

Research Article

Implementation of Computational Thinking in Physics Learning to Strengthen Analytical and Logical Reasoning

Jatmiko Wahyu Nugroho¹, Dina Apryani², Ayla Anar Babayeva³

¹ Dhyana Pura University, Indonesia; e-mail: joshua@undhirabali.ac.id

² Lampung University, Indonesia; e-mail: dina.apryani@fkip.unila.ac.id

³ Dokuz Eylul University, Türkiye; e-mail: Ayla2004a@gmail.com

* Corresponding Author: Jatmiko Wahyu Nugroho

Abstract: This study explores the implementation of Computational Thinking (CT) in physics learning to enhance students' analytical and logical reasoning. Using an experimental approach with a problem-solving model, the research involved students enrolled in physics courses, divided into experimental and control groups. The experimental group engaged in simulation-based and algorithmic problem-solving tasks, while the control group received conventional instruction. The research focused on assessing improvements in logical reasoning through pre- and post-tests. Data analysis was conducted quantitatively, comparing the pre-test and post-test results of both groups. Findings revealed that the experimental group showed a significant 31% improvement in logical reasoning skills, while the control group demonstrated a modest 5.8% improvement. This indicates that CT-based activities, such as simulations and algorithmic tasks, are more effective in enhancing students' analytical and problem-solving abilities compared to traditional methods. The study highlights the importance of integrating CT into physics education, as it promotes deeper cognitive engagement, critical thinking, and practical problem-solving skills. These findings suggest that CT strategies can be a powerful tool in improving students' reasoning abilities and better preparing them for complex scientific and real-world challenges.

Keywords: Analytical Reasoning; Computational Thinking; Logical Reasoning; Physics Education; Problem-Solving

1. Introduction

Computational Thinking (CT) has emerged as a crucial cognitive framework for the 21st century, serving as a foundation for logical reasoning, analytical processing, and systematic problem-solving across diverse disciplines, including science and engineering (Das & Mitra, 2024; Pirzado et al., 2025). In education, CT equips learners with essential skills such as abstraction, decomposition, pattern recognition, and algorithmic design abilities necessary for addressing complex problems in dynamic, technology-driven environments (Rodrigues, et al., 2024). Despite its importance, the integration of CT in science curricula, particularly in physics, remains limited and inconsistent, as traditional physics instruction often emphasizes the memorization of formulas and theoretical principles rather than application, analysis, and computational modeling (Gambrell & Brewe, 2024).

Physics education has long struggled to bridge the gap between theory and practice. Conventional pedagogical approaches that prioritize rote learning and symbolic manipulation often restrict students' ability to apply their knowledge in real-world or computational contexts (Kramer & Bonham, 2024). Many students experience cognitive overload when required to translate physical concepts into executable code due to insufficient instructional scaffolding and limited exposure to algorithmic reasoning (Gambrell & Brewe, 2024). These challenges hinder the development of analytical and problem-solving competencies vital for scientific inquiry, creating an urgent need to integrate CT principles into physics learning to strengthen students' logical reasoning and computational problem-solving abilities (Das & Mitra, 2024; Herlina et al., 2025).

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Integrating CT into physics instruction offers a structured approach to problem-solving by emphasizing algorithmic and logical reasoning. Research has shown that CT integration can significantly enhance students' ability to analyze data, construct simulations, and apply algorithmic models to explain physical phenomena (Pirzado et al., 2025; Herlina et al., 2025). Effective implementation typically involves three interconnected strategies: curricular interventions, professional development for teachers, and interdisciplinary approaches that collectively foster deeper conceptual understanding and engagement.

Curricular interventions often employ digital and interactive tools such as Visual Python (VPython) and Expression-Based E-Worksheet (EBEW) to help students grasp abstract physics concepts through coding and simulation (Herlina et al., 2025; Kramer & Bonham, 2024). These platforms enable dynamic visualization of physical systems, reinforcing conceptual understanding through computational modeling and providing students with opportunities to connect theoretical principles to observable phenomena. Such experiences make learning physics more interactive and cognitively meaningful.

