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Students' Computational Thinking Abilities in Geometry Problem Solving: The Role of Self-Efficacy

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Abstrak

Kemampuan berpikir komputasi sangat krusial dalam pembelajaran geometri yang memerlukan penalaran logis dan terstruktur. Selain aspek kognitif, kemampuan ini dipengaruhi oleh aspek afektif seperti efikasi diri. Penelitian ini bertujuan menganalisis kemampuan berpikir komputasi mahasiswa dalam menyelesaikan masalah geometri serta mengkaji peran efikasi diri dalam membedakan kualitas kemampuan tersebut. Menggunakan metode kualitatif dengan desain studi kasus, penelitian ini melibatkan 60 mahasiswa semester lima Program Studi Pendidikan Matematika di Universitas Islam Negeri K.H. Abdurrahman Wahid Pekalongan. Instrumen yang digunakan meliputi tes berpikir komputasi, kuesioner, wawancara, dan observasi. Data dianalisis melalui teknik analisis isi yang mencakup reduksi, kategorisasi, dan penarikan kesimpulan. Hasil penelitian menunjukkan bahwa mahasiswa dengan efikasi diri tinggi memiliki kemampuan berpikir komputasi yang lebih unggul dibandingkan mahasiswa dengan efikasi diri rendah. Temuan ini menegaskan pentingnya efikasi diri dalam membentuk profil berpikir komputasi dan berimplikasi pada pengembangan strategi pembelajaran matematika yang mengintegrasikan aspek kognitif serta afektif.
***Kata Kunci**: Efikasi Diri; Geometri; Kemampuan Berpikir Komputasi.*

Abstract

Computational thinking is essential in geometry education, as it demands logical, systematic, and structured reasoning. Beyond cognitive dimensions, this ability is significantly influenced by affective factors, particularly self-efficacy. This study aims to analyze students' computational thinking skills in solving geometric problems and examine how self-efficacy differentiates the quality of these skills. Employing a qualitative case study design, the research involved 60 fifth-semester Mathematics Education students at Universitas Islam Negeri K.H. Abdurrahman Wahid Pekalongan. Data were collected through computational thinking tests, questionnaires, interviews, and observations, and subsequently analyzed using content analysis techniques, including data reduction, categorization, and conclusion drawing. The findings reveal that students with high self-efficacy demonstrate superior computational thinking abilities compared to those with low self-efficacy. This study underscores the critical role of self-efficacy in shaping computational thinking profiles and suggests the need for integrated cognitive-affective instructional strategies in mathematics education.
Keywords: Computational Thinking Abilities; Geometry; Self-Efficacy.

I. INTRODUCTION

Computational thinking is an essential capability in the digital era and had become a major focus in the development of mathematics education. Computational thinking is defined as a cognitive process that involves framing problems and developing solutions that can be carried out by humans, machines, or both (Wing, 2006; Weintrop et al., 2016). In mathematics learning, computational thinking plays a crucial role in supporting students' ability to solve mathematical problems effectively, particularly in topics that are complex and abstract, such as geometry (Dagienė & Sentance, 2016; Grover & Pea, 2013; Shute et al., 2017).

Geometry is one of the mathematical domains that often presents difficulties for university students, as it requires strong visualization skills, spatial reasoning, and higher-order problem-solving abilities. Solving geometric problems demands not only conceptual understanding but also well-structured computational thinking abilities (Freudenthal, 1971; Hohenwarter & Jones, 2007). However, students' computational thinking abilities vary considerably. These differences are influenced not only by cognitive factors but also by psychological factors, particularly self-efficacy (Salsabila et al., 2021). Self-efficacy refers to an individual's belief in their ability to successfully perform specific tasks and has been shown to significantly affect academic performance and problem-solving success (Bandura, 1997; Honicke & Broadbent, 2016).

Research on computational thinking in education has expanded substantially alongside the increasing integration of technology into teaching and learning process. The notion of computational thinking was initially introduced by Seymour Papert in the 1980s through his contributions to programming and educational theory, and it has since been widely adopted in educational curricula worldwide (Papert, 1980). Subsequent studies have examined various dimensions of computational thinking, including its definitions, core components, and applications across educational contexts (Wing, 2006). Moreover, numerous studies have emphasized computational thinking as a transferable competence that should be systematically developed within mathematics education (Grover & Pea, 2018; Sengupta et al., 2018).

