INSR Journal of Mathematics, Science and Technology Education

Assessment of Computational Thinking Skills through Coding-Based Learning in School-Level Mathematics Education

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Abstract

The integration of computational thinking (CT) into school-level mathematics education has emerged as a transformative approach for enhancing students' problem-solving, logical reasoning, and analytical abilities. Computational thinking—encompassing decomposition, pattern recognition, abstraction, and algorithmic thinking—aligns closely with the core objectives of mathematics learning. Coding-based learning environments provide a practical and engaging platform for nurturing these skills by enabling students to apply mathematical concepts through structured programming tasks. This study assesses the development of computational thinking skills among school-level students through coding-based mathematics instruction. Using a mixed-method research design, the study evaluates students' CT competencies, mathematical understanding, and learning engagement before and after exposure to coding-integrated pedagogy. The findings demonstrate significant improvement in students' computational thinking abilities, conceptual clarity, logical reasoning, and confidence in mathematical problem-solving. The study concludes that coding-based learning serves as an effective instructional strategy for embedding computational thinking within mathematics education at the school level.

Keywords: Computational thinking, coding-based learning, mathematics education, school-level education, algorithmic thinking, problem-solving skills, digital pedagogy.

Introduction

In the digital age, computational thinking has been recognized as a foundational skill comparable to literacy and numeracy. It equips learners with the ability to approach complex problems systematically, design logical solutions, and apply abstraction and algorithms to real-world contexts. Mathematics education, with its emphasis on reasoning, structure, and precision, provides a natural and effective context for developing computational thinking skills.

Traditional mathematics instruction at the school level often prioritizes procedural fluency and examination-oriented learning. While such approaches may develop basic computational skills, they frequently fail to cultivate higher-order thinking, creativity, and transferable problem-solving abilities. Students may learn to apply formulas mechanically without understanding underlying structures or strategies.

Coding-based learning introduces an interactive and applied dimension to mathematics education. By engaging students in programming tasks—such as writing algorithms, debugging code, and visualizing mathematical relationships—coding fosters deep engagement with mathematical concepts. It encourages learners to decompose problems, recognize patterns, generalize solutions, and test hypotheses through iterative processes.

This research assesses the effectiveness of coding-based learning in developing computational thinking skills among school-level mathematics students and examines its influence on conceptual understanding, logical reasoning, and learner motivation.

Methodology

Research Design

A mixed-method quasi-experimental research design was adopted to evaluate both quantitative learning outcomes and qualitative learning experiences.

Sample Selection

- Participants: 480 school-level students
- Grades: VI to VIII
- Schools: Government and private schools
- Groups:
  - Experimental group (coding-based mathematics instruction)
  - Control group (traditional mathematics instruction)

Coding Platforms and Tools Used

- Block-based programming environments (e.g., Scratch-type interfaces)
- Beginner-friendly text-based coding modules
- Visual programming tasks aligned with mathematics topics
- Interactive problem-solving challenges

Mathematics Topics Integrated with Coding

- Arithmetic operations and number patterns
- Fractions and ratios
- Algebraic expressions and equations
- Geometry and coordinate systems
- Data handling and logical reasoning

Data Collection Instruments

1. Computational Thinking Skills Test (pre-test and post-test)
2. Mathematics achievement test
3. Student perception questionnaire
4. Classroom observation schedule
5. Teacher interviews

Data Analysis Techniques

- Paired t-test
- Mean score comparison
- Percentage analysis
- Qualitative thematic analysis

Duration of Study

The intervention was conducted over 20 weeks.

Case Study: Coding-Based Mathematics Learning in School Classrooms

1. Pedagogical Integration of Coding and Mathematics

Coding activities were embedded within regular mathematics lessons rather than treated as separate subjects. Students solved mathematical problems by creating algorithms, writing code, and testing outputs. This integration helped students perceive mathematics as a logical and dynamic discipline rather than a static set of rules.

2. Development of Core Computational Thinking Skills

Coding-based tasks significantly enhanced students' ability to:

- Decompose complex problems into smaller, manageable steps
- Identify patterns in number sequences and mathematical relationships
- Abstract mathematical rules and generalize solutions
- Design and refine algorithms for solving problems

Students learned to think step-by-step and reflect on their reasoning processes.

3. Enhancement of Mathematical Conceptual Understanding

Coding required students to explicitly translate mathematical ideas into logical instructions. This process deepened conceptual clarity, reduced misconceptions, and strengthened connections between abstract symbols and real-world representations.

4. Student Engagement and Learning Motivation

Students exhibited high levels of enthusiasm and sustained attention during coding-based lessons. The immediate feedback provided by program execution and debugging encouraged experimentation and resilience in problem-solving.

5. Teacher Observations and Challenges

Teachers observed improved classroom interaction, peer collaboration, and questioning behavior. However, challenges included limited access to devices, initial teacher unfamiliarity with coding tools, and time constraints within rigid curricula.

Data Analysis

Table 1: Improvement in Computational Thinking Skills

CT Skill Dimension	Pre-Test Mean	Post-Test Mean	Interpretation
Problem Decomposition	49	78	Significant improvement in breaking down problems
Pattern Recognition	52	80	Enhanced ability to identify mathematical patterns
Abstraction	47	75	Better generalization of mathematical rules
Algorithmic Thinking	50	82	Strong growth in stepwise logical reasoning
Debugging and Evaluation	45	77	Improved error detection and correction skills

Table 2: Student Perceptions of Coding-Based Mathematics Learning

Learning Indicator	Positive Response (%)	Interpretation
Improved Logical Thinking	86%	Coding strengthened reasoning processes
Better Understanding of Mathematics	83%	Concepts became clearer through coding
Increased Interest in Mathematics	81%	Interactive learning enhanced motivation
Confidence in Problem-Solving	79%	Students felt more capable of tackling challenges
Preference for Coding Integration	84%	Majority supported permanent integration

Questionnaire (Sample Items)

1. Does coding-based learning help you understand mathematics concepts better?
2. Are you able to break complex problems into smaller steps after coding activities?
3. Does writing algorithms improve your logical thinking?
4. How helpful is debugging in identifying mistakes in reasoning?
5. Do coding tasks make mathematics more interesting?
6. Are you confident in applying mathematics concepts through programming?
7. Does coding encourage teamwork and discussion in class?
8. How often do you test and revise your solutions during coding activities?
9. What challenges do you face while learning mathematics through coding?
10. Should coding be permanently integrated into school mathematics education?

Conclusion

The study clearly demonstrates that coding-based learning is an effective approach for assessing and enhancing computational thinking skills in school-level mathematics education. By integrating coding with mathematical instruction, students develop strong problem decomposition abilities, pattern recognition skills, abstraction capacity, and algorithmic thinking.

Coding-based pedagogy transforms mathematics classrooms into active learning environments where students engage in exploration, experimentation, and reflection. It bridges the gap between abstract mathematical concepts and practical application, thereby improving conceptual understanding and learner confidence.

While challenges related to infrastructure, teacher training, and curriculum alignment exist, strategic planning and policy support can address these barriers. The study strongly recommends the systematic integration of coding-based learning into school mathematics curricula to prepare students for future academic and technological demands.

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