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How a Computational Thinker Solves a Non-Routine Geometry Task: A Single-Case Study

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Abstract

Problem-solving has become a core element of the mathematics curriculum, where students are encouraged to solve non-routine and higher-order thinking problems (HOTS). However, based on empirical observations in classrooms reveal that many students still struggle to solve problems. Many students often struggle to determine where to begin, especially when faced with non-routine or HOTS tasks of geometry problems. This study investigates how a student with strong computational thinking (CT) skills approaches and solves such problems. This study employs a descriptive qualitative design. The subject was selected using purposive sampling, in which one participant was chosen from a total of 48 respondents based on specific criteria, namely providing correct answers and demonstrating the four components of CT. The findings reveal that the subject utilized four main stages: decomposition, pattern recognition, abstraction, and algorithmic design. In the decomposition phase, the student broke down the square into smaller triangles to simplify the problem. In the pattern recognition stage, the student identified recurring geometric configurations, such as right triangles. During abstraction, irrelevant information was discarded to focus on key components. Finally, the student applied a sequential algorithm involving triangle similarity and the Pythagorean theorem to determine the side length of the square. These findings highlight the potential of computational thinking in enhancing problem-solving performance in geometry. The implications of these findings indicate that CT skills can be applied in instructional design, particularly in problem-solving activities. Students can be guided in engaging in CT processes by using simple questions aligned with each CT component.

Keywords: Abstraction; Algorithms; Decomposition; Computational Thinking, Geometric Problem Solving

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INTRODUCTION

The 21st century has brought about rapid technological advancements that significantly influence educational practices worldwide. In response to this transformation, the Indonesian government has introduced the "Merdeka Curriculum" as a forward-looking educational reform aimed at equipping students with the necessary competencies to thrive in a dynamic and technology-driven era (Hadi et al., 2023; Ndari et al., 2023; Purnomo et al., 2023; Yulianto, 2022). Central to this curriculum are the 4C skills—Creativity, Critical Thinking, Communication, and Collaboration—which are recognized as essential for addressing complex real-world challenges (Berkinbayeva et al., 2023; Thornhill-Miller et al., 2023). Mathematics

education, in particular, plays a pivotal role in developing students' critical and analytical thinking abilities. Problem-solving has become a core element of the mathematics curriculum, where students are encouraged to solve non-routine and higher-order thinking problems (HOTS) (Mazibuko & Maharaj, 2024). These types of tasks are designed to help learners navigate ambiguity, analyze relationships, and draw logical conclusions. However, empirical observations in classrooms reveal that many students still struggle to solve complex problems effectively, despite curricular efforts to enhance such skills (Amalia et al., 2024; Leow & Kaur, 2024; Letchumanan et al., 2022).

The main cause of the difficulties experienced by most students in solving non-routine problems is their lack of information management skills, which are crucial for deciphering and solving such problems (Shawan et al., 2021). Higher Order Thinking Skills (HOTS) are essential in mathematics learning because they encourage students to move beyond memorization and routine procedures toward deeper understanding. By fostering skills of analysis, evaluation, and creation, HOTS help students develop critical thinking abilities in solving complex and contextual problems (Lee et al., 2024; Singh et al., 2020; Somasundaram & Latha, 2021). In the context of the 21st century, mathematics is not merely a tool for calculation but also a means of reasoning, decision-making, and innovation in addressing real-world challenges (Ahsan et al., 2024; Anghel et al., 2020; Jailani et al., 2025; Santaolalla et al., 2020; Zana et al., 2024). Therefore, the implementation of HOTS in mathematics learning can nurture a generation that is more creative, reflective, and adaptive to change, while also strengthening the relevance of learning to everyday life as well as the advancement of science and technology.

The weakness of Higher Order Thinking Skills (HOTS) among mathematics education students remains a significant concern (Ismail et al., 2024; Mohamed & Saleh, 2025; Wulandari & Gusteti, 2021). Many students tend to rely on lower-order thinking skills such as memorizing formulas or following routine procedures without fully grasping the underlying concepts (Tajudin et al., 2018). As a result, they encounter difficulties when faced with tasks requiring analysis, evaluation, or creation, such as designing strategies for solving non-routine problems or connecting mathematical concepts to real-life contexts (Kurniawan et al., 2024). This condition is further exacerbated by learning practices that are still predominantly teacher-centered and outcome-oriented, rather than focused on critical and reflective thinking processes (Ahmat et al., 2022; Campbell et al., 2025; Raj et al., 2022; Zhang et al., 2021).

