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Enhancing Early Childhood Problem-Solving Abilities through Game-Based Learning and Computational Thinking: The Impact of Cognitive Styles

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Abstract
Children's understanding of solving problems related to early cognitive abilities with several levels of complexity makes children feel difficult, and students are less able to solve problems correctly according to the sequential order of how to do them. The main factor that causes low problem-solving abilities is the use of inappropriate learning strategies. So that children in the process of solving problems in a lesson also become less than optimal. This study explores the effects of computational thinking strategies with game-based learning compared to conventional approaches on early childhood problem-solving abilities, considering the cognitive styles of field-independent (FI) and field-dependent (FD) children. A quasi-experimental pretest-posttest nonequivalent control group design involved 60 children from Blitar Kindergarten. The experimental group received computational thinking instruction through game-based learning, while the control group followed conventional methods. Posttests followed a pretest established baseline abilities and an eight-week intervention. Data were analyzed using a two-way ANOVA, revealing significant improvements in problem-solving skills for the experimental group ($p < 0.05$). FI children outperformed FD peers, indicating cognitive style's impact on learning outcomes. An interaction effect between learning strategies and cognitive styles was identified, emphasizing the importance of tailored educational approaches. The study's findings suggest that computational thinking through game-based learning enhances critical thinking, creativity, and engagement in young learners. However, limitations such as a small sample size and short intervention duration highlight the need for further research. Future studies should involve diverse populations and longer interventions to understand the long-term effects better and optimize educational strategies for individual cognitive styles. These results underscore the potential of innovative educational methods in developing foundational skills essential for academic and life success.

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Introduction
Developing problem-solving abilities in early childhood is a crucial aspect of cognitive growth and is essential for fostering logical, critical, and systematic thinking skills (O'Reilly et al., 2022; Riyadi et al., 2021). As society increasingly relies on technology and innovative solutions, cultivating these abilities from a young age becomes paramount. The intersection of computational thinking and game-based learning has emerged as a promising avenue to enhance these skills, integrating entertainment and problem-solving into the learning process. This study explores how these methodologies can improve problem-solving abilities in early childhood, a critical period for cognitive development. Ensuring effective educational strategies during this formative stage is vital for long-term cognitive benefits.

Previous research has extensively documented the importance of various aspects of early childhood development, including cognitive skills vital for problem-solving (Izzah et al., 2020;

Restiyanti et al., 2017; Sriyono et al., 2022). Gardner (2011) defines cognitive development as the ability to solve problems and create culturally valuable work involving rapid and precise mental processes (Gardner, 2011). Learning and problem-solving, logical thinking, and symbolic thinking are core components of cognitive development (Rahman, 2019), each contributing to a child's ability to navigate everyday challenges effectively. Understanding these components is crucial for educators aiming to foster robust problem-solving skills in young children.

The significance of problem-solving abilities at the early childhood education level cannot be overstated. These skills enable children to think logically, critically, and systematically, laying a foundation for future learning (Dyah & Setiawati, 2019; Pollarolo et al., 2023). The scientific problem-solving process involves observing, grouping, comparing, measuring, and summarizing information, which is crucial for cognitive development (Sriwarthini et al., 2024). Despite the recognized importance of these abilities, traditional teaching methods often fail to engage young learners effectively, highlighting the need for more interactive and engaging learning strategies (Darling-Hammond et al., 2020; Agustin Husnul Khotimah et al., 2019). Innovative approaches are required to address these educational challenges adequately.

Emerging strategies such as computational thinking and game-based learning have shown promise in addressing these educational challenges. Computational thinking, involving problem formulation and solution representation in a computationally executable form, has been proposed as a fundamental skill for the younger generation (Hurt et al., 2023; Su & Yang, 2023). Game-based learning, which combines entertainment with educational content, provides an interactive platform for developing problem-solving skills (Lin et al., 2020). These approaches make learning more engaging and offer opportunities for repeated practice and instant feedback, enhancing cognitive development (Li et al., 2024; Nadeem et al., 2023). Adopting these methods could revolutionize early childhood education by making it more effective and enjoyable.

