Analysis of Computational Thinking Abilities of High School Students Based on Self-Regulated Learning

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Abstract

Computational thinking ability plays an important role in the ability of individual students when faced with a complex problem. Based on the literature review that has been conducted, the researcher found a phenomenon where students with moderate ability can achieve the highest rank in the class. In contrast, students with high intelligence often have difficulty or failure in their academic achievement. This shows that no matter how high students' abilities are, they will still be limited if they cannot self-regulate themselves in learning, known as self-regulated learning (SRL). A descriptive qualitative research method was used in this study which was conducted in class XI MIPA in a public high school in Bekasi. The research subjects were selected based on their SRL level, which was categorized into high, medium, and low. Data were obtained through interviews and CT tests, with data collection techniques such as observation, tests, and interviews. The results showed that students with high SRL levels excelled in all aspects of the computational thinking assessment. In contrast, students with moderate SRL levels only showed proficiency in three of the four indicators, namely decomposition, abstraction and generalization, and pattern recognition. Meanwhile, students with a low SRL level only showed proficiency in one indicator, namely the pattern recognition indicator.

Keywords: *Computational thinking; self-regulated learning, high school students*

1. Introduction

The ability to think computationally is one of the capabilities supporting the dimensions of 21st century education (Park & Green, 2019). Computational thinking ability is a form of ability to solve problems using students' logical thinking using structured steps (Fitriani, 2020). Computational thinking ability is the mental ability to apply basic ideas and concepts with skills such as how computers work so that anyone is able to develop ideas, avoid mistakes, enrich information, and make it easier to solve problems in everyday life. (Ansori, 2020).

Computational thinking skills play a very vital role because they are able to optimize an individual's ability to think creatively, critically and analytically when faced with complex problems, both in computing and real life. (Anggara et al., 2023). In addition, this ability also helps in developing skills to plan and implement solutions effectively and efficiently by utilizing technology (Tsai et al., 2017). Computational thinking abilities allow someone to more quickly identify and correct errors or deficiencies in a solution (Christi & Rajiman, 2023). Computational thinking skills are considered very important to face current developments and are able to help students in solving problems. In fact, there is a problem, namely that there are still students who cannot provide solutions and use abstractions to the problems given. (Supiarmo *et al.*, 2021). This phenomenon is reinforced by the results of research

carried out by Litia and Sinaga (2023) which states that this ability of high school students is still low, especially in abstraction and general indicators.

We often find the phenomenon of students with mediocre abilities becoming class champions, but students with high intelligence being unable or even failing in their academic achievements. This phenomenon proves that no matter how high a student's abilities are, they will feel less than optimal if students cannot regulate themselves or what is popularly known as self-regulated learning (SRL) in learning (Mytra et al., 2022). The relationship between SRL and student abilities was proven in research by Supiarmo et al. (2022) which shows that students with high computational thinking skills in answering PISA questions on change and relationship content have a high level of SRL.

Self-regulated learning (SRL) is an independent and active effort by controlling, monitoring and regulating cognition, motivation and behavior oriented towards learning goals. (Concannon *et al*., 2019). This ability is important for students because it is the key to their success in achieving learning goals and targeted outcomes (State *et al*., 2018). However, despite its importance to students' academic success, there are challenges to its implementation. This is similar to research carried out by Winda and Hendro (2022) shows that there are still high school students who have a self-regulated learning level in the low category. Medium level students are able to fulfill aspects of decomposition, abstraction and algorithms. Meanwhile, students with low levels are only able to reach the decomposition stage, and they have not shown independence in the learning process (Nuraisa *et al*., 2021).