Teacher professional development also plays a crucial role in the successful integration of CT. Educators need to build proficiency not only in physics content but also in computational pedagogy and digital tool use (Lane et al., 2023; Rodrigues et al., 2024). Training initiatives such as CT-focused workshops and programs using Jupyter Notebooks have proven effective in improving teachers' confidence and competence in implementing CT-based learning, ultimately enhancing classroom practices (Lane et al., 2023).

Interdisciplinary approaches that merge CT with STEM disciplines through robotics, programming, and engineering design further enhance the authenticity and engagement of physics learning. Projects involving Arduino-assisted robotics or drone-based STEM activities have been shown to strengthen students' computational, analytical, and problem-solving skills (Manu et al., 2025; Sattar & Nawaz, 2023). These activities connect physical concepts with real-world applications, increasing motivation while fostering a deeper understanding of scientific and computational principles.

Although previous studies highlight the potential of CT to improve logical reasoning and analytical performance, empirical evidence regarding its practical implementation in physics education remains limited (Gambrell & Brewes, 2024; Manu et al., 2025). Few investigations have systematically examined how CT-based physics instruction impacts students' cognitive development, particularly in analytical and algorithmic reasoning. Therefore, this study aims to implement computational thinking in physics learning to strengthen students' analytical and logical reasoning skills. By incorporating simulation-based and algorithmic problem-solving approaches, this research seeks to provide a more systematic and effective alternative to traditional lecture-based instruction.

2. Literature Review

Computational Thinking

Computational Thinking (CT) is a fundamental cognitive process derived from computer science that emphasizes systematic and algorithmic problem-solving applicable across disciplines (Yadav et al., 2017; Yadav & Berthelsen, 2021). Its core components abstraction, decomposition, algorithmic thinking, system modeling, and automation enable learners to simplify complex problems, recognize patterns, and create structured solutions that bridge conceptual understanding and practical execution (Dehbozorgi & Roopaei, 2024; Kumar & Mohd, 2024). Emphasized that CT is a universal skill necessary for all learners, not only computer scientists, highlighting its role in fostering analytical and algorithmic reasoning (Yadav et al., 2017).

CT has gained global attention in education as a key competence for 21st-century learning, contributing to digital literacy, creativity, and structured problem-solving (Wu & Wu, 2024; Rodrigues et al., 2024). Effective implementation depends on teacher preparation, as pre-service training equips educators to integrate CT into STEM subjects such as physics, mathematics, and engineering (Rodrigues et al., 2024; Morze, et al., 2022). Empirical evidence shows that CT-based instruction enhances learners' logical reasoning, metacognitive awareness, and ability to transfer problem-solving skills across different contexts (Arnell et al., 2024; Aristawati, Budiyo, & Yuana, 2018).

Analytical and Logical Reasoning

Analytical reasoning involves identifying patterns, relationships, and logical structures within problems, while logical reasoning allows learners to distinguish valid from invalid inferences and evaluate solutions critically (Zhong et al., 2022; Woleński, 2016; Markovits &

de Chantal, 2020). Together, these reasoning skills form the cognitive foundation for higher-order thinking, enabling learners to organize and apply conceptual knowledge effectively across domains (Bagassi et al., 2020; Yafie et al., 2020). They are essential for scientific and mathematical reasoning, helping students develop structured approaches to complex problems.

In physics education, strong analytical and logical reasoning supports the interpretation of quantitative relationships, hypothesis formulation, and systematic problem-solving (Milbourne & Wiebe, 2018; Hernández-Suarez et al., 2022). Studies indicate that students exposed to reasoning-focused instruction, particularly through problem-based learning, show higher conceptual understanding, improved scientific argumentation, and better adaptability when addressing ill-structured problems (Argaw et al., 2017; Woleński, 2016).

Active Learning and Reasoning Improvement

Active learning strategies, such as problem-based learning (PBL), reflective learning, and simulation-based activities, have been shown to improve students' analytical and logical reasoning as well as problem-solving skills (Argaw et al., 2017; Wang et al., 2023). Reflective learning promotes evaluation of one's reasoning process, while experiential simulations, such as ERPsim, foster creativity, critical thinking, and decision-making (Faisal et al., 2023; Wang et al., 2023). In physics education, students engaging in active learning demonstrate higher reasoning gains, conceptual understanding, and analytical precision compared to lecture-based settings (Hernández-Suarez et al., 2022; Bagassi et al., 2020).