In the context of mathematics learning, particularly geometry instruction, computational thinking contributes to the enhancement of students' abilities in geometric visualization and manipulation, pattern recognition, and the development of algorithmic problem-solving strategies (Dagienė & Sentance, 2016; Simanjuntak et al., 2023). Nevertheless, existing research reveals inconsistencies regarding the relationship between computational thinking and self-efficacy. Some studies report that high levels of self-efficacy positively contribute to students' computational thinking abilities (Honicke & Broadbent, 2016; Wang & Xu, 2024), while others indicate that additional factors, such as educational background and technological support, also play a significant role (Ansori, 2020; Grover & Pea, 2018; Marifah & Kartono, 2023; Salsabila et al., 2021).

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As the integration of technology in education continues to intensify, computational thinking has become an increasingly prioritized skill within educational curricula, particularly in STEM-related disciplines (Science, Technology, Engineering, and Mathematics). However, debates regarding the extent to which computational thinking effectively enhances mathematical problem-solving abilities remain going. Several researchers emphasize the importance of considering psychological factors, especially self-efficacy, in achieving optimal learning outcomes (Christi & Rajiman, 2023; Siregar, 2022). In this context, the present study intends to address gaps in the existing literature by investigating the relationship between students' computational thinking and self-efficacy in the context of geometry problem solving. Accordingly, this study contributes by theoretical understanding of the interplay between cognitive and affective factors in computational thinking and to provide practical implications for curriculum development and instructional strategies in mathematics education.

II. METHOD

This study utilized a qualitative case study approach to obtain a comprehensive understanding of students' computational thinking abilities in geometry problem solving with respect to their self-efficacy (Creswell & Plano Clark, 2018). This approach was selected because it enables an in-depth exploration of how cognitive processes unfold during problem solving, particularly when examined through different levels of self-efficacy (Tashakkori & Teddlie, 2010).

The research was conducted in the Mathematics Education Program at Universitas Islam Negeri (UIN) K.H. Abdurrahman Wahid Pekalongan, chosen based on contextual relevance and the availability of appropriate research participants. The research participants consisted of 60 fifth-semester students enrolled in the Mathematics Education Program. Students' self-efficacy levels were measured using a questionnaire based on Bandura's framework, administered prior to the computational thinking test. Based on the questionnaire scores, students were categorized into low, moderate, and high self-efficacy groups using a mean-based classification, where scores below the mean were classified as low self-efficacy, scores around the mean as moderate self-efficacy, and scores above the mean as high self-efficacy. From these groups, three students, M1 (low self-efficacy), M2 (moderate self-efficacy), and M3 (high self-efficacy) were purposively selected for in-depth qualitative analysis. This selection aimed to represent contrasting self-efficacy profiles and to enable a detailed comparison of computational thinking process across different self-efficacy levels. In this study, self-efficacy was positioned as the independent variable, while computational thinking was considered the dependent variable.

Data were collected using multiple instruments, including a computational thinking based on geometry problem-solving test, a questionnaire using a Likert scale, interview guidelines, and observation sheets. The computational thinking test consisted of geometry problem-solving items designed to assess four core computational thinking indicators, namely problem decomposition, pattern recognition, abstraction, and algorithmic thinking (Wing, 2006; Weintrop et al., 2016).

Problem decomposition was assessed through items requiring students to identify known and unknown elements and to break complex geometry problems into smaller components. Pattern recognition was examined by tasks that required students to identify relationships among geometric elements, such as angle relationships and properties of tangents. Abstraction was evaluated by students' ability to filter relevant information and generalized geometric relationships. Algorithmic thinking was assessed through the construction of systematic and logical solution steps leading to a correct conclusion.

The questionnaire was used to classify participants according to their level of confidence in their computational thinking abilities when completing academic tasks, particularly within the context of geometry learning, following Bandura's conceptualization of self-efficacy (Bandura, 1997). Meanwhile, interviews and observations focused on revealing students' thinking process, problem-solving strategies, and reflections during the problem-solving activities.