Several studies have been conducted regarding self-regulated learning and computational thinking abilities. The first research by Ariesandi et al., (2021) shows the importance of developing electronic inquiry modules in optimizing high school students' computational thinking abilities, especially in sequence and series material. The second research by Lestari and Roesdiana (2023) highlights the challenge of students' low computational thinking abilities in the context of mathematics. The third research (Silvia *et al*., 2023) highlights the challenge of students' low computational thinking abilities in the context of mathematics. The forth research by Hadin et al., (2018) investigated the relationship between students' SRL and their cognitive abilities. The fifth research by Firdaus et al., (2020) explore factors of student academic achievement by considering SRL and computational thinking abilities. Although these studies have explored various aspects of computational thinking abilities, the main focus is still on module development and studies related to self-regulated learning. Research that specifically analyzes students' computational thinking abilities in solving mathematical problems by considering SRL is still rarely researched. Therefore, the aim of conducting this research is to strengthen previous research by analyzing high school students' computational thinking abilities based on SRL, which is expected to provide new insights into the relationship between these two concepts..

2. Methods

Qualitative research aims to study a fact or event experienced by the research subject by describing information in the form of a story based on the results of observations (Pratiwi & Tsurayya, 2023). This method was chosen because of its focus on searching for meaning or describing phenomena naturally and holistically, with a systematic and accurate approach (Nurjannah et al., 2021). Eleventh-grade students of natural science program (MIPA) at SMAN 5 Bekasi became the source of data in this research, which was collected through interviews and written tests to measure their computational thinking abilities. The purpose of this research was to analyze high school students' computational thinking abilities in relation to self-regulated learning.

This research utilizes the results of computational thinking ability tests as the main data, which is supported by information from the self-regulated learning questionnaire instrument. Subject selection is carried out after students complete the self-regulated learning questionnaire. According to Hendrika (2022), subjects were classified into three categories based on the results of the SRL questionnaire: high (S-1), medium (S-2), and low (S-3).

Data collection methods in this research include observation, tests and interviews. To classify research subjects, two types of tests were used: a questionnaire to measure students' SRL and a computational thinking ability test to assess their computational thinking ability. There are two types of instruments applied in this research, namely the main instruments developed by researchers and supporting instruments.

3. Results and Discussions

This research was carried out on 30 eleventh-grade students of natural science program. A total of 30 students were given a questionnaire to determine their level of self-regulated learning. Next, the SRL questionnaire is processed using the Rasch Model so that it can be grouped into High (S-1), Medium (S-2), Low (S-3) groups. One student was taken from each group for further analysis regarding their computational thinking abilities. The following is the result of the Rasch Model analysis.
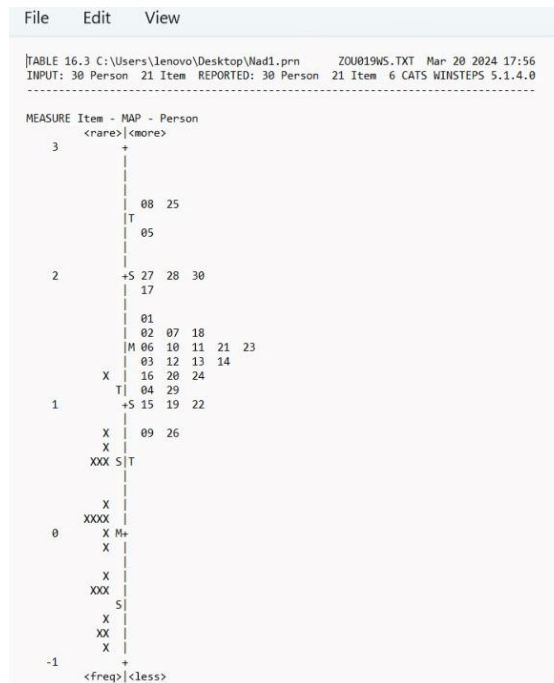
Picture 1 Rasch Model Analysis Result

Based on the results of the Rasch Model processing, it was found that the High (S-1), Medium (S-2), and Low (S-3) groups were found, where the High (S-1) group contained students with codes 08, 25, and 05, group Medium (S-2) contains students with codes 27, 28, 30, 17, 01, 02, 07, 18, 06, 10, 11, 21, 23, 03, 12, 13, 14, 16, 20, 24, 04, 29, 15, 19, and 22, while the Low group (S-3) contains students with codes 09 and 26.

