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COGNITIVE PSYCHOLOGY AS A SOLUTION FOR INTEGRATING COMPUTATIONAL THINKING IN MATHEMATICS EDUCATION

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Abstract: *Integrating computational thinking skills into mathematics education poses a particular challenge, especially for students with cognitive barriers or learning difficulties. This study aims to examine relevant strategies for addressing the challenges of integrating computational thinking into mathematics learning through a cognitive psychology approach. Employing a literature review method, the research explores a variety of scholarly sources that discuss factors contributing to learning difficulties, both internal (such as cognitive and neurobiological development) and external (such as instructional design and teaching methods). The findings indicate that a cognitive psychological approach can be an effective solution, as it emphasizes thinking processes, motivation, and emotion in learning. Teachers must design instructional strategies that are responsive to students' cognitive capacities and support the development of computational thinking components, including problem decomposition, abstraction, pattern recognition, procedural algorithms, and generalization. With appropriate interventions, mathematics learning can shift its focus beyond content mastery to the sustainable development of computational thinking skills.*
Keywords: *Cognitive Psychology; Computational Thinking; Mathematics; Education.*

Introduction

Contemporary educational development is no longer confined to mastering conceptual content but is increasingly directed toward activating students' cognitive processes. However, this approach remains relatively novel in Indonesia, partly due to teachers' paradigms that emphasize content mastery. As a result, instruction tends to prioritize knowledge acquisition over the development of competencies, including in mathematics education.

According to various studies in the United States on primary and secondary school students cited by the Ministry of National Education through the Research and Development Agency (Yuliardi, 2017), approximately 5% of students were identified as having learning developmental barriers. In Indonesia, this percentage is higher, ranging between 10% and 15% of the total number of elementary and middle school students. Nisa (2020) suggests that mathematics learning requires the integration of students' visual and motor abilities. Nari and Musfika (2016) add that understanding the meaning of numbers is more critical than simply reciting them. Students' difficulties in conceptually solving math problems can stem from internal factors such as intelligence, interest, and emotion, as well as external ones like family environment, school setting, instructional methods, and learning media. These factors contribute to poor academic performance, including delays in task completion and low engagement during instruction.

Education plays a strategic role in preparing high-quality, globally competitive human resources, particularly in response to the demands of the 21st-century digital era. To address these needs, the Organisation for Economic Cooperation and Development (OECD) regularly conducts the Programme for International Student Assessment (PISA), an international study designed to evaluate education systems worldwide. Indonesia's PISA results in 2018 revealed relatively low performance, with a mathematics score of only 379—well below the international average (Ahsan et al., 2019). As technology evolves, the PISA 2021 framework draft released in 2018 introduced an expanded assessment focus, including computational thinking as a new indicator (Puspitasari et al., 2023). Computational thinking is defined as the ability to transform mathematical knowledge into a form that can be represented through programming languages, enabling dynamic modeling of mathematical concepts and relationships. Key components of computational thinking applicable in mathematics education include problem decomposition, abstraction, pattern recognition, algorithmic procedures, and generalization (Helsa, 2023).

These shifts in the educational landscape demand that teachers design learning experiences aligned with current curricular standards. The Merdeka Curriculum in Indonesia emphasizes authentic assessment based on the 6C framework, which includes computational thinking (Ni'am et al., 2022). This introduces a new challenge for educators to identify effective instructional strategies and to promote computational thinking as a core student competency, particularly in mathematics. The development of computational thinking abilities in education is significantly influenced by individual characteristics, such as cognitive style. Cognitive style—reflecting how individuals perceive and process information—has emerged as a critical variable in mastering computational thinking (Desmita, 2009). Since each learner has distinct cognitive preferences, their comprehension, interpretation, and application of computational thinking concepts in problem-solving also vary.

Given the aforementioned considerations, this study explores appropriate strategies to address these challenges and support students in overcoming the difficulties of integrating computational thinking into mathematics education by adopting a cognitive psychology approach.

Method

This study employed a library research method, which involves analyzing concepts through the review of relevant sources such as journals, books, and scientific articles related to the research topic (Maskar, 2019). The focus of this study is to explore strategies for addressing challenges in integrating computational thinking skills into mathematics education using a cognitive psychology approach. The data sources were obtained from books, nationally accredited journals and reputable international journals. The analysis was carried out using a thematic approach to identify the relationship between the cognitive psychology approach and instructional management strategies. In the initial stage, the authors collected relevant literature and conducted an in-depth analysis of references that support the framework of the discussed issues. All references serve as the theoretical foundation for exploring concepts and supporting the problem analysis.

