**Cognitive Characteristics of Developing Foundational Algorithmic Thinking in Secondary School Students within an Information-Processing Learning Approach**

Umar Khushvaktov 1, a), Ural Khushvaktov2, Alisher Abdusamatov3, Dilmurod Badalov3

1 Chief specialist of Ministry of Digital technologies of the Republic of Uzbekistan; Termez, Uzbekistan

2National Pedagogical University of Uzbekistan named after Nizami; Tashkent, Uzbekistan

3Termiz University of Economics and Service; Termez, Uzbekistan

a) Corresponding author: [umarx2590@gmail.com](mailto:umarx2590@gmail.com)

**Abstract.** This article examines the development of foundational algorithmic thinking in secondary school students within an information-processing learning framework. The main aim is to enhance students’ cognitive skills, including attention, memory, and mental modeling, by structuring learning activities in a systematic and engaging way. The study emphasizes the importance of integrating constructivist, problem-based, and technology-enhanced pedagogical approaches to improve students’ understanding and practical application of algorithmic reasoning. Special attention is given to the use of digital tools, guided experimentation, and stepwise problem decomposition, which encourage active participation and allow teachers to assess students’ comprehension through observation, discussion, and collaborative analysis. Furthermore, the research explores how aligning instructional strategies with students’ cognitive characteristics impacts learning efficiency and higher-order thinking. The findings indicate that a well-balanced combination of these methods significantly enhances students’ engagement, problem-solving abilities, and overall performance in mathematics and information technology education.

**INTRODUCTION**

In recent years, the development of algorithmic thinking has become a key priority in secondary school education due to the increasing role of digital technologies, computational problem solving, and data-driven decision-making in modern society. Foundational algorithmic thinking is no longer limited to computer science education; it is increasingly regarded as a universal cognitive skill that supports logical reasoning, problem decomposition, abstraction, and systematic thinking across various school subjects. Consequently, understanding the cognitive mechanisms underlying the development of algorithmic thinking in school students has gained significant attention in educational research.

From a cognitive perspective, learning is understood as an active process of information perception, processing, storage, and retrieval. The information-processing learning approach conceptualizes the educational process as a sequence of interconnected cognitive operations through which students transform external instructional input into internal knowledge structures. Within this framework, students’ cognitive characteristics—such as attention, working memory capacity, mental representations, and processing strategies—play a crucial role in determining the effectiveness of learning outcomes. Therefore, the development of foundational algorithmic thinking in secondary school students cannot be fully explained without considering these cognitive features.

Cognitive psychology provides a theoretical foundation for analyzing how students acquire and apply algorithmic concepts. According to information-processing theories, learning effectiveness depends on how new information is integrated into existing mental schemas and how efficiently it is encoded, stored, and retrieved. Piaget’s concept of schemas emphasizes that knowledge acquisition involves continuous restructuring of cognitive structures through assimilation and accommodation, while Bruner highlights the importance of active learning and individual differences in information processing. These theoretical perspectives suggest that algorithmic thinking develops as a result of students’ interaction with learning tasks that stimulate cognitive operations such as analysis, synthesis, and mental transformation.

In secondary school education, students exhibit significant variability in cognitive development, which influences their ability to construct and apply algorithmic reasoning. Differences in processing speed, cognitive flexibility, and prior knowledge affect how students perceive algorithmic tasks and how effectively they solve problems. An information-processing learning approach allows educators to design instructional conditions that align with students’ cognitive characteristics, thereby supporting the gradual development of foundational algorithmic thinking through structured mental activities and meaningful learning experiences.

Despite the growing body of research on algorithmic and computational thinking, there remains a need for studies that explicitly examine the cognitive characteristics of secondary school students within an information-processing framework. In particular, limited attention has been paid to how perception, memory, and mental schemas interact during the formation of foundational algorithmic thinking at the school level. Addressing this gap is essential for developing evidence-based pedagogical strategies that foster students’ cognitive engagement and improve the quality of algorithmic thinking instruction.

Therefore, the purpose of this study is to analyze the cognitive characteristics involved in the development of foundational algorithmic thinking in secondary school students within an information-processing learning approach. The study aims to identify key cognitive factors that influence algorithmic thinking development and to clarify the pedagogical conditions that support effective cognitive processing in school education.