Higher Order Thinking Skills (HOTS) and Computational Thinking (CT) are closely interconnected, particularly in mathematics education, as both emphasize problem-solving, reasoning, and creativity. HOTS equips students with the ability to analyze, evaluate, and create solutions beyond routine procedures, while CT provides a structured framework through decomposition, pattern recognition, abstraction, and algorithmic design (Ahmat et al., 2022). When integrated, HOTS enhances students' critical reflection and decision-making in applying CT processes, ensuring that problem-solving is not merely mechanical but also conceptually meaningful.

Conversely, CT strengthens the application of HOTS by offering systematic strategies that make abstract reasoning more concrete and applicable to real-world contexts (Pangestika & Cahyaningsih, 2022). The synergy of HOTS and CT thus fosters deeper mathematical understanding, adaptive problem-solving, and the development of 21st-century skills essential for future educators and learners alike (Chongo et al.,

2020). To address these challenges, scholars and educators have turned to computational thinking (CT) as a pedagogical approach that mirrors the problem-solving processes used in computer science and engineering. CT involves four fundamental components: decomposition (breaking down problems), pattern recognition (identifying similarities and trends), abstraction (removing irrelevant details), and algorithm design (formulating step-by-step solutions) (Voon et al., 2022). First introduced this framework as a way to extend computer science thinking into broader educational contexts, and it has since gained relevance in mathematics education (Kandemir et al., 2021).

Researching Higher Order Thinking Skills (HOTS) and Computational Thinking (CT) in geometry learning is essential because geometry serves as a fundamental domain that requires students to engage in abstract reasoning, spatial visualization, and problem-solving (Baskoro et al., 2023; Surjanti et al., 2022). HOTS enables students to analyze, evaluate, and create mathematical ideas beyond procedural understanding, while CT provides systematic strategies through decomposition, pattern recognition, abstraction, and algorithmic design (Aydin & Birgili, 2023; Saltali et al., 2023). The integration of HOTS and CT in geometry allows students to approach non-routine problems more effectively, bridging conceptual understanding with structured problem-solving processes (Ibrahim et al., 2020; Nadarajan et al., 2023).

Furthermore, investigating these two dimensions offers valuable insights into how students develop critical and computational reasoning simultaneously, which is vital for preparing them to face complex challenges in the digital era and for nurturing future competencies in mathematics and STEM education. In the context of geometry, computational thinking provides a structured lens through which students can approach spatial and visual reasoning problems. Geometry often demands not only logical deduction but also the ability to visualize relationships among shapes and their properties (Dewi & Pramesti, 2023; Masfingatin & Maharani, 2019; Widodo et al., 2023). However, based on the literature search, no studies have been found that specifically address the use of CT in solving geometry problems. While several studies have explored computational thinking in programming and science contexts, its application in geometry problem solving particularly in higher education remains under investigated (Abdul Hanid et al., 2022; Hanid et al., 2022; Molina-Ayuso et al., 2024).

This study aims to explore how a high-performing solver applies Computational Thinking (CT) in addressing a non-routine geometry problem. The scope of the research is intentionally limited to a single-case analysis, focusing on one proficient participant selected purposively based on accuracy and the emergence of CT components in their initial responses. By concentrating on a single non-routine square–triangle problem, the study aims to obtain an in-depth understanding of the solver's reasoning patterns rather than generalizing findings across broader populations. The analysis employs inductive coding to categorize the solver's thought processes into CT components—decomposition, pattern recognition, abstraction, and algorithmic thinking. While this design provides rich qualitative insights, it also carries inherent limitations, such as the inability to represent the full range of student strategies and the restricted generalizability of findings beyond the specific case examined.