Despite the potential benefits, the application of computational thinking and game-based learning in early childhood education remains underexplored, particularly in comparison to studies focusing on older students (Torres-Torres et al., 2019). Research has shown that these methods can reduce gender disparities in cognitive development at early education stages, suggesting more homogeneous development between boys and girls (John Lemay et al., 2021). The role of digital games in facilitating immediate feedback and interactive learning further underscores their potential to enhance early childhood education (Clark et al., 2016; Anastasiadis et al., 2018; Flynn et al., 2019). However, significant gaps and limitations persist in the literature. Addressing these gaps is essential for developing more effective educational strategies.

Existing studies also highlight several gaps and limitations. There is a paucity of research on the specific impact of these methodologies on problem-solving abilities in early childhood (Nouvanty et al., 2023; Smith, 2012). Moreover, the influence of individual cognitive styles on learning outcomes remains inadequately addressed (Lapp et al., 2019; Sutrisno et al., 2020). Understanding these nuances is crucial for tailoring educational strategies to accommodate diverse learning preferences and cognitive styles. Addressing these research gaps could significantly enhance educational practices and outcomes.

This study aims to address these gaps by examining the impact of computational thinking and game-based learning on the problem-solving abilities of young children. It investigates the differences in outcomes between children taught using these innovative strategies versus traditional methods (Moumoutzis, 2020; Alfaro-Ponce et al., 2023). Additionally, the study explores the interaction effects between learning strategies and cognitive styles, providing insights into how these factors influence learning outcomes (Lee, 2020; Zheng et al., 2024). By doing so, this research seeks to contribute to developing more effective and inclusive educational practices (Dai, 2022; Deng, 2020). Ultimately, the goal is to enhance early learners' cognitive and problem-solving skills.

Methods

This study employed a quantitative approach with a quasi-experimental pretest-posttest nonequivalent control group design (Creswell & Creswell, 2017). Four classes of early childhood children from Blitar Kindergarten participated, with 15 children per class. Classes A and B served as the experimental group, receiving computational thinking instruction through game-based learning, while classes C and D formed the control group with conventional learning strategies (X. Wang et al., 2023). A pretest was administered to all participants to establish baseline problem-solving abilities, followed by an eight-week intervention for the experimental group. Posttests were then conducted to measure any changes. The primary tool for this study was a cognitive styles questionnaire adapted from Saracho (2001), translated into Indonesian, and validated by two experts. The intervention involved educational games implemented using digital tablets and specialized software.

Data collection included pretest and posttest scores and cognitive styles questionnaire responses. Analysis was performed using a two-way (2x2) Analysis of Variance (ANOVA) via SPSS for Windows, with significance set at 0.05. The reliability of the cognitive styles questionnaire, previously validated ($\alpha = 0.68$ for FD and $\alpha = 0.74$ for FI), was reassessed post-translation by expert review (Saracho, 2001). Pilot testing in a separate kindergarten class refined the game-based activities. Training observers maintained inter-rater reliability to consistently assess children's engagement and problem-solving behaviors. These steps ensured the study's findings were reliable and valid.

Result

This study investigates the impact of computational thinking learning strategies, combined with game-based learning approaches, on the problem-solving abilities of young children. The objective is to enhance students' analytical and problem-solving skills through engaging and interactive activities. Games are utilized not merely as entertainment but as tools to simplify and convey complex computational concepts. Table 1 illustrates the stages of learning computational thinking strategies using a game-based learning approach.

Table 1. Stages of Learning Computational Thinking Strategy with a Game-based Learning Approach

Computational Thinking Strategy	**Definition**	**Game-Based Learning**		
		Challenges	Response	Feedback
		Teacher	Child	Teacher
Sequencing	A series of steps or instructions used to solve a problem	Ask children to play the role of a robot and carry out every direction given by the teacher/peer	The child acts like a robot, and peers/teachers give directional arrow commands (for example, left/right arrows and forward/backward arrows).	Justify/provide instructions if the child makes a mistake/steps not according to orders.
		Ask children to make a traditional Javanese house from mockup media	Children construct a conventional Javanese house using mockup media	Justify/give instructions if the child makes a mistake/steps not according to orders
Decomposition	Breaking a problem into smaller parts so that the problem is more accessible to solve	Have children break (the cat's broken house) into small parts, which helps them identify the main parts of the task and the main criteria	Break down and categorize parts of the house into small parts.	Correct if the child makes a mistake/steps not according to orders

