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ORIGINAL

Analysis of students' computational thinking skills in science and mathematics subject in fifth grade of elementary school

Análisis de las habilidades de pensamiento computacional de los estudiantes de ciencias y matemáticas de quinto grado de primaria

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ABSTRACT

Introduction: this study aimed to explore the components of computational thinking skills at the End of Term Summative Assessment (ETSA) and End of Year Summative Assessment (EYSA) questions as well as the profile of computational thinking skills in science and mathematics subjects of fifth-grade students in Surakarta City, Indonesia.
Method: this was a qualitative study with a case study approach. Data were collected through analysis of ETSA and EYSA documents, which include test instruments and student answers. Sampling was carried out using purposive sampling by considering the level of cognitive development of students.
Results: the results showed that each ETSA question included components of decomposition, pattern recognition, abstraction, and algorithm design. Meanwhile, each EYSA question included different components from one question to another. The profile of students' computational thinking skills showed variation in the success of answering questions, with significant differences between components and types of questions.
Conclusions: this study concludes that ETSA questions are more consistent in covering all components of computational thinking skills compared to EYSA. The profile of student skills varies, with some components showing lower results. The implications of these findings include the need for adjustments in the curriculum and teaching methods to emphasize more evenly distributed mastery of computational thinking skills. Further research should explore the causes of variation in mastery of these skills and develop more comprehensive evaluation instruments.

Keywords: Computational Thinking; Decomposition; Pattern Recognition; Abstraction; Design Algorithms; Elementary School; Science; Mathematics.

RESUMEN

Introducción: este estudio tuvo como objetivo explorar los componentes de las habilidades de pensamiento computacional en las preguntas de la Evaluación sumativa de fin de período (ETSA) y la Evaluación sumativa de fin de año (EYSA), así como el perfil de las habilidades de pensamiento computacional en las materias de ciencias y matemáticas de estudiantes de quinto grado en la ciudad de Surakarta, Indonesia.
Método: se trató de un estudio cualitativo con un enfoque de estudio de caso. Los datos se recopilaron a través del análisis de los documentos de ETSA y EYSA, que incluyen los instrumentos de prueba y las

respuestas de los estudiantes. El muestreo se realizó mediante un muestreo intencional, considerando el nivel de desarrollo cognitivo de los estudiantes.
Resultados: los resultados mostraron que cada pregunta de la ETSA incluía los componentes de descomposición, reconocimiento de patrones, abstracción y diseño de algoritmos. Mientras tanto, cada pregunta de la EYSA incluía diferentes componentes según la pregunta. El perfil de las habilidades de pensamiento computacional de los estudiantes mostró variaciones en el éxito al responder las preguntas, con diferencias significativas entre los componentes y los tipos de preguntas.
Conclusiones: este estudio concluye que las preguntas de la ETSA son más consistentes en la inclusión de todos los componentes del pensamiento computacional en comparación con la EYSA. El perfil de habilidades de los estudiantes varía, y algunos componentes muestran resultados más bajos. Las implicaciones de estos hallazgos incluyen la necesidad de realizar ajustes en el currículo y en los métodos de enseñanza para garantizar un dominio más equitativo de las habilidades de pensamiento computacional. Investigaciones futuras deberían explorar las causas de la variación en el dominio de estas habilidades y desarrollar instrumentos de evaluación más integrales.

Palabras clave: Pensamiento Computacional; Descomposición; Reconocimiento de Patrones; Abstracción; Diseño de Algoritmos; Educación Primaria; Ciencias; Matemáticas.

INTRODUCTION

In this industrial era, 21st-century skills including critical thinking, problem-solving, searching for information, and using media and technology are highly demanded to be developed and can be achieved through computational thinking skills.[1,2] Over the past decade, the idea of developing computational skills as a set of abilities with universal value and power for every child has garnered significant research attention, while key questions have emerged regarding how to integrate Computational Thinking (CT) into the formal curriculum.[3,4] Adaptation to new methodologies in the educational process has become an urgent matter, as numerous technologies are currently influencing the demands of the workforce, driving exponential growth.[5]