Then, one student from each group was selected to have their computational thinking abilities analyzed. Selected students from the High (S-1) group is HNT because they are able to solve problems accurately and in detail according to indicators of computational thinking ability. Meanwhile, from the Medium (S-2) group, the students selected is ZPA, who were only able to meet some of the computational ability indicators. On the other hand, from the Low group (S-3), the students selected is AAM, who were unable to solve problems.

Table 1 Research Subject

No.	*Self-regulated learning category*	Name code
1.	High (S-1)	HNT
2.	Medium (S-2)	ZPA
3.	Low (S-3)	AAM

In this research, the subjects analyzed refer to indicators of computational thinking abilities. Data derived from tests of high school students' computational thinking abilities, grouped based on SRL, produced the following findings.

Table 2 Students' Computational Thinking Ability Test Results

No.	Computational Thinking Ability Indicators	Research Subjects		
		S-1	S-2	S-3
1.	Decomposition	√	√	×
2.	Pattern Recognition	√	√	√
3.	Algorithmic Thinking	√	×	×
4.	Abstraction and Generalization	√	√	×

Description:
√   : The subject is able to achieve the indicators
×   : The subject is unable to achieve the indicators

The following is a detailed review or explanation of the computational thinking abilities of high, medium and low subjects.

3.1 High Self-regulated learning Subject (S-1)
Questions related to the computational thinking ability test, which consists of four questions, have been answered resulting in the following review:

a.   The following is the result of work on S-1, question number 1.
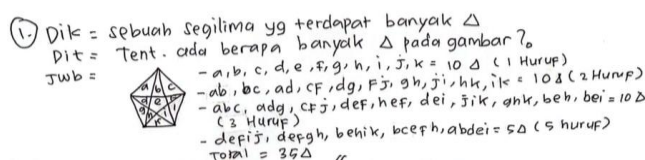
Picture 2. S-1 work on question number 1

Using the first indicator, namely decomposition, the subject can divide the problem into simpler elements correctly at number 1. He can correctly determine the number of triangles, namely 35Δ. When interviewed, the subject can provide accurate answers by explaining the information obtained and the questions asked in the questions.

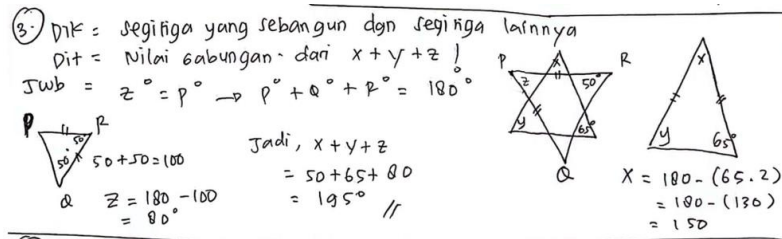b.   The following is the result of work on S-1, question number 2.
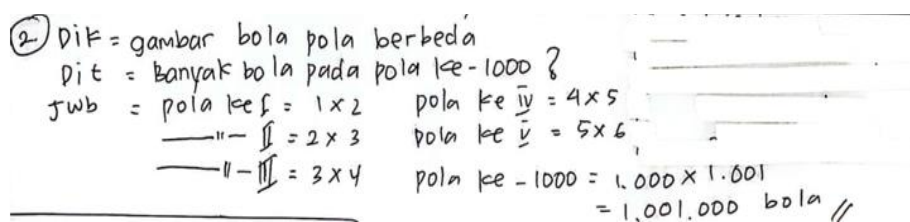
Picture 3. S-1 work on question number 2

For the second indicator, namely pattern recognition, the subject was able to identify the pattern correctly in question number 2. The subject was able to determine the number of balls in the 1000th pattern in a structured and correct manner, namely 1000 x 1,001 = 1,001,000 balls. The results of subject interviews can provide an explanation regarding how to identify patterns and determine the number of patterns according to the questions in the problem.

