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ENHANCING STUDENTS' MATHEMATICAL LOGICAL THINKING BASED ON THE REQUIREMENTS OF PISA AND TIMSS INTERNATIONAL ASSESSMENT PROGRAMS

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Abstract. This article investigates the methodology and practical mechanisms for enhancing mathematical logical thinking in 5th–9th grade students of secondary schools, aligned with the frameworks and requirements of international assessment programs such as PISA (Program for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study). The paper analyzes conceptual differences between traditional teaching methods and international frameworks in fostering logical reasoning, presenting methods for integrating contextual (real-world) tasks and cognitive activities into the educational process. Based on experimental results, scientific and practical recommendations are formulated to develop students' functional literacy and logical reasoning competence.

Keywords: mathematical logical thinking, PISA, TIMSS, functional literacy, contextual problems, cognitive processes, grades 5–9, teaching methodology, analysis and synthesis.

Introduction

In the context of modern global development, the primary objective of the education system extends beyond providing students with pure theoretical knowledge; it focuses on enabling them to apply learned concepts in real-life situations, think independently and logically, analyze problem scenarios, and make optimal decisions. According to decrees of the President of the Republic of Uzbekistan regarding the implementation of international assessment programs within the public education system, as well as national educational concepts, bringing students' functional and mathematical literacy to the level of international standards has been established as a strategic priority [1; pp. 12–15].

Students in grades 5–9 of general secondary schools undergo a crucial stage of cognitive development. During this age period, there is a transition from visual-action and visual-imagative thinking to abstract-logical reasoning [2; p. 45]. However, traditional mathematics education often prioritizes strictly algorithmic tasks, direct application of ready-made formulas, and problems detached from real-life contexts, which limits students' logical and analytical thinking.

To address this issue, the task items and assessment frameworks of international programs such as PISA (OECD) and TIMSS (IEA) serve as a methodological foundation. While PISA assesses students' ability to apply mathematical knowledge and logical reasoning in real-life contexts (functional literacy), TIMSS evaluates curriculum-based cognitive domains: knowing, applying, and reasoning [3; p. 28]. As noted by Usmonov et al., enhancing logical thinking not only deepens mathematical knowledge but also builds students' competence in complex problem-solving [4; pp. 88].

The goal of this study is to develop a pedagogical model for enhancing mathematical logical thinking in 5th–9th grade students based on the frameworks and evaluation criteria of PISA and TIMSS, and to validate its effectiveness experimentally.

Methodology and Research Methods

A comprehensive set of general scientific and pedagogical methods was employed during the research:

1. **Theoretical-Methodological Analysis:** Official framework documents of PISA and TIMSS international assessment programs, as well as scientific literature by domestic and foreign scholars in mathematics education, cognitive psychology, and logical reasoning, were thoroughly analyzed [5; p. 112].

2. **Pedagogical Observation and Diagnostics:** Observation of mathematics lessons in grades 5–9 was conducted, and diagnostic test items were developed to evaluate students' logical-cognitive skills.

3. **Pedagogical Experimentation:** The experimental work was conducted during the 2025–2026 academic year in secondary schools in Namangan Region. A total of 324 students across grades 5–9 (161 in the experimental group, 163 in the control group) and 14 mathematics teachers participated in the study.

4. **Mathematical-Statistical Methods:** Student's t-test was utilized to evaluate the statistical reliability of the differences between the experimental and control groups.

The alignment between the mathematical-cognitive model and PISA/TIMSS cognitive domains is outlined in **Table 1**.

Table 1. Integration of Cognitive Domains in PISA/TIMSS and Components of Mathematical Logical Thinking

International Program	Cognitive / Thinking Level	Key Indicators of Logical Thinking	Task Type and Characteristics
TIMSS	**Knowing**	Recalling facts, identifying concepts, performing computations	Standard algorithmic and theoretical problems
TIMSS / PISA	**Applying**	Modeling, comparing, classifying, analyzing	Multi-step, non-standard problem tasks
PISA / TIMSS	**Reasoning**	Formulating hypotheses, deductive/inductive reasoning, justifying solutions	Real-world (contextual) and open-ended problem-solving tasks

Results

The enhanced methodological model for developing mathematical logical thinking was implemented in the educational process in three distinct stages:

1. **Contextualization Stage:** Traditional academic problems in textbooks were transformed into PISA-style logical tasks based on real-life scenarios (finance, construction, ecology, everyday life).

2. **Cognitive Modeling Stage:** Aligned with TIMSS's "Reasoning" domain, strategies were established for students to test hypotheses, identify cause-and-effect relationships, and construct proofs.

3. **Reflective-Evaluative Stage:** Alternative solution paths for solved problems were systematically analyzed, focusing on identifying and correcting logical errors.

The transformation scheme of conventional mathematical problems into PISA/TIMSS-aligned logical tasks is depicted in **Figure 1**.