The research procedure was conducted through several stages, beginning with preparation stage, which included a literature review and pilot testing of the research instruments, a data collection stage through test administration, questionnaire distribution, interviews and observations, and a data analysis stage. Qualitative data were analyzed using content analysis techniques to identify key themes related to students' computational thinking processes (Krippendorff, 2019) including data reduction, categorization (data display), and conclusion drawing, to identify major themes related to students' computational thinking process. To ensure data trustworthiness, method triangulation was employed by comparing data obtained from tests, interviews, and observation, thereby ensuring the credibility and consistency of the researcher's interpretations with participants' experiences.

III. Result and Discussion

This section reports the research findings obtained from the analysis of qualitative data concerning students' computational thinking in solving geometry problems across different levels of self-efficacy. The data presentation focuses on a comparison of students' computational thinking abilities across low, moderate, and high self-efficacy levels, as analyzed using four indicators of computational thinking namely problem decomposition, pattern recognition, abstraction, and algorithmic thinking. Students' written test results are integrated with findings from interviews and observations to provide a comprehensive depiction of the computational thinking abilities demonstrated by students at each level of self-efficacy.

A. Result

The result findings indicate difference in students' computational thinking abilities in

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geometry problem solving based on their levels of self-efficacy. The variation in computational thinking demonstrated by students across different self-efficacy levels indicated that self-efficacy serves a crucial role in shaping the quality of computational thinking

Wing (2006) emphasizes that computational thinking entails the integrated use of problem decomposition, pattern, recognition, abstraction, and algorithmic thinking to effectively manage problem complexity. Students with high self-efficacy tended to demonstrated greater effectiveness in problem decomposition. This findings supports Bandura's (1997) theory, which posits that individuals with high self-efficacy possess stronger confidence in addressing cognitive challenges and exhibit greater persistence when solving complex problems. In contrast, students with lower levels of self-efficacy tended to experience difficulties in managing problem complexity, which subsequently led to errors at the initial stages of problems solving.

With respect to pattern recognition and abstraction, students with high self-efficacy were better able to identify relationships among concepts and filter essential information from the problem context. Conversely, students with low self-efficacy tended to rely on mechanical procedures without a deep understanding of the underlying problem stucture. These findings supports the argument of Shute et al. (2017) who assert that pattern recognition and abstraction are core components of affective computational thinking.

In terms of algorithmic thinking, students with high self-efficacy demonstrated greater consistency in constructing systematic and coherent solution steps. Papert (1980) emphasized that algorithmic thinking serves as a fundamental component of computational thinking, as it enables individuals to design planned and logical solution. The algorithmic errors observed among students with low self-efficacy reflect limitations in integrating conceptual understanding with procedural knowledge.

Overall, the findings of this study reinforce previous research indicating that self-efficacy significantly contributes to students' computational thinking abilities (Honicke & Broadbent, 2016; Wang & Xu, 2024). Students with high self-efficacy not only exhibited superior performance but also demonstrated greater persistence and confidence when engaging with complex geometry problems. Differences in the quality of students' responses across self-efficacy levels should therefore be a central consideration in mathematics instruction, particularly in geometry topics that require higher-order thinking skills.

B. Discussion

The analysis of computational thinking was conducted using four main indicators: problem decomposition, pattern recognition, abstraction, and algorithmic thinking. To strengthen the analysis, students' written test results were triangulated with data obtained from interviews and clasroom observations.

Students with low self-efficacy (M1) demonstrated limited computational thinking abilities. This condition is evident from M1's written responses, as illustrated in the excerpt of students' answer representing the low self-efficacy.

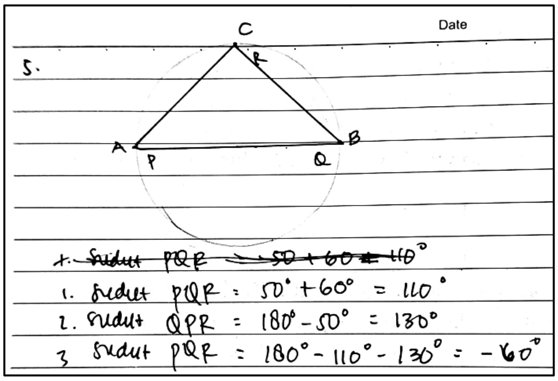

Figure 1. Excerpt of Students with Low Self-Efficacy.