c.   The following is the result of work on S-1, question number 3.
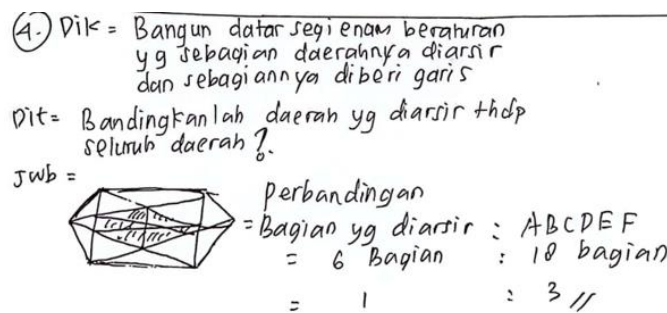
Picture 4. S-1 work on question number 3

The third indicator is algorithmic thinking. The subject was able to find the correct solution to question number 3. The subject was able to combine the values of x + y + z in the triangle image correctly, namely x + y + z = 50° + 65 °+80° = 195 °. From the results of the interview, the subject was able to state the steps used logically and systematically.

d. The following is the result of work on S-1, question number 4.
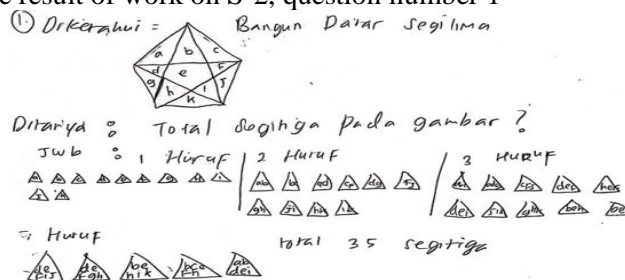

Picture 5. S-1 work on question number 4

In the fourth indicator, namely abstraction and generalization, the subject is able to compare the correct general pattern in question number 4. The subject can compare the shaded area to the entire hexagon shape area, namely the shaded part = 6 parts, while the entire hexagon shape area (ABCDEF) = 18 parts, then the results obtained are 1 : 3. From the results of the interview the subject can explain the desired area comparison in the question correctly.

3.2 Medium Self-regulated learning Subject (S-2)

Subject has completed four questions in the computational thinking ability test with the results as follows:

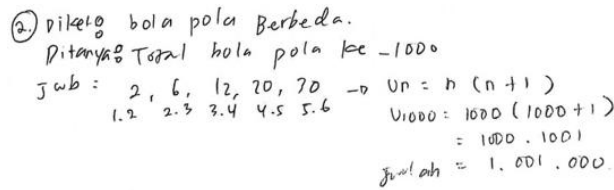a. The following is the result of work on S-2, question number 1

Picture 6. S-2 work on question number 1

In the first indicator, namely decomposition, the subject can identify what is known and questioned in the problem properly and correctly in number 1. The subject can determine the number of triangles correctly, namely 35Δ. During the interview, the subject was able to provide answers that corresponded to the question instructions precisely.
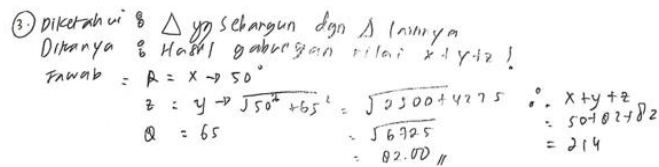
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b. The following is the result of work on S-2, question number 2

Picture 7. S-2 work on question number 2

In the second indicator, namely pattern recognition, the subject is able to identify the pattern correctly in question number 2. The subject can determine the number of balls in the 1000th pattern in a structured and correct manner, namely using the formula $Un=n(n+1)$, then $U1000=1000(1001)$ = 1,001,000 balls. The results of subject interviews can provide an explanation regarding how to identify patterns and determine the number of patterns according to the questions in the problem.

