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INTEGRATING COMPUTATIONAL THINKING INTO IPAS LEARNING IN ELEMENTARY SCHOOLS WITHIN THE CONTEXT OF THE MERDEKA CURRICULUM

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Abstract

The rapid advancement of digital technology in the 21st century has prompted a paradigm shift in education, moving from traditional rote learning toward pedagogies that emphasize higher-order thinking and problem-solving skills. One essential competency in this digital era is Computational Thinking (CT), which enables students to approach problems systematically through decomposition, pattern recognition, abstraction, and algorithmic design. This study aims to analyze the role, models, challenges, and opportunities of integrating CT into Natural and Social Sciences (IPAS) learning in Indonesian elementary schools under the Merdeka Curriculum framework. Employing a descriptive literature review approach, this research synthesizes findings from 45 scholarly articles published between 2010 and 2024. The literature was critically reviewed to identify trends, conceptual frameworks, and best practices related to CT-based IPAS learning. The analysis revealed that the integration of CT enhances students' scientific reasoning, reflective thinking, creativity, and collaborative problem-solving skills, particularly when applied through inquiry-based, project-based, and STEAM-oriented learning models. Despite its potential, the study also found several challenges, including limited teacher training, inadequate digital learning resources, and misconceptions that equate CT merely with programming. These barriers hinder effective classroom implementation and highlight the need for systemic educational reform. The findings suggest that CT-based IPAS learning not only strengthens digital and scientific literacy but also cultivates adaptive and innovative learners who are ready to navigate complex real-world problems. In conclusion, successful implementation of Computational Thinking in IPAS learning requires systematic teacher professional development, contextualized curriculum design, and collaboration among schools, universities, and policymakers. These efforts are essential to ensure that CT becomes an integral part of holistic and future-oriented education in Indonesia.

Keywords:
Computational Thinking, IPAS, elementary education, Merdeka Curriculum, problem-solving, higher-order thinking skills

INTRODUCTION

The rapid advancement of digital technology in the 21st century has transformed various aspects of human life, including the educational landscape. This transformation necessitates a paradigm shift from rote memorization toward learning models that emphasize higher-order thinking skills (HOTS), creativity, and problem-solving. Education in the digital era should not only focus on knowledge acquisition but also on developing students' abilities to think critically, logically, and adaptively in facing complex real-world challenges (Yadav et al., 2020). As Aoun (2017) notes, education systems must become "robot-proof" by cultivating uniquely human skills such as creativity, empathy, and computational reasoning—competencies that machines cannot easily replicate.

One of the essential competencies required to navigate this era of digital transformation is Computational Thinking (CT). Wing (2006) defines CT as a systematic problem-solving process involving decomposition, pattern recognition, abstraction, and algorithmic design. This concept, originally rooted in computer science, has evolved into a universal cognitive skill applicable across disciplines and everyday contexts (Shute et al., 2017). CT empowers students to analyze problems methodically, design structured solutions, and transfer these strategies to new situations (Kalelioglu & Gülbahar, 2021). Moreover, Brennan and Resnick (2012) argue that CT encourages learners to combine creative expression with analytical reasoning, bridging the gap between digital competence and lifelong learning.

In the context of elementary education, the subject of Natural and Social Sciences (IPAS) offers rich opportunities for the integration of CT principles. IPAS combines scientific and social approaches to help students understand natural phenomena and social interactions in their surroundings. According to the Ministry of Education, Culture, Research, and Technology (Kemendikbudristek, 2022), the IPAS curriculum is designed to cultivate curiosity, critical thinking, collaboration, and creativity from an early age—competencies that are in line with the essence of CT. Integrating CT into IPAS learning allows students to explore phenomena through inquiry, data interpretation, and algorithmic reasoning, thus connecting abstract thinking with real-world applications (Tsai & Hsu, 2019). Additionally, CT integration supports interdisciplinary learning by enabling students to apply logical reasoning to both natural and social contexts (Weintrop et al., 2016), fostering a deeper understanding of cause-and-effect relationships across disciplines.

Research across various countries supports the idea that CT enhances cognitive flexibility and problem-solving ability in students. Bocconi et al. (2022) emphasize that embedding CT in compulsory education fosters inclusive, analytical, and reflective learning. Similarly, Angeli et al. (2016) argue that early exposure to CT builds a foundation for computational literacy and supports cross-disciplinary learning. Furthermore, Denner et al. (2023) found that CT training enhances students' metacognitive awareness and adaptability, enabling them to approach unfamiliar problems with structured, evidence-based reasoning. Integrating CT also strengthens collaboration and communication skills, as students often work in teams to design algorithms or solve contextual challenges (Rich et al., 2021).

A more recent study by Putra and Suryani (2023) highlights that in Indonesia, CT implementation aligns with the principles of the Merdeka Curriculum, which encourages contextual and project-based learning to develop students' independence and creativity. This curriculum framework offers the flexibility for teachers to adapt CT-based learning scenarios according to students' local environments and cultural contexts, promoting relevance and engagement in learning (Pratama & Retnawati, 2022). Nonetheless, the successful integration of CT requires adequate teacher competence, supportive infrastructure, and pedagogical innovation (Hsu et al., 2021).