Findings and Discussion

Findings

Support from various stakeholders—teachers, parents, and the school ecosystem—is crucial in addressing the challenges of integrating computational thinking into mathematics instruction. Teachers, as the primary agents in the learning process, must accommodate diverse student abilities, including those who easily grasp concepts and those who struggle. Therefore, teachers need effective and adaptive instructional strategies and methods when dealing with students facing learning difficulties.

Mathematical concepts often involve high levels of abstraction, which necessitates a structured instructional flow when integrating computational thinking into math education to reinforce new concepts being introduced (Purwaningrum, 2017). This approach aims to strengthen five core components of computational thinking: problem decomposition, abstraction, pattern recognition, algorithms procedures, and generalization. Strengthening these elements is expected not only to reinforce students' long-term memory retention but also to embed computational thinking into their thought patterns and behavior. As such, the development of computational thinking skills must be aligned with students' cognitive development stages to ensure effective and relevant learning.

According to the National Institute of Health (USA), as cited in Ridwan Idris (2009:153), a significant discrepancy between intelligence levels and academic achievement is a major factor contributing to learning difficulties in children and adolescents. Such difficulties may be triggered by neurobiological disorders in the central nervous system, potentially leading to developmental impairments, such as challenges in speaking, reading, comprehension, and arithmetic. Cook et al. (2020) further explain that learning difficulties encompass a range of conditions, including learning disorders, learning dysfunctions, underachievement, slow learning, and learning disabilities. According to Syah (2000:173–174), in addition to general factors, psychological syndromes such as dyslexia (reading difficulties), dysgraphia (writing difficulties), and dyscalculia (difficulties understanding mathematical concepts) are also major contributors to learning challenges. Students with these conditions often possess normal or even above-average intelligence levels. Their challenges usually stem from mild brain function disorders rather than intellectual deficiencies.

Students with behavioral disorders, cognitive impairments, learning difficulties, or attention deficits tend to struggle in understanding mathematical concepts (Vaughn, 2013). One manifestation of this difficulty is the challenge of integrating computational thinking skills into mathematics learning. Since computational thinking requires the ability to decompose problems, abstract information, recognize patterns, design algorithms, and generalize solutions, these processes can be particularly challenging for students with cognitive or behavioral limitations. This finding aligns with Steenbrugge et al. (2010), who emphasize that learning difficulties are not solely caused by students' intellectual capabilities but are also influenced by inappropriate instructional designs and methods. When instructional strategies fail to accommodate students' characteristics and needs, it becomes increasingly difficult for them to master complex concepts such as computational thinking. Consequently, pedagogical interventions based on cognitive psychology are essential for bridging the gap between student needs and the abstract nature of mathematics. This approach offers systematic support to help students develop conceptual understanding in a gradual and contextual manner.

The brain serves as the primary organ responsible for controlling thinking processes, emotions, and motivation (Sternberg, 2011). In educational contexts—particularly cognitive processing—the brain's function plays a critical role in students' success in developing computational thinking skills such as problem decomposition, abstraction, pattern recognition, algorithmic procedures, and generalization. Even minor disruptions in the nervous system can inhibit these processes, leading to decreased motivation and difficulties in building the cognitive frameworks essential for learning mathematics.

Given the central role of the nervous system in thinking and learning, interventions must consider not only pedagogical aspects but also students' cognitive and neuropsychological conditions. A cognitive psychology approach is highly relevant as it focuses on how learners process, store, and organize information. Teachers can implement strategies that stimulate brain activity, such as scaffolding, visual concept mapping, logic games, or contextual problem-based learning.

This approach can progressively help students develop the components of computational thinking—without immediately overwhelming them with complex problems. Therefore, cognitive psychology-based interventions can serve as a bridge between students' neurological limitations and the demands of high-level thinking in mathematics. Additionally, teachers can modify instructional design to be more flexible and adaptive to varying cognitive abilities, thereby improving student motivation and academic outcomes.

Considering the role of the nervous system in supporting cognitive and learning processes, it is essential for teachers to adopt instructional strategies that not only emphasize content mastery but also facilitate students' cognitive engagement. Integrating computational thinking into mathematics education requires adaptive methods grounded in cognitive psychology while also considering each student's individual learning profile.

As a recommendation, teachers should be equipped with an understanding of students' cognitive development characteristics and the appropriate instructional strategies, including techniques that stimulate computational thinking abilities. Furthermore, a collaborative and responsive learning environment is vital to ensure that students with cognitive challenges still have the opportunity to develop and actively participate in mathematics learning.