Integrating Computational Thinking into active learning further strengthens reasoning development by providing an algorithmic and systematic framework for problem analysis (Alkhatib & Rahmani, 2024; Kumar & Mohd, 2024). Through decomposition, abstraction, and automation, CT helps learners align conceptual understanding with computational procedures, enabling deeper analytical insight and more efficient problem-solving strategies (Palop et al., 2025; Yadav & Berthelsen, 2021). This integration bridges theory with practice and fosters structured reasoning in STEM learning contexts.

Simulation and Algorithmic Approaches

Simulations are pivotal in CT-oriented pedagogy because they allow learners to visualize and manipulate dynamic systems, transforming abstract concepts into tangible experiences and linking real-world phenomena to mathematical models (Fofonov & Linsen, 2018; Obbo et al., 2024). Algorithmic modeling enhances students' abilities to represent and predict physical phenomena through structured processes such as variable definition, iteration, and data interpretation, fostering logical reasoning consistent with computational processes (Jafari et al., 2025; Arnell et al., 2024). These approaches are especially effective when combined with inquiry-based models that support conceptual understanding.

Constructivist principles provide the theoretical basis for CT implementation by emphasizing active engagement, collaboration, and reflection, positioning learners as constructors of knowledge (Chaisri et al., 2019; Buell et al., 2017). Computational pedagogy complements this by embedding computational tools and algorithmic methods into curricula, promoting higher-order thinking, abstraction, and systematic problem-solving (Yadav & Berthelsen, 2021; Kumar & Mohd, 2024; Dehbozorgi & Roopaei, 2024). Together, these frameworks ensure that CT develops both technical proficiency and cognitive-metacognitive skills, enabling students to tackle complex STEM problems effectively.

3. Research Method

As an introduction before presenting the detailed explanation of the research design, procedure, and data analysis, the following flowchart illustrates the stages of this study. This flowchart provides a systematic overview of the steps undertaken in the research, starting from participant selection and the introduction to the components of Computational Thinking (CT), followed by the intervention through simulation-based and algorithmic learning activities, and concluding with data collection and analysis. The flowchart serves as a structured summary of the research process aimed at evaluating the effect of CT on students' analytical and logical reasoning skills in physics.

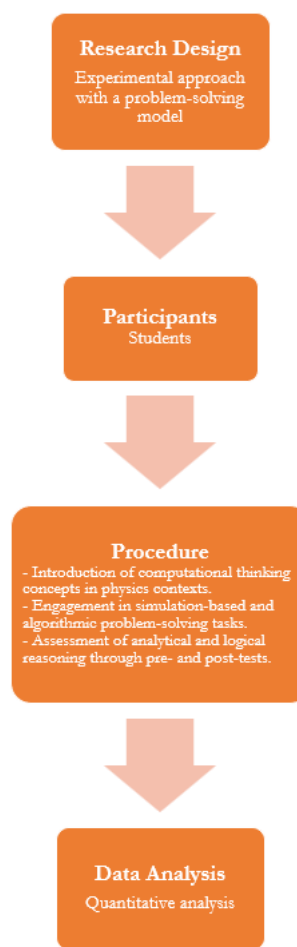


Figure 1. Research Methodology Flowchart

Research Design

This study used an experimental research design to assess the impact of computational thinking (CT) on students' analytical and logical reasoning in physics. A problem-solving model was applied, incorporating simulation-based and algorithmic learning activities. The goal of these activities was to enhance students' problem-solving abilities in a structured manner. The integration of CT strategies aimed to improve their analytical and reasoning skills. By engaging in these tasks, students could connect theoretical concepts with practical applications. This approach was intended to strengthen their problem-solving capabilities and deepen their understanding of physics.