These skills teach how to think critically, understand, and solve problems with technological methods. Colin[6] Computational thinking skills are defined as the process of formulating problems and expressing solutions that can be done by computers or humans effectively by using basic computing concepts such as decomposition, pattern recognition, abstraction, and algorithm design.[7,8,9] Education plays an important role in developing these skills to prepare individuals to face the challenges of the 21st century.[10,11] Many countries have integrated computational thinking skills into their national curriculum. Ching et al.[12], Verawati et al.[13], Abdulrasool et al.[14], Santos et al.[15] including Indonesia through the Education Standard, Curriculum, and Assessment Agency Decree Number 032/2024. Amiri[16] In Indonesia, computational thinking skills are taught from elementary school to high school, with integration into various subjects. The elementary schools in Surakarta city have implemented the ICT curriculum, utilizing information and communication technology in the learning process in the learning process to develop computational thinking skills.[17]

Similarly, Benakli et al.[18], Wing[19], Hsu et al.[20] emphasized that like reading, writing, and basic mathematics skills, CT is a skill that everyone should have. Hsu et al.[20] considered CT as a universal skill that should be integrated into everyday life. Researchers agree that CT is a 21st-century skill that students at all levels of education from preschool to higher education must have. Recently, Tsai et al.[21] indicated that CT can be understood from both domain-general and domain-specific perspectives. Del Olmo et al.[22] experimented with unplugged and plugged activities with second-grade children. Tang et al.[23] reviewed current CT assessments from kindergarten to higher education, in terms of context, construct, assessment type, and psychometric evidence. Computational thinking refers to the decomposition of most problems, pattern recognition, and solving them step by step.[24]

Computational thinking is mentioned as a cognitive activity that is needed to solve problems through algorithms and can be done by artificial agents or humans.[25] In his research, Tsarava showed that algorithmic thinking, abstraction, pattern recognition, and decomposition are cognitive processes related to computational thinking. Liu et al.[26] Computational thinking can be applied to the problem-solving process in various contexts and disciplines.[27] The same thing explains that computational thinking is not only used in the field of computer science, but can be implemented in various other disciplines such as mathematics and natural sciences.[28]

Science and mathematics are a combination of two interconnected disciplines.[29] According to Sudjana[30] Natural Sciences or science is important for improving people's lives so that science needs to be taught to students as early as possible. Meanwhile, according to Maharani et al.[31] shows that computational thinking skills in mathematics tend to provide ideas and teaching strategies for teachers and students, leaving gaps that require further research. In the context of mathematics education, computational thinking helps students understand mathematical concepts more deeply through an analytical and systematic approach. Computational Thinking (CT) is useful for improving students' understanding. Computational thinking is able to support the rapid development of information technology.[32]

Computational thinking is very suitable to be developed in facing the development of current technology. Review of the concept of the material is always found in everyday life, even the concept of science can help humans in running.[33] Along with this, the integration of computational thinking into mathematics and science curricula is increasingly recognized as an important step in preparing students for a world full of digital and algorithmic technologies.

The algorithmic approach in computational thinking skills is also called the main component in computational thinking skills which includes: decomposition, pattern recognition, abstraction, and algorithm design. Rukayah, et al.[28] Decomposition is the process of breaking down problems from complex to simple parts using existing information so that the problem is easy to understand and solve. Wen, Ottenbreit (29,30) Pattern recognition is the process of identifying the same patterns or rules so that they can be used to solve problems.[22,31] Abstraction is the process of focusing on important things or eliminating unimportant data. Ottenbreit-Leftwich, Ashour[30,32] The last component is algorithm design which is defined as the process of creating orderly and logical steps that are followed to solve problems.[33,34]

Dagienė et al.[35] mentioned the indicators for these four components. Decomposition indicators are: simplifying problems and dividing problems into sub-problems. Pattern recognition indicators consist of identifying patterns, similarities, or relationships and utilizing general solutions. Abstraction indicators include: removing unnecessary details, finding key elements, and choosing representations. Algorithm design component indicators are: thinking sequentially or according to rules, creating algorithms or problem-solving steps, and running algorithms.[36]

The profile of students' computational thinking skills can be identified by analyzing and measuring students' abilities in demonstrating computational thinking skills. Fagerlund[37] This can be done by using test instruments that contain components of computational thinking skills as previous studies have developed several instruments on this matter such as the Computational Thinking Test, Computational Thinking Assessment, TechChec-K, or Bebras Challenge questions. Bocconi et al.[38,39] Creativity, critical thinking, communication, and collaboration, which are included in CT, are seen as key skills that will help students succeed in the future.[17]