As shown in Figure 1, M1 was unable to decompose the geometry problem accurately. The students' response to the given geometry task reveals several significant weakness when examined through the four indicators.

Regarding problem decomposition, the student attempted to solve the problem by calculating the angles of triangle PQR individually. However, a fundamental error occured in the decomposition process. The student failed to break down the problem into components that aligned with the underlying geometric concepts. Specifically, the student did not recognize that the angles of traingle PQR should be determined based on the properties of tangents to the circle that touches triangle ABC, rather than by directly summing the angles of triangle ABC.

In the terms of pattern recognition, the student tended to apply a general rule concerning the sum of interior angles of a triangle (180°) without considering the specific characteristics of geometric figures involving tangent circles. The student was unable to recognize that the angles in triangle PQR cannot be directly derived from those in trangle ABC without accounting for the geometric relationships formed by the tangential lines. This error reflects a limitation in recognizing and applying more complex geometric patterns.

With respect to abstraction, the student attempted to simply the problem by focusing on the given angles and basic geometric rules. However, the abstraction process was overly simplistic and failed to capture the essence of the problem, namely the relationship between the triangle formed by tangential lines and the original triangle. This inadequate abstraction led to misconceptions regarding the corrrect determination of the angles in triangle PQR.

Finally, in terms of algorithmic thinking, the students followed a sequence of steps that appeared logical, such as adding angles or subtracting values from 180°. Nevertheless, the algorithm applied was not appropriate for the given problem. Misunderstanding the geometric basis for determining the angles in triangle PQR resulted in the use of incorrect procedures, such as assuming that angle PQR is the sum of angles A and B in triangle ABC. This finding indicates that the student had not yet developed the ability to design accurate and systematic solution steps grounded in relevant geometric concepts.

Overall, the responses of students with low self-efficacy reflect difficulties in effectively applying all four indicators of computational thinking. Weaknesses in problem decomposition, inappropriate pattern recognition, insufficient abstraction, and inaccurate algorithmic thinking collectively contributed to incorrect solutions. Therefore, strengthening students' conceptual understanding of geometry and fostering the systematic application of computational thinking strategies are essential, particularly for students with low self-efficacy.

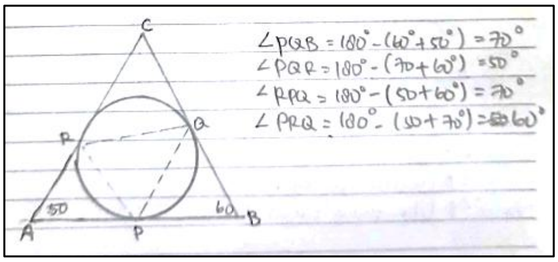

Figure 2. Excerpt of Students with Moderate Self-Efficacy.

Based on Figure 2, students with a moderate level of self-efficacy (M2) were able to identify relevant information and perform problem decomposition in a more structured manner. In terms of pattern recognition, M2 were able to determine the relationships among the involved angles; however, inconsistencies were still observed in the calculation process. Errors in the initial calculations, such as inaccuracies in determining angles PQR and PRQ, indicate shortcomings in verification and carefulness that are required to achieve accurate solutions. These findings are further corroborated by the interview data, which reveal that the students were not fully confident in the algorithmic steps they applied, leading to errors during the result verification stage. The ability to detect and correct errors, as well as to apply appropriate solution strategies, requires a higer level of computational thinking. Based on this analysis, the students' responses reflect a moderate level of computational thinking, as they demonstrate a sound foundational understanding but still require improvement in terms of accuracy and consistency in calculations.

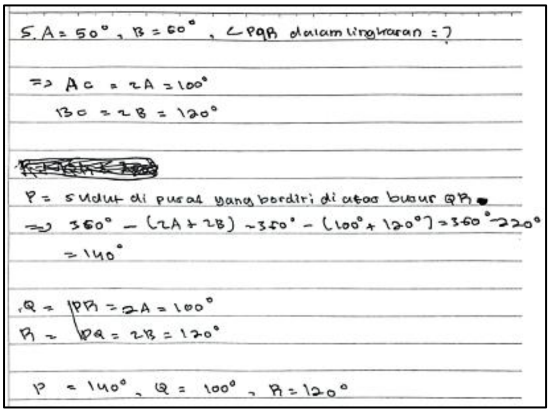

Figure 3. Excerpt of Students with High Self-Efficacy.

