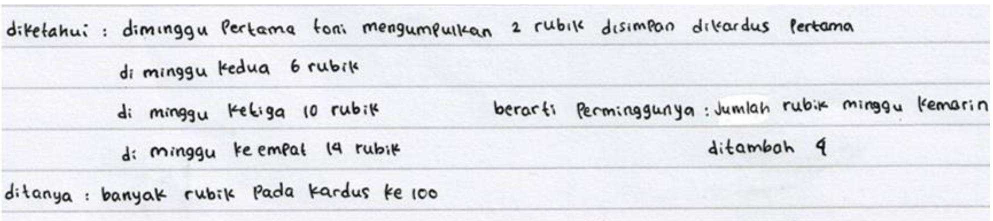


Figure 6. Decompotition thinking of subject FS

3.1.3. Student of low attitude CT category (RH)

Subject RB was able to understand the questions. This is demonstrated by being able to write down important information contained in the question and the information asked. Based on the results of the answers, it shows that subject RB was able to show abstraction indicators. The results of students' answers are shown in Figure 7.



Translation:
known information: the first week Toni collected 2 rubik's
second week 6 rubik
third week 10 rubik
fourth week 14 rubik
the information requested : the number of rubiks on the 100th cardboard

The number of Rubik's cubes increases by 4 every week

Figure 7. Abstraction thinking of subject RB

However, in the next stage, subject RB was unable to write down the stages and explanations in solving the questions. This is shown by subject RB writing down all the numbers in the series. This has implications for not finding the concept of patterns and generalizations to get the number of rubiks on the 100th day. The results of students' answers are shown in Figure 8.

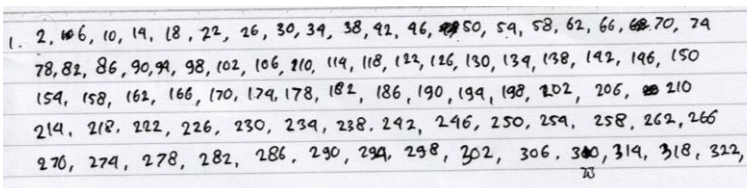


Figure 8. Answers of subject RB

Next, the researcher confirmed this answer with the following interview results:

R	:	Why is that your answer? Haven't you found a more efficient way?
RB	:	That's right sir, I didn't find a more efficient way. I just thought, I have to write it sequentially in multiples of 4 starting from number 1 to number 100
R	:	However, after you wrote it down, you haven't found the correct answer?
RB	:	I think I lost concentration and made a mistake in adding up?

R : Don't you want to try again to find the best way?
RB : I haven't been able to find another way; this is the only way I can think of.

Based on the results of the interview, it is clear that subject RB has not been able to demonstrate the ability to decompose problems, think algorithms and the ability to create patterns and generalizations.

3.2. Discussion

From the research results, it is known how students' thinking processes are in solving number pattern problems using CT components. Skills in using aspects of CT can be explored after students go through the interview process and complete assignments in the form of mathematical problems. All subjects in this research began with the abstraction process. Abstraction is an important component in CT [33]. Abstraction is the student's ability to determine or select important information contained in the question as initial data [34]. This is very necessary for the next stage of completion.

The abstraction ability of subject's RH and FS is expressed in the form of visual representation, while subject RB is represented verbally. So that 3 subjects also have the ability to express mathematical ideas. The ability to express mathematical ideas in both visual and verbal form is called mathematical representation ability [35]. RH subjects with high CT attitude were not only able to demonstrate abstraction abilities. He can also describe the stages of a problem in a coherent and detailed manner and is able to complete these stages. In other words, Subject RH was able to demonstrate decomposition and algorithmic thinking abilities. Decomposition is solving a complex problem into small problems so that the problem is easy to understand and solve separately [36]. Meanwhile, thinking algorithms is the ability to explain the steps in solving sub-problems and finding solutions to problems [37], [38]. Skills in understanding patterns so that a formula is formed to determine the total number of rubik's cubes on the 100th day. Furthermore, different conditions were found in the FS and RB subjects. Even though the FS subject was able to find an answer that the number of rubik's cubes on the 100th day was 398, this did not refer to finding formulas that could be generalized in mathematical problems regarding number patterns in other contexts. Meanwhile, FB subjects do not yet have an efficient strategy for solving problems.

Pattern understanding and generalization skills are the ability to recognize patterns or characteristics and find general patterns in order to build a problem solution [16]. This skill is very important as a more effective strategy for solving mathematical problems. In the concept of number patterns, the skills to understand patterns and generalize are very basic skills. This skill is also the basis for developing mathematical reasoning [39]–[41]. Students' inability to find patterns and produce formulas is because mathematics learning still emphasizes the ability to memorize concepts [42]. Even though mathematics is a tool for developing thinking and reasoning skills [43]. Students' thinking and reasoning skills will get better, when the concepts studied are constructed by students both in groups and individually, rather than memorized [44], [45].

Based on this analysis, it was found that there is a relationship between the ability to think computationally in solving mathematical problems to the attitude of CT. Subjects with a high CT attitude were able to demonstrate all components of their CT skills in solving mathematical problems. Meanwhile, subjects with medium and low attitudes were only able to demonstrate some indicators of CT. This is similar to the results of research by Sun, that CT attitudes influence CT abilities, and there is a significant relationship between CT abilities and CT attitudes [28], [46].

The findings resulting from this research can be used to develop mathematics learning in class which can facilitate students to explore CT skills and in parallel can foster their CT attitude. One of them is project-based learning and CT STEM-based learning [47]–[49]. The results of this study indicate that increasing project-based learning and integrated CT STEM contributes positively to the development of students' CT. This can also be a teacher professional development program regarding CT integrated learning.

4. CONCLUSION

Based on the results of this study, it was found that subjects with high CT attitude were able to show all indicators of mathematical CT skills, namely abstraction, problem decomposition, algorithm thinking, and pattern recognition and generalisation. Subjects with low moderate CT attitude were only able to show an indicator of CT skills, namely abstraction. Based on the results of this study, it can also be said that a high CT attitude will produce good mathematical CT skills, while a moderate or low CT attitude produces less than optimal mathematical CT skills.

The results of this study can be used as a reference for further research, namely the development of innovative learning designs to develop CT skills and attitudes, as well as differentiated mathematics learning designs based on mathematical CT skills. There are limitations to this research. The research subjects were taken from an Islamic-based junior high school. Therefore, other subjects from public and private schools other than Islamic-based schools, or subjects at the high school to university level are needed. With such further research, it is expected to strengthen the results of this study.

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