METHOD

Research Design

This research employed a descriptive qualitative approach within a single-case study design framework to explore how a university student utilizes computational thinking skills in solving a complex geometric problem. A case study method was considered appropriate as it enables an in-depth investigation of cognitive and problem-solving behaviors in a real-world context, particularly focusing on the four dimensions of computational thinking: decomposition, pattern recognition, abstraction, and algorithm design.

Participants and Sampling

The participant was selected using purposive sampling, specifically based on performance and cognitive characteristics. The pool of participants consisted of 48 second-year students from the Mathematics Education program at Universitas Muhammadiyah Malang, who were given a non-routine geometry problem involving the calculation of the side length of a square based on partial triangle information. Among them, six students answered the question correctly. However, only one student provided a solution that clearly indicated step-by-step reasoning aligned with computational thinking processes. This student was also able to articulate their thought process effectively during preliminary discussions, making them an ideal subject for a deeper case analysis.

Instrument or Task

The research instruments included a geometric problem-solving task designed to prompt higher-order thinking and a semi-structured interview protocol aimed at probing the subject's reasoning and decision-making during the problem-solving process. The task required the subject to deconstruct and analyses multiple geometric components—triangles within a square—while the interview further explored their rationale for choosing specific strategies, recognizing patterns, excluding irrelevant information, and developing logical procedures. The problem-solving task used in this study is illustrated in Figure 1. This test item was adopted from the junior high school teacher selection examination for the 105th academic year (2016), this is link https://www.public.tw/prog/dannyer/exam_papers130130/Uploads/105台北市國中-數學.pdf.

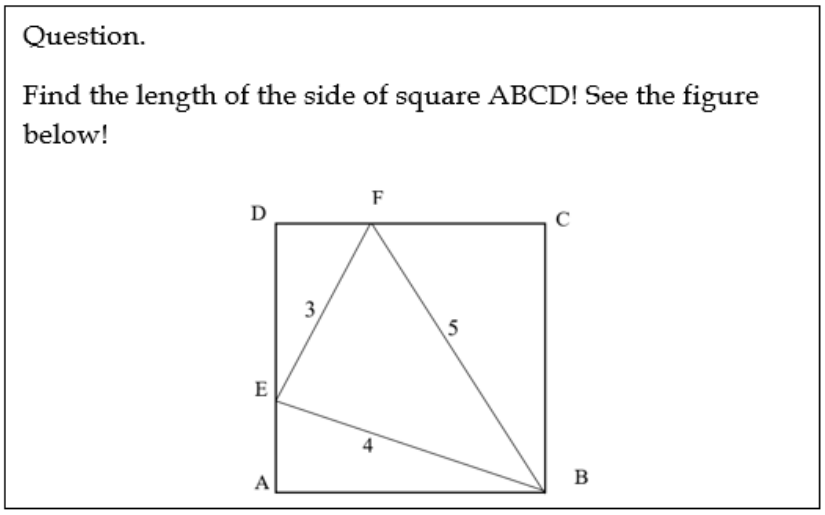


Figure 1. Geometry problem

Procedure

Data collection involved three main stages: (1) administering the geometry problem in a controlled setting, (2) collecting the subject's written responses, and (3) conducting a semi-structured interview to gain insight into the student's cognitive process. The interview, which lasted approximately 30 minutes, was recorded with the subject's consent and transcribed for analysis. During the interview, the researcher used guided prompts such as "What was the first thing you noticed?" or "Why did you ignore this shape?" to elicit detailed responses.

Data Analysis

The collected data were analysed thematically using the procedures outlined by Miles et al (2014). Analysis began with data condensation—extracting and organizing relevant statements from written work and interviews. This was followed by open coding to identify instances of computational thinking behaviors. These codes were then grouped into categories representing each of the four computational thinking components. Finally, the categories were interpreted to develop a cohesive understanding of how the subject navigated the problem-solving process.

Trustworthiness and Ethics

To ensure the validity of the findings, the study used source triangulation by comparing the written solution with the verbal explanations during the interview. Additionally, member checking was conducted by presenting the interpreted findings back to the subject for verification, ensuring that the researcher's interpretations accurately reflected the subject's intended meaning. Ethical approval was obtained from the university's research ethics committee, and informed consent was secured from the participant, with assurance of confidentiality and voluntary participation.