This study aimed to analyze the computational thinking skills of fifth-grade elementary school students in Surakarta City, Indonesia, using ETSA and EYSA assessment instruments. The key scientific problem addressed is whether these assessments effectively measure students' computational thinking skills and what their skill profile reveals. Despite the importance of computational thinking in modern education, there is limited research on its assessment at the elementary level, particularly in Indonesia. Understanding how well these tests cover decomposition, pattern recognition, abstraction, and algorithm design is crucial for improving curriculum and teaching strategies. The findings will help identify gaps in current assessments and provide recommendations for enhancing computational thinking education in elementary schools.

METHOD

This research is qualitative research with a case study approach. Qualitative research is research used to examine the condition of natural objects.[40] The research population consisted of fifth-grade students from three elementary schools: Al-Abidin ICT Elementary School, Muhammadiyah 1 Elementary School, and Ta'mirul Islam Inovatif Elementary School. The selection of grade V students was based on their cognitive abilities, particularly their proficiency in higher-order thinking skills, such as analyzing (C4) and evaluating (C5).[36] The inclusion criteria for this study were students enrolled in the fifth grade during the 2023/2024 academic year and those who had participated in both the End of Term Summative Assessment (ETSA) and the End of Year Summative Assessment (EYSA) in the Computational Thinking subject. ETSA and EYSA are test instruments that can be used to see students' mastery of computational thinking skills because the questions contain components of computational thinking skills and are similar in form to instruments that have been used in previous studies.[41,42,43] Students who were absent during the administration of either the ETSA or EYSA or those who did not complete the assessments due to personal or academic reasons were excluded from the study. A total of 50 students were selected through purposive sampling, considering their cognitive development and familiarity with computational thinking concepts. Besides that, the sampling technique using the purposeful sampling technique is a sampling technique used when the researcher already has a target individual with characteristics that are appropriate for the research.[44]

The primary variables analyzed in this study included the type of assessment (ETSA and EYSA) as the independent variable and students' computational thinking skills as the dependent variable, which encompassed decomposition, pattern recognition, abstraction, and algorithm design. Data collection was carried out through document analysis of ETSA and EYSA, which served as assessment instruments for evaluating students' computational thinking skills. The questions in these assessments were designed to align with established computational thinking components and previous research-based evaluation instruments. The results of quantitative data of the test with questions containing components of computational thinking skills were calculated using Microsoft Excel. The results of student answer data measured using questions containing computational thinking skill components were calculated using Microsoft Excel. The calculation only focuses on finding the percentage of data for each question, and interpreting the data by dividing it into five categories (very high, high, sufficient, very low, and low).

RESULTS AND DISCUSSION

The distribution of the four components of computational thinking skills in science and mathematics learning, namely decomposition, pattern recognition, abstraction, and algorithms in ETSA questions is different from EYSA questions (figure 1).