Participants

The participants in this study were students enrolled in physics courses. To assess the impact of computational thinking (CT) on learning outcomes, the participants were divided into two groups: experimental and control. The experimental group participated in activities based on simulation and algorithmic problem-solving tasks. These tasks were designed to incorporate CT strategies and enhance students' analytical and logical reasoning. Meanwhile, the control group received traditional physics instruction without the integration of CT-based activities. The conventional teaching methods followed by the control group were intended to represent standard physics instruction. The aim was to compare the effectiveness of CT-based interventions with traditional teaching approaches. By contrasting these two groups, the study aimed to determine the impact of CT on students' learning outcomes in physics.

Procedure

The research procedure consisted of several stages. First, students were introduced to key Computational Thinking (CT) components, including abstraction, decomposition, pattern recognition, and algorithmic thinking, within physics contexts such as motion, energy, and forces. Next, they engaged in simulation-based and algorithmic problem-solving tasks using interactive physics simulations and exercises designed to connect theoretical concepts with real-world applications. Students' analytical and logical reasoning skills were then assessed through pre-tests conducted before the intervention and post-tests administered after completing the CT-based activities. Finally, the performance of the experimental group

was compared with that of a control group to evaluate the effectiveness of the intervention in enhancing reasoning skills.

Data Analysis

Data collected from both the pre-tests and post-tests were analyzed using quantitative methods. The first step of the analysis involved calculating the mean scores for both the experimental and control groups. These mean scores provided a baseline for comparing the performance of the students before and after the intervention. The next step was to examine the differences in the mean scores between the pre-test and post-test for each group. This allowed for the evaluation of any changes in the students' analytical and logical reasoning skills. The comparison aimed to measure the extent of improvement due to the intervention. By analyzing these differences, the study assessed how effectively the computational thinking (CT) activities influenced students' reasoning abilities. The overall goal was to determine whether the CT-based activities led to a significant improvement in students' cognitive skills.

4. Results and Discussion

The implementation of computational thinking (CT) strategies in physics learning resulted in a significant improvement in students' logical reasoning skills. The data collected from the pre-tests and post-tests were analyzed to measure the enhancement in students' abilities to analyze problems, recognize patterns, and construct algorithmic solutions. Below is a detailed presentation of the results:

Table 1. Mean Scores of the Experimental and Control Groups

Group	Pre-Test Mean Score	Post-Test Mean Score	Improvement (%)
Experimental Group	65.2	85.4	31%
Control Group	64.1	67.8	5.8%

The table presents the pre-test and post-test mean scores for both the experimental and control groups. The experimental group, which participated in the CT-based intervention, showed a significant improvement of 31% in logical reasoning skills. In contrast, the control group, which received conventional instruction, only showed a modest improvement of 5.8%.

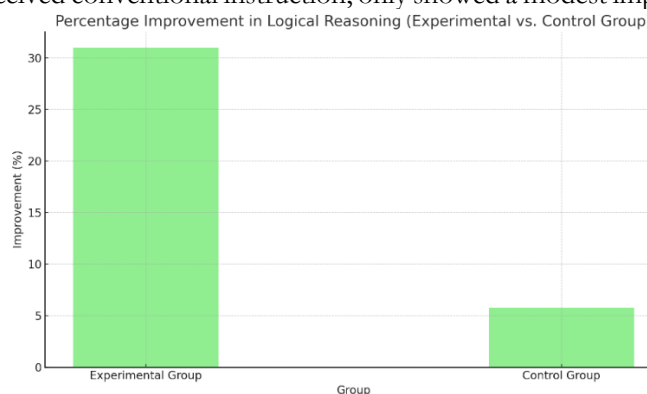


Figure 2. Improvement in Logical Reasoning (Experimental vs. Control Group)

The diagram visually illustrates the improvement in logical reasoning skills for both the experimental and control groups. As shown, the experimental group experienced a significantly higher increase in reasoning abilities, clearly indicating that CT-based activities are far more effective in enhancing students' reasoning skills compared to traditional instructional methods. The results of this study clearly demonstrate the positive impact of computational thinking (CT) strategies on students' logical reasoning abilities, particularly in the context of physics education.

