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Coding Learning to Stimulate Early Childhood Computational Thinking

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Abstract:

This study aims to explore how coding activities can stimulate computational thinking in early childhood. Specifically, it investigates the effects of coding learning on computational thinking skills in young children and identifies the most effective coding activities for this purpose. An experimental design was employed, involving 100 children aged 4-6 years. Participants engaged in coding activities using platforms such as ScratchJr and Code.org over 12 weeks. Pre and post-intervention assessments measured changes in computational thinking skills, supplemented by qualitative observations and feedback from educators. The findings indicate a significant improvement in computational thinking skills among participants following the coding intervention. Descriptive statistics revealed notable advancements in pattern recognition, algorithmic thinking, and problem-solving abilities. Qualitative data provided insights into the engagement levels and learning experiences of the children. Coding learning has a positive impact on the development of computational thinking in early childhood.

1. Introduction

In the contemporary digital era, computational thinking has emerged as a crucial skill set essential for problem-solving, logical reasoning, and comprehending intricate systems [1]. This cognitive process encompasses various components such as decomposition, pattern recognition, abstraction, and algorithmic thinking, all of which are fundamental for navigating the complexities of the modern world [2]. Introducing computational thinking early in education is paramount, especially during early childhood, a critical period for cognitive development [3]. Coding, often perceived as a technical skill, serves as a potent tool for nurturing computational thinking in young learners, allowing them to develop these foundational skills in a playful and interactive manner [4].
The integration of technology in early childhood education has been a subject of increasing interest and research [5]. Technology in Early Childhood Education has been explored to enhance learning experiences and foster the development of essential skills such as computational thinking [6]. Studies have shown that technology can play a significant role in engaging young children and supporting their cognitive growth [7]. By incorporating digital tools and resources, educators can create dynamic and interactive learning environments that stimulate children's curiosity and creativity[8]. STEM education, which encompasses science, technology, engineering, and mathematics, has gained prominence in early childhood education due to its potential to cultivate critical thinking and problem-solving skills from a young age [9].
The inclusion of STEM education in early childhood has been advocated for as a means to prepare children for the demands of a rapidly evolving technological landscape [10]. Research has highlighted the importance of integrating STEM activities early on to lay a strong foundation for children's future academic success [11]. By engaging in STEM-related activities, young learners can develop a range of skills, including computational thinking, that are essential for their academic and professional growth[12]. Educational robotics and computer programming have emerged as innovative tools for enhancing early childhood

education and promoting computational thinking skills [13]. By introducing students to robotics and programming concepts at an early age, educators can foster creativity, problem-solving abilities, and logical reasoning [14].

These technologies provide hands-on learning experiences that engage children in meaningful ways, allowing them to apply computational thinking principles in real-world scenarios [15]. Moreover, the use of robotics in education has been shown to enhance student engagement and motivation, making learning more interactive and enjoyable [16]. The development of children's creative thinking and problem-solving abilities through STEM education has been a focal point in early childhood research [17]. STEM learning activities have been designed to stimulate children's creativity and critical thinking skills, preparing them for the challenges of the future [2]. By engaging in play-based STEM activities, young children can explore, experiment, and collaborate, fostering a holistic approach to learning that integrates computational thinking with hands-on experiences [15]. These activities not only enhance cognitive skills but also promote social interaction and teamwork among children [18]. Incorporating technology-enhanced, STEAM-based teaching approaches in early childhood education has been shown to have positive outcomes, especially when supported by parental involvement[19]. By leveraging technology in remote teaching settings, educators can create dynamic learning environments that cater to children's diverse learning needs [20]. These approaches not only enhance children's understanding of STEM concepts but also promote creativity, collaboration, and critical thinking [21].

Additionally, parental support plays a crucial role in reinforcing learning outcomes and sustaining children's motivation and engagement [3], [15]. the integration of computational thinking skills through coding, the incorporation of technology in early childhood education, the emphasis on STEM education, the utilization of educational robotics, and the promotion of creative thinking through STEM activities collectively contribute to fostering a generation of young learners equipped with the essential skills needed to thrive in the digital age. By embracing these innovative approaches and leveraging technology in educational settings, educators can empower children to become critical thinkers, problem solvers, and lifelong learners, preparing them for success in an increasingly complex and interconnected world.

Despite the recognized importance of computational thinking, there is a significant gap in its incorporation into early childhood education. Traditional early childhood curricula often overlook computational skills, focusing primarily on basic literacy and numeracy. Consequently, young children miss out on opportunities to develop critical thinking and problem-solving abilities through coding. This study aims to address this gap by investigating how coding learning can stimulate computational thinking in early childhood. The primary objective of this study is to explore the impact of coding activities on the development of computational thinking skills in young children. To achieve the objectives, this study is guided by the following research questions: How does coding learning affect computational thinking skills in young children? And What are the most effective coding activities for stimulating computational thinking?

This study holds significant implications for both educational practices and policy. By demonstrating the benefits of coding learning in early childhood, it advocates for the integration of computational thinking into early education curricula. The findings can inform educators, curriculum developers, and policymakers about effective strategies to incorporate coding activities, ultimately contributing to enhanced STEM education from an early age. Moreover, the study provides a foundation for future research on the long-term impacts of early coding education on cognitive and academic development.