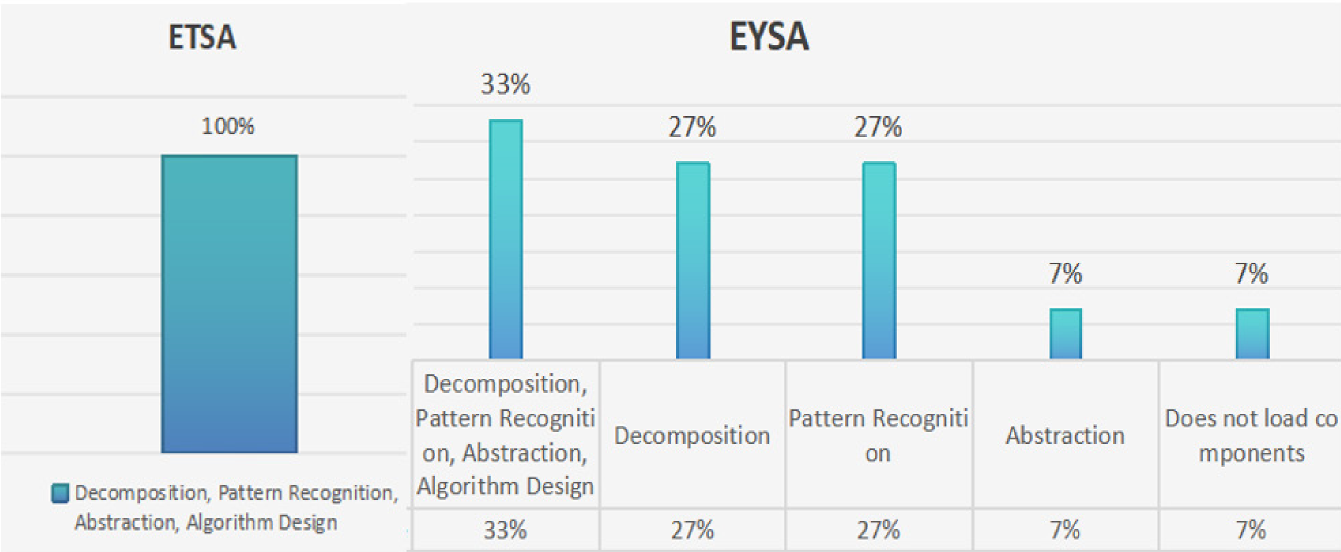

Figure 1. Percentage Distribution of Computational Thinking Skills Components in Science and Mathematics Learning

The test of the Computational Thinking in science and mathematics learning for Class V in Elementary School in Surakarta City, consisted of 15 questions. The questions were in the form of ten multiple-choice questions and five essay questions. The EYSA questions also had the same number, but the identification results showed that there were only 14 questions that contained computational thinking skill components. The profile of students' computational thinking skills in this study consisted of the profile of students' computational thinking skills on ETSA questions (figure 2) and EYSA questions (figure 3). The profile was based on the success of students in demonstrating their computational thinking skills on each ETSA and EYSA question item.