c. The following is the result of work on S-2, question number 3

Picture 8. S-2 work on question number 3

In the third aspect, namely algorithmic thinking, the subjects failed to find a suitable solution for problem number 3. They were only able to explain the value of each angle in the triangle image, but were unable to combine the values $x + y + z$ correctly. When interviewed, the subjects were less confident in detailing the steps they used because the results were too small, less than 180°, while the total angle in the triangle was 180°. As a result, they tried to use a formula, but the resulting answer was inaccurate.

d. The following is the result of work on S-2, question number 4
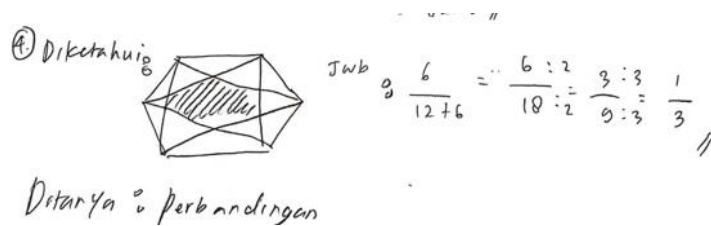
Picture 9. S-2 work on question number 4

The fourth indicator is abstraction and generalization. Question number 4, Subjects are able to compare general patterns and shaded patterns correctly. Subjects can compare the shaded area to the entire hexagon shape area, namely the shaded part = 6 parts, while the entire hexagon shape area (ABCDEF) = 18 parts, both are equally divided by 3 and then divided by 2, so the result obtained is 1 : 3. The results of the subject interview can explain the appropriate method according to the results of the test carried out.

3.3 Low Self-regulated learning Subject (S-3)

Four questions in the computational thinking ability test have been worked on by student with this subject. The results are reviewed as follows:

a. The following is the result of work on S-3, question number 1

Picture 10. S-3 work on question number 1

In the first indicator, namely decomposition, the subject was unable to decompose the question given into several simple parts in number 1. However, the subject was only able to determine the number of triangles but the method and results of the answer were not correct. The results of the interview session showed that the subject was only able to summarize the existing information and the questions asked in the question, but the subject needed to read the question several times to find the answer.

b. The following is the result of work on S-3, question number 2

Picture 11. S-3 work on question number 2

In the second indicator, namely pattern recognition, the subject was able to identify the pattern correctly in question number 2. However, the subject was unable to determine the number of balls in the 1000th pattern. The results of the subject interviews can provide an explanation regarding how to identify patterns by looking at the length and width of each image which is multiple, but the answer is not correct.

c. The following is the result of work on S-3, question number 3
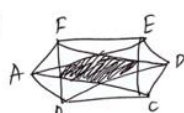
Picture 12. S-3 work on question number 3

The third indicator is algorithmic thinking. Problem number 3, the subject was unable to find a solution. The subject is only able to describe the value of each angle in the triangle shape but the subject cannot combine the values of x + y + z in the triangle image correctly. The results of this interview were less confident in stating the steps used because the subject experienced difficulties and forgot the formula.

d. The following is the result of work on S-3, question number 4

Picture 13. S-3 work on question number 4

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The fourth indicator is abstraction and generalization. The subject was unable to compare the general pattern and the shaded pattern correctly in question number 4. The subject was unable to compare the shaded area to the entire hexagonal plane area. From the interview results, the subject did not use a ruler and measured manually so that the answers obtained were less valid.

Based on the research results, there are variations between the subjects that have been investigated. These results indicate that high level (S-1) students are able to decompose questions into simpler components through a decomposition process. They are also able to recognize patterns in a structured and correct way in finding algorithmic solutions. Apart from that, these subjects can also carry out abstractions and generalizations by analyzing the relationships between different patterns and more complex patterns. Students with a high level of SRL are able to contain all indicators. This is consistent with the findings in research by Lestari & Roesdiana (2023) which confirms that students in the very good or high category have succeeded in meeting all the indicators measured. Jamna et al., (2022) also shows that students in the very high category are able to achieve all the indicators in the questions and achieve appropriate final results.