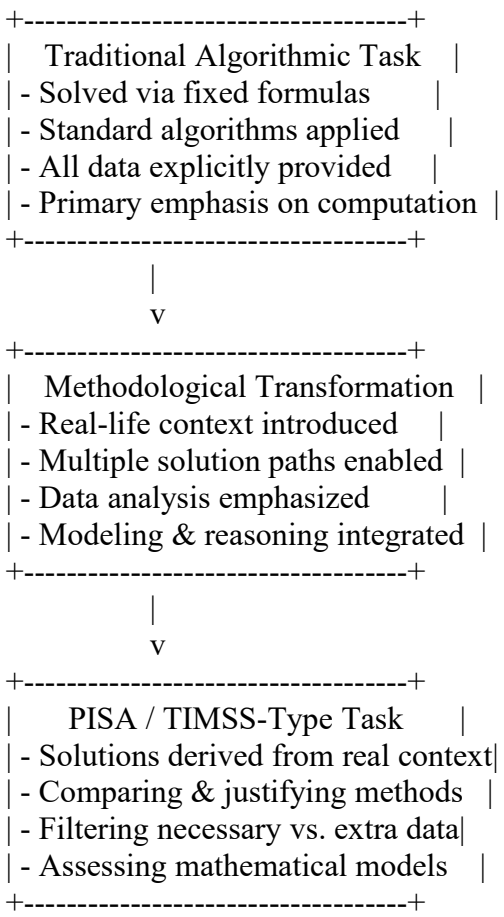



Figure 1. Scheme for transforming traditional mathematics problems into logical tasks based on PISA/TIMSS criteria.

Statistical Analysis of Experimental Results

At the beginning and conclusion of the experiment, diagnostic assessments were administered to evaluate logical thinking, contextual problem-solving, and reasoning skills in both groups using a 100-point scale. The performance metrics before and after the experiment are summarized in **Table 2**.

Table 2. Logical Thinking Performance Indicators of Experimental and Control Groups (in Points)

Groups	Sample Size (N)	Pre-Test (M±SD)	Post-Test (M±SD)	Growth Indicator (Δ)
Control Group	163	54.2±10.8	61.5±10.2	+7.3
Experimental Group	161	53.8±11.1	82.3±8.9	+28.5

Note: M = Arithmetic Mean; SD = Standard Deviation.

To determine the statistical significance of the post-test results between the two groups, a two-sample Student's t-test was conducted. The calculated value of the t-criterion yielded $t = 19.46$. At degrees of freedom $df = 322$, the obtained significance level was $p < 0.001$, which significantly exceeds the critical value ($t_{crit} = 1.97$).

This statistical significance confirms that integrating the improved methodology and international assessment tasks into the experimental group reliably improved students' mathematical logical thinking capabilities.

Discussion

The findings indicate that developing mathematical logical thinking in grades 5–9 involves more than simply increasing the volume of math puzzles or riddles. When tasks aligned with PISA and TIMSS requirements are integrated into the curriculum, the following cognitive developments are observed:

1. **Visualization and Modeling of Abstract Concepts:** Students learn to translate real-life scenarios into mathematical models (equations, inequalities, graphs, tables) and interpret mathematical results back into practical contexts [7; p. 204].
2. **Development of Inductive and Deductive Reasoning:** Tasks within the TIMSS "Reasoning" domain allow students to derive general rules from specific cases (induction) and apply general principles to concrete situations (deduction) [8; p. 55].
3. **Critical and Analytical Thinking:** PISA-type contextual problems compel students to evaluate missing or redundant information, judge data reliability, and justify the logical validity of their conclusions.

As noted by Abduqodirov et al., preparing students for international assessment systems demands a fundamental reform of teaching methodology and curriculum design [9; p. 33]. Our study demonstrates that systematically replacing conventional routine exercises with cognitive, problem-oriented, and contextualized tasks in grades 5–9 yields high educational efficacy.

Conclusion

Based on theoretical and empirical findings, the following conclusions were drawn:

1. The standards of PISA and TIMSS serve as a solid methodological framework for advancing mathematical logical reasoning in 5th–9th grade students, shifting the educational focus from memorization to cognitive skill development.
2. Transforming traditional textbook problems into contextualized, problem-based tasks based on PISA/TIMSS frameworks significantly improves students' functional literacy and logical competence.
3. Empirical results and statistical analysis ($p < 0.001$) confirm the high efficacy of the proposed model. Students in the experimental group scored an average of 20.8 points higher in logical reasoning tasks compared to those in the control group.

Practical Recommendations:

1. Integrate PISA and TIMSS-style contextual logical tasks directly into 5th–9th grade mathematics textbooks and teaching materials.
2. Expand professional development modules for mathematics teachers focused on designing and implementing international assessment items in classroom instruction.
3. Adopt criteria-based assessment models that prioritize solution logic and reasoning quality over merely obtaining a correct numerical answer.

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