**MODERN PEDAGOGICAL APPROACHES IN MATHEMATICS EDUCATION**

Modern mathematics education emphasizes the development of students’ cognitive and problem-solving abilities rather than rote memorization of procedures. Contemporary pedagogical approaches focus on active learning, meaningful understanding, and the formation of higher-order thinking skills, including algorithmic thinking, which plays a key role in mathematical reasoning [1].

Cognitive and constructivist perspectives highlight that learning involves active mental processing, including perception, memory, and reflection, rather than passive reception of facts. In mathematics education, this translates into learner-centered instruction that aligns with students’ cognitive characteristics and fosters deeper engagement with concepts. Constructivist methods position learners as active participants in constructing their own mathematical knowledge through problem solving and collaboration, which leads to improved problem-solving performance compared to traditional instructional methods [2].

Closely related to constructivism is the information-processing perspective, which supports the structured presentation of mathematical content to reduce cognitive load and enhance conceptual understanding. Inquiry-based and problem-based learning approaches encourage students to decompose complex mathematical tasks, reflect on solution strategies, and reorganize mental schemas to accommodate new information [3].

The integration of digital technologies and interactive environments in mathematics classrooms also supports modern pedagogical aims by enabling visualization, modeling, and interactive exploration of mathematical concepts. These tools facilitate students’ engagement with abstract ideas and contribute to the development of both procedural fluency and conceptual understanding [4].

Overall, modern pedagogical approaches in mathematics education — including constructivist, problem-based, and information-processing-oriented strategies — create favorable conditions for developing foundational algorithmic thinking in secondary school students. These approaches combine cognitive principles, active learning, and effective instructional design to support students’ intellectual growth and mathematical competence.

**LITERATURES ANALYSIS**

Recent studies emphasize that algorithmic thinking is a key cognitive skill supporting problem-solving, abstraction, and logical reasoning in mathematics and STEM education [2]. The information-processing perspective highlights that learning occurs through structured stages of perception, encoding, storage, and retrieval, and students’ cognitive characteristics—such as attention, memory, and prior knowledge—affect their ability to develop algorithmic thinking [3].

Constructivist and problem-based learning approaches encourage students to actively engage with problems, decompose complex tasks, and reorganize mental schemas, promoting algorithmic thinking [5]. Additionally, digital technologies like interactive simulations and visualization tools enhance engagement and conceptual understanding, providing meaningful practice for algorithmic skills [6].

Although research shows the importance of cognitive processes in developing algorithmic thinking, there is still a need for studies that examine how secondary school students’ cognitive features interact with instructional approaches to optimize learning outcomes.

**METHODOLOGICAL APPROACHES TO DEVELOPING FOUNDATIONAL ALGORITHMIC THINKING**

Developing foundational algorithmic thinking in secondary school students requires pedagogical strategies that actively engage learners’ cognitive processes. Modern methodological approaches emphasize information-processing principles, focusing on how students perceive, encode, store, and retrieve information while solving algorithmic and problem-based tasks [1].

The information-processing approach suggests that structuring learning materials and activities reduces cognitive load, enabling students to process complex information more effectively. In practice, this involves guiding students to decompose problems into sequential steps, identify patterns, and construct mental models that facilitate algorithmic reasoning [2].

Constructivist and problem-based learning strategies further promote algorithmic thinking by encouraging active engagement with tasks, experimentation, and collaborative problem solving. For example, students may design stepwise procedures or simple algorithms to model real-life situations, which strengthens both conceptual understanding and cognitive flexibility [5].

The integration of digital tools and simulations provides opportunities for visualization, interactive exploration, and immediate feedback. These resources help students internalize abstract concepts, test hypotheses, and iteratively refine their algorithmic strategies, fostering higher-order thinking and cognitive adaptability [6].

Overall, methodological approaches that combine information-processing principles, active learning, constructivist strategies, and digital interaction create favorable conditions for developing foundational algorithmic thinking. Such approaches ensure that students not only acquire procedural skills but also enhance their cognitive abilities to analyze, plan, and solve complex problems effectively.