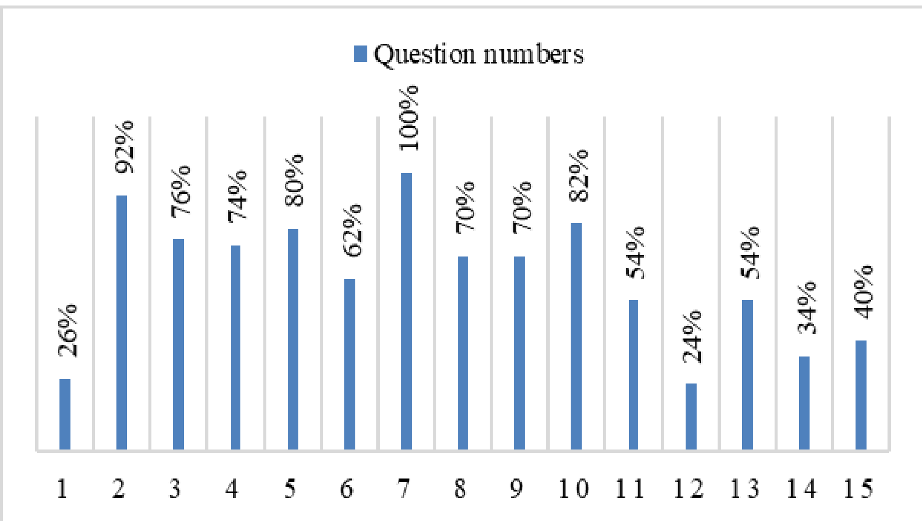

Figure 2. Profile of Students' Computational Thinking Skills in ETSA Questions

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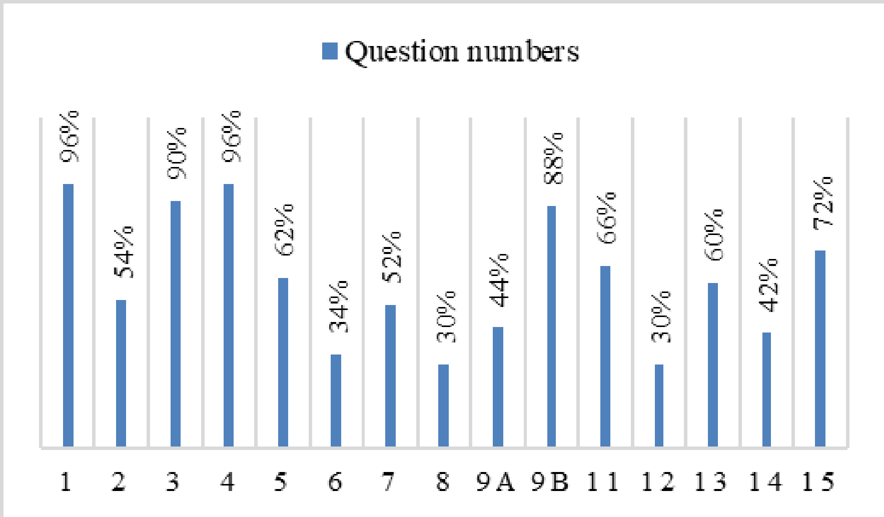

Figure 3. Profile of Students' Computational Thinking Skills on EYSA Questions

Components of computational thinking skills in science and mathematics learning in ETSA and EYSA questions

ETSA and EYSA in the computational thinking subject are forms of summative assessment used to assess students' achievements and abilities after completing learning, specific in science and mathematics learning.[45] This assessment is included in the cognitive domain because it involves giving tests to students and is used to evaluate mental abilities or brain activities such as computational thinking.[46,47] Therefore, tests with the ETSA and EYSA formats are suitable for measuring mastery of computational thinking skills, which are cognitive activities.[48]

The ETSA and EYSA tests are written tests. The ETSA consisted of 15 questions with 10 multiple-choice questions and five objective essay questions, while the EYSA consisted of 15 questions. The 15 questions were divided into five multiple-choice questions, five true-false questions, and five objective essay questions. Assessment formats such as multiple-choice or structured questions with essay form to assess computational thinking skills were used in several previous studies.[49,50]

The assessment of computational thinking skills must ensure that the questions used contain computational thinking components.[51] Questions are said to contain computational thinking skill components if the questions require thinking processes such as decomposition, pattern recognition, abstraction, or algorithm design for their solution.[52] Research shows that all questions in the ETSA contained all four components of computational thinking skills simultaneously, in line with the Bebras Challenge format.[53] EYSA questions 11-15 contained the same computational thinking skill components as ETSA, namely all four components in each question.[54]

Profile of students' computational thinking skills in science and mathematics learning in ETSA and EYSA questions

Computational thinking skills are taught in schools because students need to master them.[55] Students who have computational thinking skills can develop problem-solving skills, improve critical thinking skills, encourage creativity and innovation, understand and manage data, help in decision-making, and strengthen 21st-century competencies.[56,57] The profile was described based on students' ability to demonstrate their computational thinking skills based on the indicators mentioned by Dagiene through answers to each ETSA and EYSA question.[54] Students successfully demonstrated computational thinking skills when they answered the questions correctly.

The profile of students' computational thinking skills in science and mathematics learning on ETSA questions shows variation in their abilities. Here is a sample summary for ETSA question:

Question 1: only 26 % of students answered correctly and demonstrated good computational thinking skills. Most (74 %) chose the wrong answer, often due to errors in simplifying the problem and identifying key elements, especially ignoring the word 'except'. Question 1 was the ETSA question with the lowest percentage of correct answers which can be seen below.

Antoni, Nando, and Aldi are playing ball. Initially, Antoni's ball moved towards the goal. However, after being kicked by Aldi, the ball moved towards Nando. This shows that the force.

- Speed up the movement of an object.
- Slow down the movement of an object.
- Change the shape of an object.

- Change the direction of the movement of an object.

Question 7: the question was successfully answered correctly by 100 % of students, indicating good computational thinking skills across all students. Question 7, which was successfully answered correctly by all students, can be seen in below.

Six children are running on the field when one of them throws a ball, breaks a window, and runs away. From the ball throw, the teacher wants to see the pull of the ball. The greater the weight of an object, the greater the pull required.

- Small.
- Normal.
- Large.
- Constant.

Question 15: 40 % of the students answered correctly and demonstrated good computational thinking skills. 46 % of them answered incorrectly but with indications of poor computational thinking skills, while 14 % did not demonstrate computational thinking skills.

Sarah, the beaver, is playing a ring toss game with her friends. Each beaver must throw five rubber rings onto a wooden peg.