2. Materials and Methods

2.1 Research Design

This study employs a quasi-experimental design to investigate the impact of coding learning on the development of computational thinking skills in early childhood. The design includes a pre-test and post-test assessment to measure changes in computational thinking skills before and after the coding intervention. Both quantitative and qualitative data collection methods are utilized to provide a comprehensive analysis of the effects of coding activities.

2.2 Participants

The study involves 100 children aged 4-6 years from several preschools in an urban area. Participants are selected using purposive sampling to ensure a diverse representation in terms of socio-economic background, gender, and prior exposure to technology. Parental consent and child assent are obtained for all participants.

2.3 Instruments and Materials

1) Coding Tools and Platforms:
   - ScratchJr: A visual programming language designed for young children to create interactive stories and games.
   - Code.org: An educational platform offering age-appropriate coding activities and tutorials.
2) Assessment Tools:
   - Computational Thinking Test for Young Children (CTTYC): A validated instrument measuring key computational thinking skills such as pattern recognition, sequencing, and algorithmic thinking.
   - Observational Checklists: Tools for recording children's engagement, problem-solving behaviors, and collaboration during coding activities.

2.4 Procedure

1) Pre-Intervention Assessment:
   - Administer the CTTYC to all participants to establish baseline computational thinking skills.
   - Conduct initial observations to document children's natural problem-solving behaviors and interactions.
2) Coding Learning Intervention:
   - Implement a 12-week coding program where children engage in weekly coding sessions (30-45 minutes each) using ScratchJr and Code.org.
   - Sessions are facilitated by trained educators who guide children through coding activities, ensuring a balance of structured tasks and free exploration.
   - Activities include creating simple animations, interactive stories, and basic games, progressively increasing in complexity to challenge children's thinking skills.
3) Post-Intervention Assessment:
   - Re-administer the CTTYC to all participants to measure changes in computational thinking skills.
   - Conduct follow-up observations to capture any shifts in problem-solving behaviors and engagement levels.

2.5 Data Collection and Analysis

1) Quantitative Data:
   - Pre-test and post-test scores from the CTTYC are analyzed using paired t-tests to determine the statistical significance of changes in computational thinking skills.
   - Descriptive statistics (mean, standard deviation) are calculated to summarize the data.
2) Qualitative Data:
   - Observational data are coded and analyzed thematically to identify patterns and insights related to children's engagement, collaboration, and problem-solving strategies during coding activities.
   - Feedback from educators and children is collected through semi-structured interviews and focus group discussions, providing additional context to the quantitative findings.
3) Mixed Methods Integration:
   - Quantitative and qualitative data are triangulated to provide a comprehensive understanding of the impact of coding learning on computational thinking.
   - The integration of data helps to validate findings and draw nuanced conclusions about the effectiveness of the coding intervention.

3. Results and Discussions

The sample consisted of 100 children aged 4-6 years (mean age = 5.2 years; 50% male, 50% female). The pre-test and post-test scores for the Computational Thinking Test for Young Children (CTTYC) revealed notable changes in computational thinking skills following the coding intervention. Descriptive statistics for the pre-test and post-test scores are presented in Table 1.

Table 1. *Descriptive Statistics of CTTYC Scores.*

Measure	Pre-test (SD)	Post-test (SD)	Mean Difference (SD)
Pattern Recognition	3.8 (1.2)	6.5 (1.1)	2.7 (1.1)
Sequencing	4.1 (1.3)	7.0 (1.2)	2.9 (1.2)
Algorithmic Thinking	3. 5 (1.4)	6.2 (1.3)	2.7 (1.3)
Overall Score	11.4 (2. 5)	19.7 (2.3)	8.3 (2.4)

3.1 Analysis of Coding Learning Impact

A paired t-test was conducted to compare pre-test and post-test scores for each component of computational thinking. The results indicate significant improvements across all measured skills scores are presented in Table 2.

Table 2. *The Results of the Paired t-test*

Measure	t-table	p-Value
Pattern Recognition	18.4	0.001
Sequencing	19.32	0.001
Algorithmic Thinking	17.89	0.001
Overall Score	21.56	0.001

- Pattern Recognition: The mean score increased from 3.8 to 6.5 ($t(99) = 18.45$, $p < 0.001$).
- Sequencing: The mean score increased from 4.1 to 7.0 ($t(99) = 19.32$, $p < 0.001$).
- Algorithmic Thinking: The mean score increased from 3.5 to 6.2 ($t(99) = 17.89$, $p < 0.001$).
- Overall Score: The overall mean score increased from 11.4 to 19.7 ($t(99) = 21.56$, $p < 0.001$).

These results demonstrate that the coding intervention had a statistically significant positive impact on children’s computational thinking skills.