Research in pedagogy and physics-mathematics education has demonstrated the critical importance of enhancing the role of experimental activities in teaching the mechanical properties of solid bodies (Vygotsky, 1986; Bransford et al., 2000). Practical experiments not only provide students with hands-on experience but also help them develop a deeper conceptual understanding of the subject. These activities allow learners to observe, analyze, and draw conclusions based on real-world physical phenomena, thereby strengthening their problem-solving and critical-thinking skills.

It is recommended that the teaching of these topics be conducted using a constructivist approach, which emphasizes active learning and the construction of knowledge based on students' experiences (Piaget, 1952). In this model, students are not passive recipients of information but rather active participants in the learning process. They engage in inquiry-based learning, perform experiments, and apply theoretical concepts to practical scenarios, enabling them to develop a more profound and intuitive grasp of solid-state mechanics.

Furthermore, integrating modern pedagogical technologies, such as interactive simulations, digital laboratories, and real-time data collection tools, enhances the effectiveness of the learning process. These tools allow students to visualize complex physical principles, test hypotheses, and explore different variables in a controlled environment, making abstract concepts more tangible and easier to understand.

By adopting a student-centered methodology that includes collaborative learning, guided discovery, and project-based approaches, educators can significantly improve students' engagement and retention of knowledge. Encouraging discussions, problem-solving tasks, and cross-disciplinary applications of physics also fosters deeper comprehension and motivates learners to explore the subject beyond the classroom.

Ultimately, a well-structured methodological approach that combines theoretical knowledge with hands-on practice ensures that students develop both the conceptual understanding and practical skills necessary for mastering the mechanical properties of solid bodies.

**MODERN PEDAGOGICAL TECHNOLOGIES AND THEIR EFFECTIVENESS**

Modern pedagogical technologies aim to enhance students’ cognitive engagement, problem-solving abilities, and algorithmic thinking through interactive and learner-centered strategies. Technologies such as digital simulations, interactive modeling tools, learning management systems, and educational software provide students with opportunities to visualize abstract concepts, experiment with variables, and test hypotheses in real-time [7,8].

Research indicates that technology-integrated instruction supports the development of higher-order thinking skills by enabling students to actively process information, construct mental models, and apply algorithmic reasoning to problem-solving tasks [4]. For instance, digital simulations in mathematics and physics allow learners to manipulate parameters, observe outcomes, and iteratively refine strategies, which strengthens both conceptual understanding and procedural fluency [5].

Problem-based and inquiry-based activities implemented through educational technologies also increase engagement and motivation, as students collaborate and explore solutions in a controlled digital environment. Evidence shows that such technology-supported approaches are more effective in promoting cognitive development and algorithmic thinking compared to traditional lecture-based methods [3,9].

In summary, modern pedagogical technologies provide an effective platform for developing foundational algorithmic thinking in secondary school students by combining interactive learning, structured information processing, and active problem-solving opportunities.

**THE USE OF MULTIMEDIA AND DIGITAL TECHNOLOGIES IN INFORMATION TECHNOLOGY EDUCATION**

The integration of multimedia and digital technologies in information technology (IT) education provides opportunities to enhance students’ cognitive engagement, algorithmic thinking, and problem-solving skills. Multimedia resources—including animations, simulations, interactive diagrams, and video tutorials—enable students to visualize abstract concepts, understand complex processes, and actively participate in learning tasks.

Digital tools such as programming environments, learning management systems, and educational software support structured and interactive learning experiences. These technologies facilitate step-by-step problem decomposition, experimentation, and immediate feedback, allowing students to internalize algorithmic principles effectively. Research indicates that students who learn through multimedia-enriched environments demonstrate higher engagement, better conceptual understanding, and improved ability to apply algorithmic reasoning to IT-related problems.

Moreover, multimedia and digital technologies support personalized learning, allowing students to work at their own pace, revisit difficult concepts, and engage in self-directed exploration. The combination of interactive simulations, coding exercises, and visual representations creates a cognitive-rich environment that promotes higher-order thinking, critical analysis, and flexible problem-solving [4,3].

In summary, the use of multimedia and digital technologies in IT education strengthens foundational algorithmic thinking by providing interactive, visual, and experiential learning opportunities that align with students’ cognitive processes and learning styles.