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Debugging	Finds and corrects errors in instructions	Encourage children to analyze and evaluate activities to look for discrepancies/errors.	1. Identify an existing error. 2. Make assumptions about the problems found. 3. Try to solve the problem.	Correct if the child makes a mistake/steps not according to orders
Pattern recognition	The process of identifying patterns in data sets to categorize, process, and resolve information more effectively	Applying the results of problem-solving planning: The teacher asks the children what strategies are used to help them solve problems/puzzles. Teachers can use the above as an opportunity to describe the implementation of problem-solving planning as an algorithm children have designed.	1. Children solve problems. 2. Children recognize their algorithmic patterns.	Provide feedback regarding implementing problem-solving planning to recognize algorithm patterns owned by children.

Learning computational thinking through games helps students develop critical thinking and problem-solving skills. Learning stages include an introduction to the concept of computational thinking through simple games, application of concepts in more complex games, and reflection and evaluation to ensure student understanding. This method is fun and helpful in developing students' skills.

Meanwhile, researchers used direct learning stages as the teacher carried out them to implement learning in the control group. They started by presenting the material and practicing questions.

3.1. Test Research Data Assumptions

3.1.1. Data Normality Test Results and Data Variance Homogeneity Problem Solving Ability (Pre-Test)

The normality test is used to see whether the distribution of data on problem-solving abilities in the control and experimental groups is usually distributed. The results of the data normality test using Shapiro-Wilk obtained a p-value for the experimental group = 0.06 > 0.05 and the control group = 0.1 > 0.05. Thus, it can be concluded that children's problem-solving abilities in both the control and experimental groups are normally distributed.

Table 2. Normality Data Pre-Test Result

		Shapiro-Wilk		
		Statistic	df	Sig.
Pre-Test Score	Control Group	.941	30	.100
	Experiment Group	.935	30	.067

Meanwhile, the data homogeneity test was used to see whether the data variance in problem-solving abilities in the two groups was homogeneous. Levene's test results obtained a Sig value of 0.22. In other words, the p-value is 0.22 > 0.05. So, the variance of problem-solving ability data in the two groups is homogeneous.

Table 3. Homogeneity Data Pre-Test Result

		Levene Statistic	df1	df2	Sig.
Pre-test	Based on Mean	1.483	1	58	.228

3.1.2. Data Normality Test Results and Data Variance Homogeneity Problem Solving Ability (Post-Test)

The normality test is used to see whether the distribution of data on problem-solving abilities in the control and experimental groups is usually distributed. The results of the data normality test using Shapiro-Wilk obtained a standardized residual value = 0.183 > 0.05. Thus, it can be concluded that children's problem-solving ability scores (post-test) in both the control and experimental groups and those with FD and FI cognitive styles are typically distributed.

Table 4. Normality Data Post-Test Result

	Shapiro-Wilk		
	Statistic	df	Sig.
Standardized Residual	.972	60	.183

Meanwhile, the data homogeneity test was used to see whether the data variance in problem-solving abilities in the two groups was homogeneous. Levene's test results obtained a Sig value of 0.68. In other words, the p-value is 0.68 > 0.05. So, the variance of children's problem-solving ability data (post-test) in the two groups is homogeneous.

Table 5. Homogeneity Data Post-Test Result

		Levene Statistic	df1	df2	Sig.
Problem-Solving	Based on Mean	.494	3	56	.688

3.1.3. Different Tests of Children's Problem-Solving Abilities in the Pre-Test

The results of different tests show that children's problem-solving abilities (pre-test) obtained a Sig. (2-tailed) = 0.57, p > 0.05, it can be concluded that children's problem-solving skills (pre-test) did not show a significant difference between the control and experimental groups.