However, despite these promising developments, research on CT integration in Indonesian elementary schools remains relatively limited. Most existing studies focus primarily on coding, robotics, or programming-based activities (Wijaya & Sutrisno, 2021), while few address the contextual integration of CT into subject areas such as IPAS. This gap suggests that CT is often perceived narrowly as a digital skill rather than a broader cognitive process applicable to diverse learning domains. Consequently, there is a growing need to examine how CT principles can be naturally embedded within IPAS learning experiences that reflect students' daily lives and the holistic aims of the Merdeka Curriculum.

Therefore, this study aims to: (1) describe the importance of Computational Thinking in IPAS learning at the elementary level; (2) analyze previous research related to the implementation of CT in elementary education; and (3) identify challenges and opportunities for integrating CT within the framework of the Merdeka Curriculum in Indonesia.

METHODOLOGY

This study employed a descriptive qualitative approach using a literature review method as the primary procedure for data collection and analysis. The purpose of this method was to synthesize and critically analyze various research findings related to the integration of Computational Thinking (CT) in Natural and Social Sciences (IPAS) learning, particularly within the context of elementary education. The descriptive literature review approach was chosen because it allows for a comprehensive understanding of theoretical frameworks, pedagogical models, and empirical findings from both global and Indonesian perspectives (Snyder, 2019). Data were collected from various scholarly sources, including peer-reviewed journal articles, conference proceedings, and educational reports published between 2010 and 2024. These sources were retrieved from international databases such as Scopus, ERIC, SpringerLink, and Google Scholar, as well as national databases like Garuda and Sinta, using specific keywords such as "computational thinking," "elementary education," "science learning," "social science learning," "STEM education," and "Merdeka Curriculum."

The inclusion criteria for the selected studies were as follows: (1) the study explicitly discussed Computational Thinking in the context of primary or elementary education, (2) the research was published between 2010–2024 and underwent a peer-review process, (3) the study focused on pedagogical strategies, curriculum design, or learning outcomes associated with CT integration, and (4) the publication was written in English or Indonesian and available in full-text format. The collected data were analyzed through several stages, including data reduction, content analysis, and synthesis. Data reduction involved filtering and organizing studies based on relevance, methodology, and focus. Content analysis was conducted to identify recurring themes such as CT definitions, pedagogical approaches, integration models, benefits, and challenges (Bramer et al., 2018). The synthesis and interpretation stage involved comparing and interpreting findings across studies to identify key patterns, conceptual frameworks, and emerging trends (Grant & Booth, 2009).

The synthesis process emphasized conceptual generalization and contextual applicability, particularly in relation to Indonesia's Merdeka Curriculum, which promotes flexibility, student-centered learning, and inquiry-based instruction (Putra & Suryani, 2023). This methodological framework allowed the researcher to explore how CT principles have been applied in educational practices globally and to identify how these implementations can be effectively adapted to IPAS learning in Indonesian elementary schools.

RESULTS AND DISCUSSION

The Role of Computational Thinking in IPAS Learning

The literature review reveals that Computational Thinking (CT) plays a critical role in enhancing students' *scientific reasoning*, *analytical capability*, and *problem-solving skills* within the Natural and Social Sciences (IPAS) domain. As emphasized by Weintrop et al. (2016), CT encourages students to think like scientists and social analysts by focusing on exploration, data analysis, and evidence-based reasoning. Through CT-based learning, students learn to decompose complex natural and social phenomena, identify interconnections, and formulate algorithmic solutions grounded in logic and evidence.

Shute et al. (2017) and Bocconi et al. (2022) found that integrating CT into project-based learning (PBL) strengthens reflective, logical, and collaborative thinking. For instance, when analyzing climate change, students not only learn scientific principles but also design simple algorithms to predict weather patterns or social adaptation strategies. Similarly, Denner et al. (2023) demonstrated that CT integration enhances metacognitive awareness, allowing students to plan, monitor, and evaluate their reasoning processes systematically.

In the IPAS context, CT encourages interdisciplinary understanding, bridging scientific inquiry and social reasoning. This dual perspective fosters holistic learning—students explore how technological, ecological, and social systems interact—making learning more contextual and meaningful (Kalelioglu & Gülbahar, 2021; Putra & Suryani, 2023).

CT-Based Learning Models in Elementary Schools

Several studies have proposed pedagogical frameworks for embedding CT into classroom practice. Angeli et al. (2016) and Lye & Koh (2014) suggest that CT can be effectively integrated through Project-Based Learning (PBL), Inquiry-Based Learning (IBL), and STEAM (Science, Technology, Engineering, Arts, and Mathematics) approaches. These models position students as active problem-solvers who engage in authentic investigations that reflect real-life contexts.