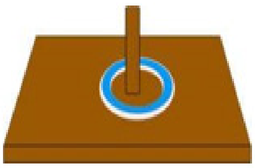

Figure 4. Ring toss

Each successful ring that lands on the peg earns points according to the following scoring system:

Table 1. Score system

Throw Attemp	Points
First	5
Second	4
Third	3
Fourth	2
Fifth	1

Sarah made the following throws. How many points did she score?

Figure 5. Sarah throws

The profile of students' computational thinking skills on EYSA questions also varied with the following explanation:

Question 1: almost all of the students (96 %) managed to answer correctly by choosing the answer 'b'. This question tested pattern recognition skills (see below), and all participants demonstrated the ability to identify image patterns correctly.

Carefully observe the images below!

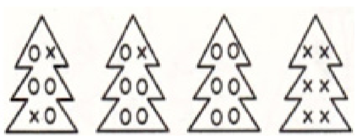

Figure 6. Image patterns

What is the next pattern in the sequence?

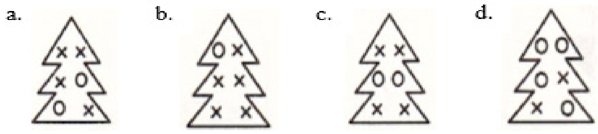

Figure 7. Image patterns

Questions 6, 7, 8: these three questions tested decomposition, and had different success rates. Correct answers to question 6 (34 %), question 7 (52 %), and question 8 (30 %). Questions 6 and 8 were among the questions with a low percentage of correct answers this showed students' difficulty in simplifying statements and drawing appropriate conclusions. One of these questions can be seen below.

Look at the following table!

Table 2. Activities

No	Influence of Style	Examples of Activities
I	Changing the direction of motion of an object	Ride a bicycle
II	Changing the shape of an object	Kick a ball
III	Changing the direction of motion of an object	Squeeze a can
IV	Changing the shape of an object	Breaking a bicycle

The exact match between the effect of a force on an object and an example of its activity is shown by.

1. *I*
2. *II*
3. *III*
4. *IV*

Question 9: contained two true-false questions with a pattern recognition component. Question 9 a was only answered correctly by 44 % of the students, while question 9b was answered correctly by 88 %. This difference showed that different image patterns affected students' pattern recognition abilities. The image patterns in questions 9a and 9b can be seen below.

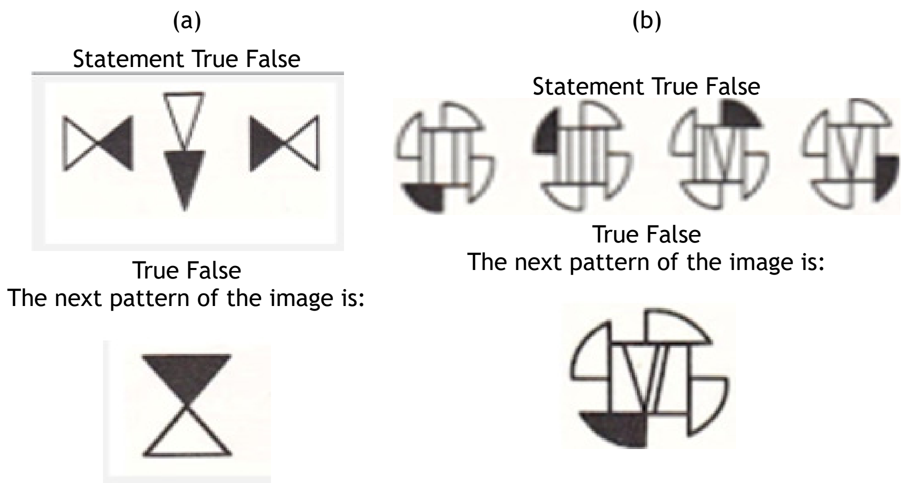

Figure 8. Image patterns in questions 9a and 9b

Question 13: 60 % of the students answered correctly with 'get hockey sticks', showing good computational thinking skills. 28 % of the students showed poor skills, and 12 % of them answered carelessly.