Table 6. Test Results for Different Students' Problem-Solving Abilities (Post-Test)

Group	M	SD	T	Sig. (2-tailed)	Information
Experiment Control	2.86 3.03	1.28 1.07	.56	.57	Not Significant

3.1.4. Differential Test of Children's Problem-Solving Abilities in the Post-Test

The results of different tests show that children's problem-solving abilities (post-test) are F (1.56) = 333.25, p= 0.000, p < 0.05, so it can be concluded that children's problem-solving abilities (post-test) show significant differences between the control and experimental groups.

Table 7. Test Results for Different Students' Problem-Solving Abilities (Post-Test)

Kelompok	M	SD	F	Sig	Keterangan
Eksperimen Kontrol	10.61 7.95	0.58 0.90	333.251	.000	Significance

3.1.5. Description of Cognitive Style

Cognitive style is a characteristic related to a person's mental processes. According to (Ismail et al., 2023), cognitive style is part of a learning style that describes a person's permanent behavioral habits in receiving, solving problems, and storing information. Teachers can accommodate children's cognitive styles with various learning strategies by knowing children's cognitive styles. Overall, 30 groups of children have the FD learning style, with a mean score of 8.78. Meanwhile, 30 groups of children have the FI learning style, with a mean score of 9.77.

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3.1.6. Hypothesis testing

Based on the two-way ANOVA assumption test results, which show that the post-test scores meet the assumption tests of both normality and homogeneity, the hypothesis test in this study can be analyzed using parametric statistical techniques. Three hypotheses will be tested in this research. The following are the results of hypothesis testing in Table 8.

Table 8. SPSS Two-Way Anova Test Output

Source	Type III sum of Squares	df	Mean Square	F	Sig.
Corrected Model	122,094 [a]	3	40,698	127,596	,000
Intercept	5168.218	1	5168.218	16203.329	,000
Class	106,294	1	106,294	333,251	,000
Cognitive Style	14,504	1	14,504	45,473	,000
Class*Cognitive Style	1,297	1	1,297	4,065	,049
Error	17,862	56	,319		
Total	5308.174	60			
Corrected Total	139,956	59			

a. R Squared = .872 (Adjusted R Squared = .866)

Based on the two-way ANOVA test results, the calculated F value is 333.251 with a probability value 0.000. This means the significance value is smaller than 0.05. So, it can be concluded that there are differences in the problem-solving abilities of children who are taught using computational thinking strategies with game-based learning and conventional approaches. The F-value is 45.473 with a probability value of .000. This means the significance value is smaller than 0.05. Therefore, it can be concluded that H_0 is rejected. In other words, there are differences in the problem-solving abilities of children who have FI and FD cognitive styles. The calculated F-value is 4.065, with a probability value of .049. This means the significance value is smaller than 0.05. These results indicate an interaction effect between learning strategies and cognitive style on children's problem-solving abilities.

Discussion

This study set out to explore the impact of computational thinking strategies combined with game-based learning on the problem-solving abilities of young children, comparing these effects to traditional methods. Additionally, it delved into the differences in problem-solving skills between children with field-independent (FI) and field-dependent (FD) cognitive styles and the interaction between learning strategies and these cognitive styles. Previous studies have indicated that computational thinking can significantly boost problem-solving capabilities (Dewi et al., 2021; X. Wang et al., 2023; Alfaro-Ponce et al., 2023). Game-based learning, in particular, has been shown to effectively nurture these skills by offering engaging and interactive environments (Anastasiadis et al., 2018; LIU, 2021). This research builds on existing knowledge by examining how these strategies work for young children with different cognitive styles (Marwazi et al., 2019; Nugroho et al., 2021).

The study's findings reveal that computational thinking strategies paired with game-based learning significantly enhance children's problem-solving skills compared to conventional methods. Children engaged in game-based learning showed substantial improvements in problem-solving, as evidenced by notable differences in post-test scores between the experimental and control groups ($F(1.56) = 333.25$, $p = 0.000$). Moreover, FI children outperformed FD children in problem-solving tasks, underscoring the role of cognitive styles ($F = 45.473$, $p = 0.000$). Additionally, a significant interaction effect was found between learning strategies and cognitive styles on problem-solving abilities ($F = 4.065$, $p = 0.049$). These outcomes are consistent with existing literature highlighting FI children's superior performance in problem-solving tasks compared to their FD peers (He & Li, 2023; Saracho, 2001).