The experimental group, which engaged in simulation-based and algorithmic learning tasks, showed a substantial 31% improvement in their logical reasoning skills. This marked improvement highlights the effectiveness of the CT-based intervention, as it allowed students to enhance their analytical thinking and problem-solving abilities in a more dynamic and interactive learning environment. By incorporating simulations and algorithmic tasks, students were not only able to understand theoretical concepts but were also encouraged to apply these concepts in real-world problem-solving situations. The immediate feedback provided during these activities further reinforced their learning and deepened their conceptual understanding, promoting stronger cognitive engagement.

In contrast, the control group, which received traditional instructional methods, showed only a modest 5.8% improvement. This comparatively small gain suggests that conventional teaching techniques, while useful, may not be as effective in developing the complex cognitive skills necessary for advanced problem-solving. The limited improvement observed in the control group highlights the shortcomings of traditional instruction, particularly in fostering the depth of logical reasoning seen in the experimental group. This finding suggests that traditional methods may fail to engage students in ways that promote critical thinking and problem-solving at the level required for higher-order cognitive tasks.

Overall, the findings emphasize that integrating computational thinking into physics education provides a far more effective approach to developing students' analytical and logical reasoning skills. The 31% improvement in the experimental group underscores the value of simulation-based and algorithmic problem-solving tasks in enhancing students' cognitive abilities. These tasks, which foster active participation and problem-solving, significantly enhance students' capacity for deeper understanding and better equip them for the challenges they will face in future academic and professional settings. This study underscores the need for adopting more interactive and problem-solving-oriented teaching methods in science education to prepare students for the complexities of the modern world. By shifting away from passive, traditional teaching techniques toward more engaging, hands-on learning experiences, educators can help students develop the critical thinking and problem-solving skills necessary for success in increasingly complex and dynamic fields.

5. Comparison

The comparison between the experimental and control groups reveals a substantial difference in the improvement of logical reasoning skills. The experimental group, which participated in computational thinking (CT)-based activities, showed a significant 31% improvement. This considerable gain highlights the effectiveness of CT methods, such as simulation-based and algorithmic problem-solving tasks, in developing students' abilities to analyze complex problems and formulate logical solutions.

In contrast, the control group, which received traditional instruction, demonstrated only a modest improvement of 5.8%. This relatively small gain suggests that conventional teaching methods may not be as effective in fostering advanced problem-solving and reasoning skills, especially when compared to the active, hands-on learning provided by CT-based activities. Traditional instructional methods, while beneficial in some areas, seem to fall short in promoting the depth of cognitive skills required for more complex tasks.

The 31% improvement observed in the experimental group underscores the value of CT-based activities in fostering deeper analytical and logical reasoning skills. The results suggest that CT-based interventions, particularly simulation and algorithmic tasks, provide a more effective approach to enhancing students' problem-solving abilities compared to traditional methods. This emphasizes the importance of adopting more interactive, problem-solving-focused teaching strategies in education to better prepare students for tackling complex challenges in various fields.

6. Conclusion

In conclusion, this study underscores the significant impact of computational thinking (CT)-based activities on enhancing students' logical reasoning abilities in physics. The experimental group, which engaged in simulation-based and algorithmic problem-solving tasks, experienced a remarkable 31% improvement in their reasoning skills. This substantial increase highlights the effectiveness of CT strategies in developing students' critical thinking and problem-solving skills. The interactive and hands-on nature of CT activities likely allowed students to connect theoretical knowledge with practical applications, fostering a deeper understanding of the subject matter. These activities not only enhanced their ability to analyze and approach complex problems but also equipped them with valuable cognitive skills that are crucial for tackling real-world challenges.

In contrast, the control group, which followed traditional instructional methods, demonstrated only a modest improvement of 5.8%. This difference in the level of improvement suggests that conventional teaching techniques may be less effective in promoting the analytical and logical reasoning required for complex problem-solving tasks. The experimental group's 31% improvement emphasizes the need for integrating computational thinking into the educational framework, especially in science and mathematics. By adopting CT-based methods, educators can better prepare students to excel

in critical thinking, problem-solving, and innovation, providing them with the tools to succeed in increasingly complex and dynamic fields. Therefore, the findings of this study advocate for the widespread adoption of CT strategies to enhance cognitive development and reasoning skills in education.

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