There are three siblings, namely Amar, Kiki, and Lulu. They have different heights, specifically 160 cm, 165 cm, and 170 cm. They also have different body weights, namely 50 kg, 55 kg, and 60 kg. However, several known facts are as follows:

1. Amar is taller than Kiki but lighter than Kiki.

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2. Kiki is heavier than Amar but shorter than Lulu.
3. Lulu is taller than Kiki but lighter than Amar.

The results of the EYSA question analysis showed the profile of computational thinking skills of grade V in Elementary School in Surakarta City in science and mathematics learning based on certain components. The success of students in the pattern recognition component consisting of five questions was 83 %. Success varied between questions with the best results on questions 1 and 4 (96 %), and the lowest on question 9a (56 %). In second place was one question that tested abstraction ability and its success was 62 %. In the lowest position was the success on the four decomposition questions which was 43 %. This finding is supported by previous studies showing that 7th grade students' CT skills improved after they experienced programming learning. The activity had a broad and effective impact on students to improve and develop their CT skills.(58) Most studies with computational thinking reviews focus on programming concepts.(59) They consider this approach to be preferable to other types of learning approaches.

Another study reported that CT activities in mathematics subjects have succeeded in building their understanding of mathematical concepts (partial integration).(60) Other findings provide an overview of computational thinking in science classrooms. The results demonstrate the value of using modeling-based pedagogy in incorporating core computational thinking skills into science content so that educators should use technology-based media to enhance science learning using a computational thinking framework.(61) This is also in line with previous findings which reported that most students have mastered computational skills which are indicated by the ability to analyze the given questions, recognize patterns in questions, sort information in situations or abstractly, and solve questions correctly.(62)

Categorization of students' computational thinking skills profile in science and mathematics learning

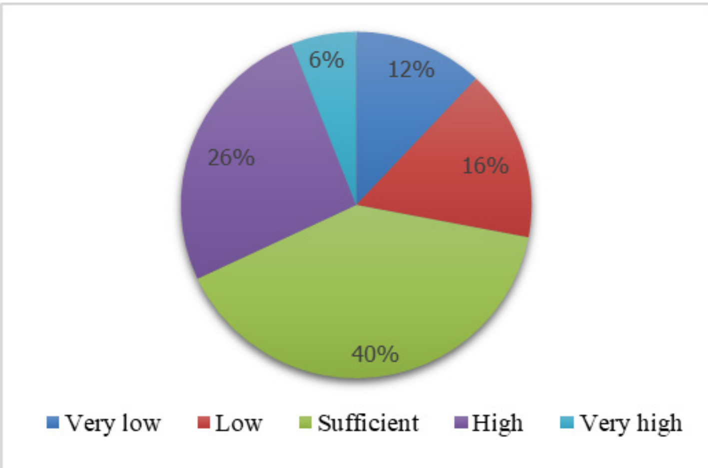

Figure 9. Categorization of Students' Computational Thinking Skills in Science and Mathematics Learning Based on ETSA Scores

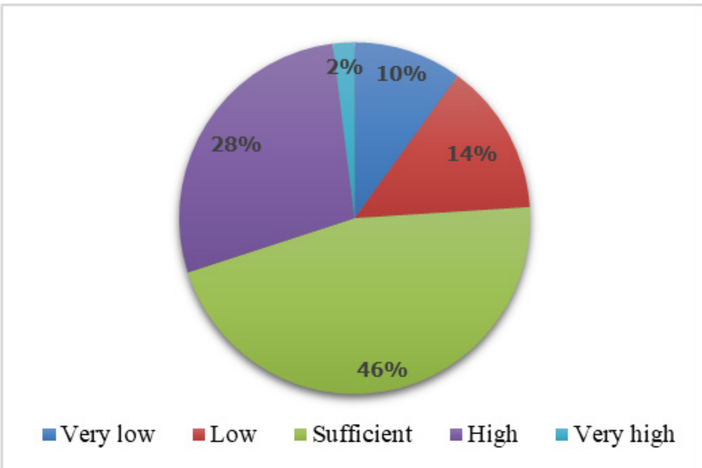

Figure 10. Categorization of Students' Computational Thinking Skills in Science and Mathematics Learning Based on EYSA Scores

Categorization of the computational thinking skills profile of fifth-grade Elementary School students in Surakarta City in science and mathematics learning can be seen from the scores obtained in answering ETSA and EYSA questions in the computational thinking subject, which have been identified as containing elements of computational thinking skills. The average ETSA score was 69,3 with SD 12,6 while the average EYSA score decreased to 67,5 with SD 16,3. Based on the results of the study from the score data processing, students' computational thinking skills in ETSA and EYSA questions were categorized into five levels, namely: very low, low, sufficient, high, and very high.