RESULTS AND DISCUSSION

Decomposition

In the decomposition stage, the student broke down the complex geometric problem into smaller, more manageable sub-problems. The initial problem provided limited information—only the lengths of sides BF, BE, and EF were given. To determine the side length of square ABCD, the student divided the square into four triangles and aimed to calculate the lengths of their sides individually. A segment of the interview supports this observation.

Researcher: What kind of problems do you think are present in this question?

Student: There are many problems within the square. A lot of information needs to be found. I think I need to observe and analyse the parts inside the square.

Researcher: What specific information are you looking for?

Student: 'I need to find the lengths of the triangle sides that are not given. There are three triangles, and I need to determine the side lengths of each one.

As shown in Figure 2, the student's decomposition involved several steps: (1) identifying the shapes within the square, (2) recognizing that certain triangles were right-angled, and (3) determining the lengths of their sides. This process exemplifies the core principle of decomposition in computational thinking—breaking down a complex structure into simpler, solvable parts.

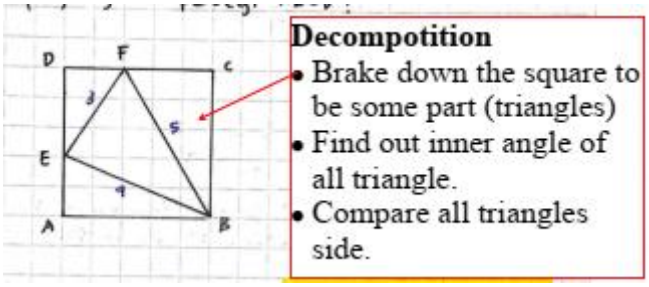


Figure 2. Decomposition

Pattern Recognition

In the second stage, pattern recognition, the student identified and classified the geometric shapes present within square ABCD. Specifically, the student noted the existence of right triangles based on the known side lengths of 3, 4, and 5, which satisfy the Pythagorean theorem. Additionally, the student inferred that the remaining triangles within the square were also right triangles, based on the square's internal right angles. This inference is supported by the following interview excerpt.

Researcher: What shapes do you observe in the diagram?

Student: First, I see a right triangle with side lengths 3, 4, and 5—it must be a right triangle. The triangles above and below also appear to be right-angled. When compared, they seem to be similar.

The student's ability to recognize and classify right triangles based on angle properties and side-length patterns indicates a clear application of pattern recognition in computational thinking (Figure 3). Recognizing that the angles and proportions matched allowed the student to make valid mathematical generalizations necessary for the solution.

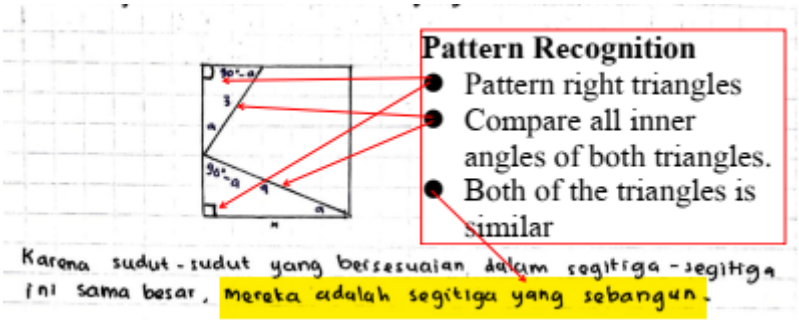


Figure 3. Pattern Recognition

Abstraction

In the abstraction phase, the student selectively focused on relevant data and disregarded unnecessary information. For instance, although the problem contained a triangle with side lengths 3, 4, and 5, the student strategically ignored certain triangle elements that did not contribute directly to solving the problem.

Researcher: Was there any information you chose not to use?

Student: Yes, there was a triangle with side lengths of 3, 4, and 5. This forms a right triangle based on the Pythagorean theorem. But there was another triangle I didn't use because its sides were harder to calculate.

This behavior demonstrates abstraction, where the student filtered out non-essential parts of the problem to streamline the solution process. Such cognitive

filtering is crucial in computational thinking, particularly when navigating problems with complex or distracting elements (see Figure 4).