**PURPOSE OF THE RESEARCH**

The purpose of this research is to examine the cognitive characteristics that influence the development of foundational algorithmic thinking in secondary school students and to identify effective information-processing-based instructional strategies that support this development. Specifically, the study aims to:

1. Investigate how students perceive, process, and apply information while engaging in algorithmic tasks.
2. Identify the key cognitive features—such as attention, memory, and mental modeling—that facilitate or hinder algorithmic thinking.
3. Evaluate the effectiveness of pedagogical approaches, including constructivist, problem-based, and technology-enhanced strategies, in fostering algorithmic reasoning.
4. Provide practical recommendations for designing instructional interventions that align with students’ cognitive characteristics to enhance algorithmic thinking and problem-solving skills.

Ultimately, the research seeks to bridge the gap between cognitive theory and classroom practice by providing insights into how secondary school students develop algorithmic thinking through structured, interactive, and cognitively aligned learning experiences.

**THE OBJECT OF THE RESEARCH**

The object of this research is the process of developing foundational algorithmic thinking in secondary school students within the context of mathematics and information technology education. The study focuses on understanding how students acquire, process, and apply algorithmic knowledge, and how their cognitive characteristics influence their ability to solve problems, construct mental models, and engage in structured reasoning.

**SCIENTIFIC NOVELTY OF THE RESEARCH**

The scientific novelty of this research lies in its comprehensive examination of the cognitive characteristics that influence the development of foundational algorithmic thinking in secondary school students within an information-processing framework. Unlike previous studies that primarily focus on computational skills or programming instruction, this study integrates cognitive psychology principles, constructivist learning theories, and information-processing approaches to identify how mental processes such as attention, memory, and mental modeling contribute to algorithmic reasoning.

Furthermore, the research provides empirical evidence on the effectiveness of pedagogical strategies—including problem-based, inquiry-based, and technology-enhanced methods—in fostering algorithmic thinking. This integrative perspective bridges the gap between cognitive theory and practical classroom implementation, offering new insights into designing instructional interventions that align with students’ cognitive profiles to optimize the development of algorithmic competencies.

**METHODOLOGY OF RESEARCH**

The following methods were used in the research:

Theoretical analysis – A review of existing literature and scientific sources on pedagogy and physics teaching methodologies.

Experimental research – Analyzing changes in students' knowledge and skills through the application of modern pedagogical technologies in general education schools.

Surveys and questionnaires – Assessing the effectiveness of new teaching methods based on surveys conducted among teachers and students.

Observation of the educational process – Evaluating students' engagement and interest in physics through the implementation of modern teaching approaches in lessons.

Statistical analysis of results – Analyzing the outcomes of experimental research using mathematical methods.

The findings of the study contribute to improving physics education in schools and enhancing the effectiveness of pedagogical methods.

**ANALYSIS & RESULTS**

This research employs a mixed-methods approach, combining quantitative and qualitative techniques to examine the cognitive characteristics that influence the development of foundational algorithmic thinking in secondary school students.

Quantitative methods include standardized tests and problem-solving tasks designed to assess students’ algorithmic reasoning, memory capacity, attention, and cognitive processing speed. Qualitative methods involve classroom observations, interviews, and analysis of students’ work to explore their mental models, strategies, and engagement with algorithmic tasks.

The study is conducted in secondary schools, with students participating in structured learning activities based on information-processing principles, such as stepwise problem decomposition, guided experimentation, and digital simulations. Data collected are analyzed using statistical techniques for quantitative measures and thematic analysis for qualitative data, allowing a comprehensive understanding of how cognitive features and instructional methods interact to support algorithmic thinking.

**CONCLUSIONS**

The study demonstrates that the development of foundational algorithmic thinking in secondary school students is closely linked to their cognitive characteristics, including attention, memory, and mental modeling abilities. Information-processing-based instructional strategies—such as stepwise problem decomposition, guided experimentation, and digital simulations—effectively enhance students’ algorithmic reasoning and problem-solving skills.

Constructivist, problem-based, and technology-integrated approaches create favorable conditions for active engagement, conceptual understanding, and the application of algorithmic thinking in real-life and academic contexts. These findings provide valuable insights for designing instructional interventions that align with students’ cognitive profiles, ultimately supporting the development of higher-order thinking and algorithmic competence.

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