The profile of students' computational thinking skills in science and mathematics learning can also be categorized by calculating the score results on students' answers to ETSA and EYSA questions. Based on the score results on ETSA and EYSA questions, the percentage of students' computational thinking skills profiles in each category can be seen in figure 9 for ETSA questions and in figure 10 for EYSA questions.

CT skills in science and mathematics learning involve cognitive processes to formulate problems and find solutions algorithmically, with or without computers, and are applicable across a variety of contexts. These skills are essential for the development of problem-solving, critical thinking, creativity, innovation, data literacy, decision-making, and 21st-century competencies. These processes include the following key elements: (a) Reformulating the problem. This redefines the challenge and transforms it into a familiar and solvable format. (b) Recursion. The system is built incrementally based on previously acquired information. (c) Problem decomposition. Complex problems are broken down into manageable and accessible units. (d) Abstraction involves creating simple models that capture the fundamental aspects of a complex problem or system. (e) Systematic testing. Korkmaz(63) concluded that students' computational thinking includes the following skills: creativity, algorithmic thinking, collaboration, critical thinking, and problem-solving. Specifically, students' creativity is defined as self-expression, a skill that is not only related to art but can be used throughout life.

This finding is in line with previous research which states that there is a correlation between computational skills and students' critical thinking.(64) Critical thinking skills can open up thinking space for students that is not limited by distance. Students can do all thinking activities fully. As in this study, science and mathematics learning inherit the potential for computational thinking skills. This learning accommodates the process of achieving full computational thinking skills. In mathematics, computational thinking is very important because it is related to calculations in every question that is worked on. On the same side, in science learning, computational thinking is also needed to achieve students' scientific thinking processes in various ways. This is because computational thinking is not only related to calculations, but also things related to natural thoughts.(65) This can happen with a maximum learning process, such as in the STEAM approach.

Computational skills can also be realized through the STEAM learning process.(66) STEAM is recognized by students as a learning approach that facilitates a variety of skills, referring to science, technology, engineering, art, and mathematics. This is in line with this finding which focuses on computational skills. These skills are in line with the STEAM stages, mathematics specifications.(67) Not only that, their conceptual understanding is also honed as a result of the habit of computational thinking.(68) As previous findings reported that virtual or real teaching affects students' conceptual understanding and process skills.(69) In its implementation, students get different ways of learning that indirectly hone their computational skills. The realization of this ability requires full support from teachers. Therefore, teachers should prepare themselves to fulfill all students' skills. Teachers must fully master learning. In line with previous findings which state that teachers' contributions are very large in supporting students' mastery of computational skills in learning.(70)

CONCLUSIONS

This study analyzed the components of computational thinking skills in ETSA and EYSA assessments and examined the computational thinking skill profiles of fifth-grade elementary school students in science and mathematics learning. The findings indicate that ETSA questions consistently integrate all four components of computational thinking, while EYSA questions vary in coverage, with some including only a single component. Students demonstrated diverse levels of success across different computational thinking components, with pattern recognition emerging as the most mastered skill and decomposition as the least mastered.

Based on these findings, it can be concluded that ETSA provides a more comprehensive assessment of computational thinking skills compared to EYSA in science and mathematics learning. However, the variation in student performance highlights the need for curriculum adjustments to ensure a more balanced mastery of all computational thinking components in science and mathematics learning. Additionally, the observed differences in student success rates suggest that assessment methods should be refined to enhance accuracy in evaluating computational thinking skills. The implications of this study include (1) The curriculum and teaching methods need to be adjusted to emphasize the components of skills that are still lacking; (2) ETSA questions are more consistent in covering all components of computational thinking skills compared to EYSA so that materials and assessments need to be designed in a balanced way; and (3) The need for further evaluation to improve students' computational thinking skills. Further research should explore the underlying factors affecting students' computational thinking proficiency and consider alternative assessment formats, such as essay-based evaluations, for a more in-depth analysis.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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