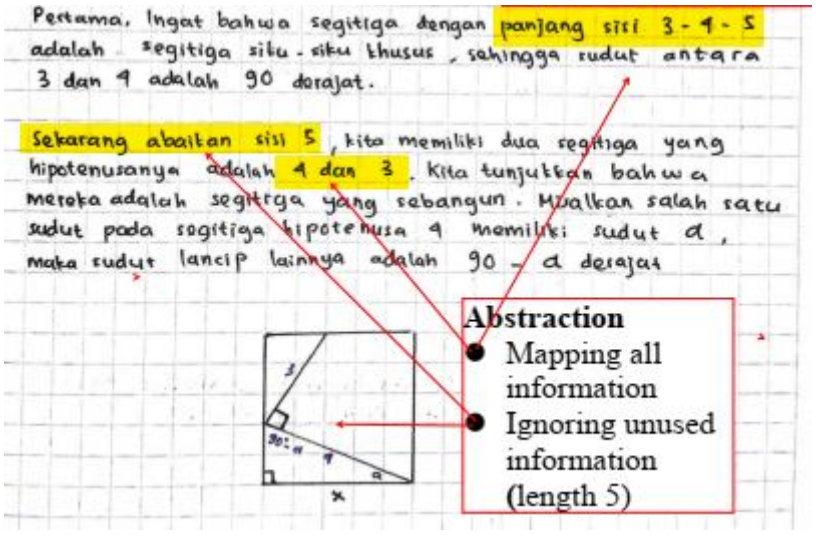


Figure 4. Abstraction

Algorithm

In the final stage, the student formulated and applied a logical sequence of steps to solve the problem (Figure 5). The approach began with identifying the geometric shapes and their properties, followed by recognizing triangle similarity based on corresponding angles and proportional sides. Using these properties, the student set up ratios between the sides of similar triangles. Once all necessary side lengths were determined, the student applied the Pythagorean theorem to find missing lengths and ultimately the side length of square ABCD. This strategic sequence illustrates the development of an algorithmic process—a hallmark of computational thinking—which the student followed systematically to reach a correct solution.

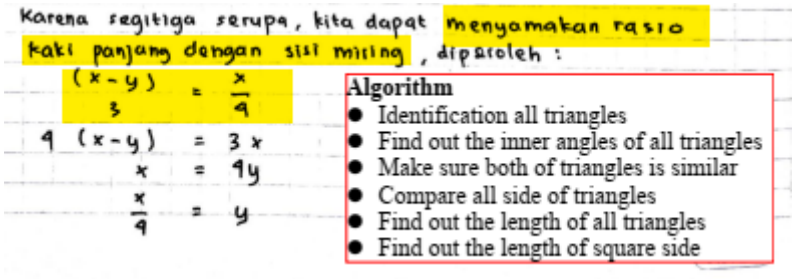


Figure 5. Algorithm

Discussion

The findings of this study highlight the role of computational thinking (CT) as a systematic framework in addressing complex geometric problems. The subject demonstrated clear engagement in all four stages of CT decomposition, pattern recognition, abstraction, and algorithm design—which aligns with previous research emphasizing the importance of CT in mathematics learning (Aydin & Birgili, 2023; Voon et al., 2022). By breaking down a complex square-based problem into simpler components, the student was able to transform a seemingly overwhelming task into manageable sub-problems. This supports the idea that decomposition is essential in reducing cognitive load and guiding learners toward feasible solution paths (Saltali et al., 2023).

The pattern recognition process shown in the student's reasoning reflects how learners can leverage prior mathematical knowledge, particularly the recognition of right triangles and proportional relationships. This aligns with the findings of (Masfingatin & Maharani, 2019), who reported that CT helps students generalize and transfer previously learned geometric concepts to new contexts. The identification of right-angled triangles within the square not only facilitated accurate reasoning but also enabled the student to use properties such as similarity and the Pythagorean theorem efficiently. Another important outcome of this study is the demonstration of abstraction. The student filtered out irrelevant details and focused only on essential information. Such selective attention is consistent with (Ibrahim et al., 2020), who argued that abstraction is a vital bridge between conceptual understanding and efficient problem-solving. In practice, abstraction allowed the student to ignore distracting elements while concentrating on key geometric relationships, which is particularly useful when solving higher-order thinking problems that require precision and clarity of reasoning.