For students with a medium level of SRL, only three indicators were achieved, namely decomposition, abstraction, and pattern recognition and generalization. However, in the third indicator, students are only able to explain the angle values in a triangle shape without being able to accurately combine the x+y+z values in the triangle image. This finding is in line with the results of previous research conducted by Supiarmo et al., (2021) which states that students have not applied algorithmic thinking processes in solving mathematical problems. Apart from that, research carried out by Nuvitalia et al., (2022) also concluded that students with low computational thinking abilities have not succeeded in meeting the algorithmic thinking indicators.

At the low category SRL level, students are only able to achieve one indicator, namely pattern recognition. In the first indicator, namely decomposition, the subject was unable to decompose the question given into several simple parts in number 1. However, the subject was only able to determine the number of triangles but the method and results of the answer were not correct. This is in line with research carried out by Kamil et al., (2021) which states that there are students who are unable to achieve the decomposition indicators, especially students in the low SRL category. The third indicator is algorithmic thinking. The subject was unable to find a relevant alternative in question number 3. The subject was only able to explain the value of each angle in the triangle shape but the subject was unable to combine the values of x + y + z in the triangle image correctly. This is identical to research carried out by Kamil et al., (2021) which revealed that some students in the low and very low categories still faced difficulties in solving questions related to algorithm indicators. In the fourth indicator, namely abstraction and generalization, question number 4 was not able to be compared by the subject starting from the general pattern and the pattern that was shaded correctly. The subject was unable to compare the shaded area to the entire hexagonal plane area because the subject forgot to use a ruler and the subject measured manually so the results were invalid. This is comparable to research of Lestari and Annizar (2020) which revealed that subjects included in the low category were able to record the information needed to solve the problem, but the implementation was not appropriate.

Based on the explanation above, this research is relevant to previous research. The results of previous research showed that students in the high SRL category met all the indicators. Students in the medium SRL category still do not meet the algorithmic thinking indicators. Students in the low SRL category only fulfill the pattern recognition indicators. These results are similar to the results from this study which showed that students with high levels of SRL excelled in all aspects of the computational thinking assessment. Students with a medium SRL level only show abilities in three of the four indicators, namely decomposition, abstraction and generalization, and pattern recognition. Meanwhile, students with low SRL levels only show ability in one indicator, namely the pattern recognition indicator. In this research, the test instrument used does not refer to one specific material, but uses complex problems. This is what differentiates this research from previous research where previous research refers to one material in particular.

4. Conclusion

Based on the presentation of the results and discussion, it can be concluded that high school students' computational thinking abilities, which are evaluated based on SRL, show variations in results between different subjects. The following are the conclusions from the results of this research.

a. Students' ability to think computationally, especially those with high SRL, in answering questions shows that they can meet all the criteria measured. These subjects successfully cover the four indicators which include decomposition, pattern recognition, application of algorithms, abstraction and generalization, as well as the ability to identify required information, formulate solution steps, and solve problems in an effective and appropriate way.
b. The computational thinking abilities of students who have a medium SRL level in answering questions show that they are only able to fulfill three indicators, namely indicators of abstraction and generalization, pattern recognition, and abstraction. However, in the third indicator, the subject can only explain the value of each angle in a triangle, without the ability to combine these values correctly.
c. The computational thinking ability of students who have a low level of SRL in answering questions shows that they are only able to fulfill one indicator, namely pattern recognition. However, in the indicators of decomposition, algorithmic thinking, abstraction, and generalization, the subject was unable to present the required information, was unable to detail the problem solving process, and the choice of problem solving approach made was the wrong approach.

Researchers also suggest that further research continues to develop analysis of the relationship between computational thinking abilities and SRL. To identify factors that can optimize students' computational thinking abilities, so that they can contribute to improving the quality of education in Indonesia is the aim of this research.

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