Meanwhile, students with a high level of self-efficacy (M3) demonstrated the most optimal computational thinking abilities. This was reflected based on Figure 3, in which they were able to decompose the problem systematically, recognize patterns in the relationships among geometric elements, and construct coherent and logical algorithmic steps. At the abstraction stage, M3 was able to simplify the problem without omitting essential information. Although minor errors were still identified at the final calculation stages, the overall thinking process exhibited by M3 aligned well with the expected indicators of computational thinking. These findings were further supported by interview results, which revealed a high level of confidence and persistence in solving the given problems.

The calculation steps presented reflect the application of fundamental principles of computational thinking, such as applying mathematical formulas and identifying relationships among angles in geometry. This approach requires proficiency in organizing and correctly implementing mathematical procedures. However, errors in the calculation of angles Q dan R indicate shortcoming in accuracy and result validation, which may affect the final outcome. The ability to systematically identify and correct such errors and to ensure the consistency of results reflects a higher level of computational thinking. Based on this analysis, the response demonstrates a high level of computational thinking, as it shows a sound foundational understanding and appropriate application of principles, despite remaining weaknessess in result verification and consistency that require improvement.

Based on result and discussion, students with low self-efficacy tend to make errors in applying algorithms, as illustrated in this case, where the algorithm employed was not appropriate for the problem at hand. Previous studies have demonstrated that levels of self-efficacy can influence students' computational thinking abilities. For example, a study by Honicke & Broadbent (2016) and Wang & Xu (2024) reported that students with higher self-efficacy were more successful in solving computational and geometry problems, as they exhibited greater confidence and persistence in identifying appropriate solutions. In contrast, students with low self-efficacy tend to experience anxiety and hesitation, which may hinder their ability to engage in computational thinking effectively.

IV. Conclusion

The findings highlight the significant role of self-efficacy in influencing the effectiveness of students' computational thinking. Self-efficacy denotes an individual's belief in their ability to accomplish desired objectives, has been shown to significantly affect learning outcomes and performance Bandura (1997). Students' computational thinking abilities are closely associated with their levels of self-efficacy. Consequently, efforts to improve computational thinking should incorporate instructional strategies that strengthen students' self-efficacy, including supportive feedback, scaffolding, and the creation of learning environments that encourage confidence and perseverance involving mathematical problems.

The study demonstrates that students' self-efficacy serves a critical role in determining the quality of computational thinking abilities in geometry problem solving. In particular, the detailed analysis of students with low self-efficacy reveals that difficulties in computational thinking often emerge at the earliest stage, namely problem decomposition. These findings indicate that errors in later stages, such as pattern recognition, abstraction, and algorithmic thinking, may stem from an initial failure to correctly decompose the problem. One limitation of this study is that the in-depth qualitative analysis focused on a small number of representative cases; however, this approach allowed for a detailed examination of how specific weakness in computational thinking are manifested across different self-efficacy levels.

Based on the findings, instructional interventions should be designed to address specific weakness in computational thinking, particularly for students with low self-efficacy. Since students such as M1 experienced significant difficulties at the problem decomposition stage, teachers are encouraged to provide targeted scaffolding

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that focuses on guiding students to identify relevant information, break complex geometry problems to manageable components, and explicitly connect given data to underlying geometric concepts. Such scaffolding may include the use of guiding questions, worked examples emphasizing decomposition, and structed problem-solving templates before students proceed to subsequent stages of pattern recognition and algorithmic thinking.

This findings of this study suggest several instructional strategies to enhance both students' self-efficacy and computational thinking abilities. Problem-based learning and the integration of technology are identified as effective approaches for fostering computational thinking abilities (Jonassen, 2011). In addition, collaborative learning and constructive feedback play a crucial role in supporting the development of these skills, as emphasized by Hattie & Timperley (2007). By integrating these instructional strategies, students are expected to develop stronger computational thinking abilities and achieve more optimal learning outcomes (Grover & Pea, 2013; Miller & McNear, 2018).

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