The final stage, algorithm design, revealed the student's ability to construct a logical sequence of steps that combined multiple strategies, such as similarity and the Pythagorean theorem. This structured approach resonates with the work of Lee et al. (2024), who suggested that CT not only enhances mathematical reasoning but also cultivates systematic strategies applicable across STEM disciplines. The student's problem-solving trajectory reflects the iterative nature of CT, where each stage builds upon the previous one to reach an optimal solution. Overall, this study reinforces the close interconnection between CT and Higher-Order Thinking Skills (HOTS). While HOTS provide the critical and creative foundation, CT offers a procedural structure that makes reasoning more concrete and actionable. The integration of both dimensions can empower students to tackle non-routine problems with confidence, moving beyond rote memorization toward adaptive and reflective problem-solving. These results suggest that incorporating CT explicitly into mathematics instruction, particularly in geometry, can strengthen students' cognitive flexibility, analytical skills, and preparedness for real-world challenges in the digital era.

This study employed a single participant, which inherently limits the generalizability of the findings. The participant was selected from a group of correct responders, introducing a potential ceiling-effect bias because the solver was already performing at a high level. Furthermore, the study used only a single item, restricting the breadth of evidence that could be collected about the participant's problem-solving processes. Another limitation is the lack of inter-coder reliability, as the coding and interpretation of the participant's responses were not independently validated by multiple coders. Finally, the absence of a delayed post-test to measure transfer prevents conclusions about the durability or adaptability of the participant's computational thinking skills over time The implications of these findings indicate that CT skills can be applied in instructional design, particularly in problem-solving activities. Students can be guided in engaging in CT processes by using simple questions aligned with each CT component.

CONCLUSION

This study provides evidence that computational thinking (CT) can serve as an effective framework for solving complex geometric problems. The subject demonstrated the ability to engage in all four stages of CT decomposition, pattern

recognition, generalization and abstraction, and algorithm design through a systematic and logical problem-solving process. Decomposition allowed the problem to be simplified into smaller sub-tasks, pattern recognition facilitated the use of prior mathematical knowledge such as right-triangle properties, abstraction enabled the focus on relevant information, and algorithm design provided a structured sequence to reach the solution. These findings confirm that CT is not only a tool for computer science but also a transferable skill that enhances mathematical reasoning, especially in geometry. The study also highlights the strong interconnection between Higher Order Thinking Skills (HOTS) and CT, where HOTS cultivate critical and creative thinking while CT provides procedural strategies to operationalize such thinking effectively. The implications of this research suggest that integrating CT explicitly into mathematics learning can improve students' ability to approach non-routine problems, strengthen conceptual understanding, and foster adaptive problem-solving skills. Future studies may expand this investigation by involving more participants, exploring different mathematical domains, or integrating digital tools to support the development of CT in diverse learning contexts.

RECOMMENDATION

This study provides valuable insights into how computational thinking skills can support students in solving complex geometric problems. Through a focused case study, it was observed that the student engaged in all four core components of computational thinking—decomposition, pattern recognition, abstraction, and algorithm design—during the problem-solving process. Decomposition enabled the student to break the problem into smaller, manageable parts, while pattern recognition helped identify mathematical relationships and shape similarities. Abstraction allowed the student to disregard irrelevant information and focus on critical elements, and algorithmic thinking led to a systematic solution strategy based on geometric principles such as triangle similarity and the Pythagorean theorem. These findings suggest that computational thinking can serve as a powerful cognitive framework for tackling non-routine problems in mathematics. Therefore, integrating computational thinking into mathematics instruction may enhance students' analytical abilities, foster deeper conceptual understanding, and better prepare them to navigate future academic and real-world challenges.

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Conflict of Interest Statement

Authors state no conflict of interest.

Data Availability

Data availability is not applicable to this article because no new data were created or analyzed in this study.

Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
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A. A. Putri Rosyadi					✓			✓		✓				
D. W. Ekowati				✓		✓	✓				✓			
Erna Yayuk	✓									✓				✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

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