When compared to previous research, these findings are in line with the established evidence that computational thinking enhances problem-solving skills (Dewi et al., 2021; X. Wang et al., 2023). Game-based learning has also been noted for fostering critical thinking and creativity (Anastasiadis et al., 2018; LIU, 2021), supporting the observation that children using these strategies perform better. While earlier studies often focused on older students or adults, this study uniquely demonstrates these benefits in early childhood, indicating the effectiveness of such approaches across various age groups (Alfaro-Ponce et al., 2023; Kusumawati & Andriyani, 2020). The engaging and interactive nature of game-based learning environments is particularly beneficial for cognitive development (Surur et al., 2020; Wahidah et al., 2024).

Regarding cognitive styles, this study supports the findings by Saracho (2001) and Hardiansyah et al. (2024), which highlight the superior problem-solving abilities of FI children over FD children. The observation that FI children excel in problem-solving tasks aligns with the understanding that they are better equipped to handle abstract and analytical tasks (Saracho, 2001; Ahna et al., 2022). In contrast, FD children, who tend to excel in socially oriented and concrete tasks, displayed comparatively lower problem-solving abilities, reflecting their struggles with abstract thinking (He & Li, 2023; Muyassaroh & Masduki, 2023). Previous research has also noted that FI children thrive in structured problem-solving environments, whereas FD children perform better in collaborative and socially driven tasks (Son, 2020; Surur et al., 2020).

The significant interaction between learning strategies and cognitive styles suggests that computational thinking strategies with game-based learning are particularly beneficial for FI children. This could be due to FI children's natural preference for structured and analytical tasks, which align well with computational thinking (Muyassaroh & Masduki, 2023; Ahna et al., 2022). However, while there are benefits for FD children, they are less pronounced, possibly due to their difficulties with abstract problem-solving tasks (Rasmini, 2017; Yen & Liao, 2019). These findings highlight the importance of tailoring educational strategies to individual cognitive styles to maximize learning outcomes (Marwazi et al., 2019; Nugroho et al., 2021).

Despite these promising results, caution is needed to generalize the findings due to the specific context and sample of the study. The controlled experimental setting and relatively small sample size may limit the external validity of the results. Additionally, the short duration of the intervention might not fully capture the long-term effects of computational thinking strategies on problem-solving abilities (Wahidah et al., 2024; Yen & Liao, 2019). Future research should examine these dynamics over extended periods and in diverse educational settings to validate and expand on these findings. It is also crucial to explore how these strategies can be adapted to better support FD children in enhancing their problem-solving skills effectively (Muyassaroh & Masduki, 2023; Ahna et al., 2022).

The implications of these findings are significant for educational practice. Implementing computational thinking strategies through game-based learning can notably improve early childhood problem-solving abilities, especially for FI children. This approach fosters critical thinking and creativity and provides an engaging learning environment that can motivate young learners (Anastasiadis et al., 2018; LIU, 2021). Educators should consider incorporating these strategies into early childhood curricula while considering individual cognitive styles to ensure that all children can benefit optimally. This study underscores the potential of innovative educational approaches to develop foundational skills crucial for future academic and life success (Hadi. S, 2013; Rasmini, 2017)

Conclusion

This study explored the differences in problem-solving abilities among children taught using computational thinking strategies with game-based learning versus conventional approaches and the effects of field-independent (FI) and field-dependent (FD) cognitive styles. The results indicate that game-based learning strategies significantly enhance problem-solving skills compared to traditional methods, with children in the experimental group showing substantial improvement. FI children outperformed their FD peers, demonstrating that cognitive style plays a crucial role in learning outcomes. The interaction between learning strategies and cognitive styles further underscores the importance of personalized educational approaches. These findings significantly impact educational practice, suggesting that integrating computational thinking and game-based learning can foster young learners' critical thinking, creativity, and engagement. However, the study's limitations, such as a small sample size and short intervention duration, highlight the need for further research involving diverse populations and examining long-term effects. Future studies should continue exploring these innovative strategies to better tailor educational methods to individual cognitive styles and enhance children's problem-solving abilities.

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