In IPAS, teachers can guide students through a sequence of CT processes—decomposition, pattern recognition, abstraction, and algorithm design—to address environmental or social issues. For example, when studying the theme "Environmental Changes," students may decompose the problem by identifying causes, consequences, and potential solutions; recognize weather or ecosystem patterns; construct abstractions through simplified models; and design mitigation algorithms. This structured approach aligns with the higher-order thinking framework required by the Merdeka Curriculum (Kemendikbudristek, 2022).

Empirical studies in Indonesia, such as Suryani et al. (2021), reveal that CT-oriented learning increases student engagement, curiosity, and collaboration. Students not only gain scientific literacy but also develop critical reflection and creativity in interpreting local phenomena. Furthermore, Pratama and Retnawati (2022) argue that CT supports the Merdeka Curriculum's principles of student agency, contextual learning, and differentiated instruction. By incorporating CT, IPAS evolves from a subject that merely delivers scientific concepts to a platform for cultivating systematic, reflective, and solution-oriented thinking.

Challenges in Implementing Computational Thinking

Despite the growing recognition of CT's benefits, several implementation barriers persist, particularly in elementary education. Studies by Hestness et al. (2019) and Sari & Nugroho (2023) indicate that many teachers still struggle to understand CT concepts and to integrate them meaningfully into classroom activities. The main challenges include limited teacher training, inadequate technological infrastructure, and the absence of comprehensive CT-based teaching resources or assessment instruments.

Moreover, the misconception that CT is exclusively linked to computer programming remains widespread, hindering broader adoption in non-digital disciplines such as IPAS. Lye and Koh (2014) stress that CT can be developed through unplugged activities, including experiments, simulations, and social analysis projects that do not require computers. Similarly, Rich et al. (2021) found that low-tech approaches can effectively foster algorithmic thinking and logical reasoning among young learners.

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To overcome these challenges, it is crucial to provide professional development programs for teachers, focusing on CT pedagogy and curriculum integration. Collaborative learning communities and reflective teaching practices have been proven effective in increasing teachers' confidence and understanding of CT principles (Yadav et al., 2020; Hsu et al., 2021).

Opportunities and Future Directions

The integration of CT into IPAS presents a promising opportunity to strengthen students' digital and scientific literacy from an early age. Recent studies (Denner et al., 2023; Tsai & Hsu, 2019) demonstrate that students trained in CT show greater adaptability, analytical flexibility, and metacognitive control in addressing real-world issues.

In the Indonesian context, CT aligns strongly with the Merdeka Curriculum, which promotes flexibility, contextual learning, and project-based inquiry. Developing CT-based IPAS modules tailored to local contexts—such as environmental conservation, community economics, or cultural adaptation—can make learning more relevant and empowering.

Moreover, enhancing teacher competencies through sustained mentoring, workshops, and *learning communities of practice* can ensure effective classroom implementation (Putra & Suryani, 2023). Partnerships between schools, universities, and educational technology developers can also accelerate curriculum innovation and provide accessible resources for teachers and students alike.

Ultimately, embedding CT within IPAS does not only cultivate cognitive skills but also nurtures critical citizenship and adaptive problem-solving, equipping learners to thrive in a complex, technology-driven society.

CONCLUSION

Based on the research objectives, this study concludes that Computational Thinking (CT) holds a vital role in enhancing the quality and relevance of Natural and Social Sciences (IPAS) learning at the elementary level. CT equips students with essential cognitive skills such as logical reasoning, abstraction, and problem decomposition, which are crucial for understanding scientific and social phenomena. The integration of CT into IPAS encourages students to engage in inquiry, exploration, and experimentation rather than rote memorization. This shift aligns with the goals of 21st-century education that emphasize critical thinking, creativity, and collaboration as core competencies for lifelong learning.

The analysis of previous studies reveals that the implementation of CT in elementary education yields positive impacts when applied through various pedagogical models, such as project-based, inquiry-based, and STEAM learning. These approaches not only improve students' motivation, reflective thinking, and problem-solving abilities but also foster collaboration and innovation in the classroom. The success of CT implementation depends greatly on effective teacher facilitation, well-designed digital resources, and learning environments that support active participation. Hence, CT-based learning can transform IPAS into a more interactive, student-centered subject that promotes both academic and personal development.

Furthermore, this study identifies key challenges and opportunities in integrating CT within Indonesia's Merdeka Curriculum framework. Challenges include limited teacher understanding, inadequate access to digital tools, and misconceptions that reduce CT to programming alone. However, these challenges also create opportunities for innovation through comprehensive teacher training, curriculum redesign, and collaboration among educators, universities, and policymakers. The Merdeka Curriculum's flexibility and focus on meaningful learning make it an ideal platform for CT integration. In conclusion, strengthening CT-based IPAS learning is essential for preparing Indonesian students to thrive in the digital era—cultivating critical, creative, and adaptive thinkers ready to face future challenges.

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