Discussion

The findings of this study indicate that integrating computational thinking into mathematics instruction still faces numerous challenges, particularly for students with learning difficulties. These challenges are not necessarily linked to low intelligence levels, but often stem from mild disorders in the central nervous system or specific cognitive issues, such as dyslexia, dysgraphia, and dyscalculia. Despite these challenges, many students with such conditions possess normal or even above-average intelligence, suggesting that the right instructional strategies can help them reach their full potential.

A cognitive psychology approach offers a relevant framework for addressing these needs. By understanding how students think—how they receive, process, and store information—teachers can design more adaptive and meaningful learning experiences. Cognitive interventions, such as scaffolding, visual representations, concept mapping, and activities that stimulate logical and analytical thinking, can serve as bridges to strengthen the core components of computational thinking: problem decomposition, abstraction, pattern recognition, algorithmic procedures, and generalization.

In addition, it is critical for teachers and schools to foster an inclusive and supportive learning ecosystem. Collaboration among teachers, parents, and professionals such as educational psychologists is essential to identifying learning difficulties early and determining appropriate strategies. The process of integrating computational thinking into mathematics instruction should not be uniform; rather, it must be customized to accommodate each student's cognitive and emotional characteristics.

Thus, the challenge of integrating computational thinking is not merely a methodological issue—it is closely related to an understanding of the psychological and neurological aspects of learning. When instruction is designed with these elements in mind, learning will not only result in better content mastery but also promote the development of critical and systematic thinking skills, which are essential for 21st-century education.

Policy Implications in Education

Within the framework of Indonesia's national education policy, the enhancement of 21st-century skills—including computational thinking—has been mandated through the Merdeka Curriculum and various policies issued by the Ministry of Education, Culture, Research, and Technology (Kemendikbudristek). This curriculum promotes project-based learning, interdisciplinary integration, and the development of critical thinking and problem-solving abilities. However, the practical implementation of these policies in schools has not fully addressed the needs of students with learning difficulties. A major constraint is the limited availability of teacher training focused on differentiated instruction and cognition-based pedagogy. Therefore, it is essential to strengthen teachers' capacity through continuous professional development programs that emphasize adaptive teaching strategies based on cognitive psychology and the Universal Design for Learning (UDL) framework. Additionally, educational policy must allocate more space for diagnostic assessment, allowing for the early identification of individual student needs. This would ensure that instructional interventions can be tailored and targeted effectively to support diverse learners, particularly in mathematics education.

Practical Implications in the Classroom

Practically, teachers can implement the integration of computational thinking through cognitive-based approaches in several ways:

1. Scaffolding: Providing instructional support adjusted to students' current levels of ability. This may involve breaking down complex tasks into manageable steps and offering guided assistance as students progress.
2. Manipulatives, Visuals, and Logic Games: Incorporating hands-on activities, visual representations, and logic-based games to stimulate components of computational thinking such as pattern recognition and abstraction.
3. Process-Oriented Feedback: Delivering meaningful feedback that focuses on the students' learning processes rather than solely on final outcomes. This helps build metacognitive awareness and motivation.
4. Furthermore, teachers must distinguish between procedural, conceptual, and cognitive errors in students' work to ensure that interventions are appropriately targeted. For instance, a student with dyscalculia may require extended processing time or visual strategies to understand numeric patterns and relationships.

Collaboration with parents and educational professionals, such as school psychologists, is also highly recommended to ensure consistent and comprehensive support both in and outside the classroom. A multi-disciplinary and inclusive approach is necessary to foster a learning environment where all students, regardless of their cognitive limitations, can thrive and develop computational thinking competencies.

Conclusion

Difficulties in integrating computational thinking skills into mathematics education are not solely caused by students' intellectual capacities but are also influenced by neurological, psychological, and instructional strategy factors. Disruptions in the nervous system and cognitive development can affect student motivation and their ability to think critically, especially in developing abstraction, problem decomposition, pattern recognition, and algorithmic reasoning.

Therefore, a cognitive psychology-based approach is highly relevant for bridging students' learning needs with the inherently abstract nature of mathematics. Teachers, as facilitators, must adopt adaptive strategies that are grounded in an understanding of cognitive processes and that foster a supportive learning environment conducive to the development of higher-order thinking skills. With the right instructional interventions, students can not only overcome learning barriers but also achieve optimal growth in computational thinking competencies.

Future research should include empirical studies, such as classroom action research or experimental designs, to test the effectiveness of cognitive psychology approaches in supporting mathematics learning integrated with computational thinking. Moreover, the development of instructional models that combine computational thinking and cognitive psychology should be pursued to ensure more systematic and contextual implementation. Research can also focus on improving teacher competence through training programs that introduce computational thinking and strategies for addressing learning difficulties. Lastly, a policy and curriculum analysis is essential to ensure computational thinking is properly embedded within national curriculum design, particularly in mathematics education..

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