3.2 Qualitative Insights

Thematic analysis of observational data and interviews revealed several key insights:

1) Engagement and Enjoyment:
Children were highly engaged and displayed enjoyment during coding activities. They often expressed excitement and curiosity, which contributed to sustained attention and motivation.
2) Collaboration and Social Interaction:
Coding activities promoted collaboration. Children frequently worked in pairs or small groups, discussing problems and sharing solutions. This collaborative environment enhanced their social and communication skills.
3) Problem-Solving and Creativity:
Children demonstrated improved problem-solving abilities. They were able to break down tasks into smaller steps, identify patterns, and develop creative solutions to challenges encountered during coding projects.
4) Educator Feedback:
Educators observed that children became more confident in their abilities to tackle complex tasks. They noted improvements in children’s logical reasoning and perseverance.

The integration of quantitative and qualitative data provides a comprehensive understanding of the impact of coding learning on computational thinking. The significant improvements in CTTYC scores, coupled with positive qualitative feedback, underscore the effectiveness of coding activities in enhancing computational thinking skills in early childhood.

The findings suggest that coding learning not only improves cognitive skills but also fosters a collaborative and engaging learning environment. These results support the integration of coding into early childhood education curricula to develop essential skills for the digital age. The results of this study demonstrate that coding learning has a significant positive impact on the development of computational thinking skills in early childhood. The combination of quantitative improvements and qualitative insights provides robust evidence for the effectiveness of coding activities. These findings contribute to the growing body of research advocating for the inclusion of computational thinking in early childhood education and provide practical recommendations for educators and policymakers.

3.3 Discussion

The study aimed to investigate the impact of coding learning on the development of computational thinking skills in early childhood, revealing significant enhancements in pattern recognition, sequencing, and algorithmic thinking following a 12-week coding intervention [22]. The findings indicated that children exhibited improved problem-solving abilities, increased engagement, and enhanced collaboration, underscoring the effectiveness of coding activities in nurturing computational thinking skills [23]. The research design employed a quasi-experimental approach, incorporating pre-test and post-test assessments to measure changes in computational thinking skills before and after the coding intervention [24]. By utilizing both quantitative and qualitative data collection methods, the study aimed to provide a comprehensive analysis of the effects of coding activities on the development of computational thinking skills in early childhood [25].

The results of the study align with previous research emphasizing the importance of integrating technology, such as coding and robotics, into early childhood education to enhance cognitive development and problem-solving skills [26]. By engaging children in coding activities, educators can create dynamic learning environments that stimulate critical thinking and creativity, essential for navigating the complexities of the digital age[8] . Moreover, the study's focus on computational thinking in early childhood education resonates with the broader trend in educational research towards promoting STEM education from a young age [27]. STEM activities, including coding and robotics, have been recognized for their ability to cultivate essential skills like computational thinking, preparing children for future academic and professional challenges [28].

The findings of the study also underscore the significance of hands-on learning experiences, such as coding interventions, in fostering computational thinking skills in young learners [29]. By providing children with interactive and engaging activities that involve problem-solving and algorithmic thinking, educators can lay a strong foundation for their cognitive development and future success (Jung & Won, 2018). The study contributes to the growing body of research highlighting the positive impact of coding learning on the development of computational thinking skills in early childhood[30]. By integrating coding activities into early childhood education, educators can empower children with essential skills for the digital age, including problem-solving, logical reasoning, and collaboration, setting them on a path towards academic and professional success.

3.4 Implications for Practice

The findings have several important implications for early childhood education:

1) Integration of Coding in Early Childhood Curriculum:
   The study provides strong evidence supporting the integration of coding activities into early childhood education. Coding not only develops computational thinking but also promotes creativity, collaboration, and problem-solving skills. Educators should consider incorporating age-appropriate coding platforms like ScratchJr and Code.org into their teaching practices.
2) Teacher Training and Professional Development:
   Effective implementation of coding in early childhood education requires well-trained educators. Professional development programs should be designed to equip teachers with the necessary skills and knowledge to facilitate coding activities. Training should focus on understanding computational thinking, using coding tools, and creating a supportive learning environment.
3) Development of Engaging and Interactive Learning Materials:
   The study highlights the importance of engaging and interactive coding activities. Educational technology developers should create materials that are accessible, user-friendly, and designed to captivate young learners. Such materials can enhance the learning experience.

4. Conclusions

The study demonstrated that coding learning significantly enhances computational thinking skills in early childhood. By engaging in coding activities, young children showed substantial improvements in pattern recognition, sequencing, and algorithmic thinking. These skills are critical for cognitive development and are foundational for future learning in STEM disciplines. This research contributes to the growing body of literature advocating for the integration of computational thinking into early childhood education. It provides empirical evidence supporting the effectiveness of coding as a learning tool for young children. The findings underscore the potential of coding to not only develop cognitive skills but also foster creativity, collaboration, and problem-solving abilities.

As the digital age continues to evolve, equipping young children with computational thinking skills is increasingly important. This study highlights the need for educational policymakers and practitioners to embrace coding in early childhood curricula. By doing so, we can prepare the next generation for the challenges and opportunities of the future. Future research should continue to explore the long-term impacts of early coding education and identify best practices for integrating these activities into diverse educational settings.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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