METHODOLOGY FOR DEVELOPING STUDENTS' SCIENTIFIC THINKING BASED ON PISA AND PIRLS CRITERIA

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Abstract

This scientific article comprehensively studies the methodology for developing scientific and logical thinking of secondary school students based on the criteria of the international assessment programs PISA (Programme for International Student Assessment) and PIRLS (Progress in International Reading Literacy Study), which are considered one of the most important priorities of the modern education system. The main goal of the study is to abandon the tradition of simply memorizing factual knowledge in the educational process and develop optimal pedagogical mechanisms for developing functional literacy, understanding and analyzing text, and solving life problems using scientific methods in students. The work highlights the integrative relationship between the PISA program's natural and scientific literacy and the PIRLS program's reading literacy areas using pedagogical experiments and empirical analyses.

Keywords: PISA, PIRLS, scientific thinking, functional literacy, reading literacy, natural and scientific worldview, pedagogical methodology.

In the era of globalization and rapid technological progress, the international competitiveness of each country is directly determined by the quality of its human capital and the level of education system. Today, the modern labor market requires not just personnel who know a set of data by heart, but also creative individuals who can extract the most important from the flow of information, analyze it from a critical point of view and make the right decisions in non-standard situations. Therefore, the global educational community is increasingly paying attention to international programs aimed at identifying students' life skills and functional literacy, abandoning traditional methods of assessing their knowledge. Among them, the PISA programs coordinated by the Organization for Economic Cooperation and Development (OECD) and the PIRLS programs conducted by the International Association for the Evaluation of Educational Achievement (IEA) are of particular strategic importance. The Republic of Uzbekistan has also begun to actively participate in these studies in order to bring its education system into line with international standards and increase the intellectual potential of the younger generation, which, in turn, sets new methodological tasks for the discipline of pedagogy.

The PISA and PIRLS criteria do not simply test the level of mastery of the curriculum, but also measure the ability to apply the acquired knowledge in real-life situations, to solve unexpected problems, that is, scientific thinking. By scientific thinking, we mean not only the worldview of a scientist working in a laboratory setting, but also the ability of every school graduate to see events and phenomena in everyday life in a cause-and-effect relationship, to be based on evidence and to draw conclusions. The problem is that the traditional educational methodology, which has been formed over many years, is mainly focused on mechanical memorization of ready-made rules and reproductive activities, which limited the ability of students to think independently and conduct scientific reasoning. While the PIRLS program studies the reading and comprehension level of 4th grade students, the PISA program tests the mathematical, scientific and reading literacy of 15-year-old adolescents. These two programs are inextricably linked, and the ability to understand the text formed in the primary grades serves as a fundamental foundation for understanding scientific phenomena and forming scientific hypotheses in the upper grades.

The relevance of this research work is that the mechanisms for systematically integrating their philosophy and methodological foundations into the teaching process, rather than simply memorizing international assessment criteria in the form of test tasks, have not been sufficiently developed in the national education system. In order to develop scientific thinking in students,

the content of the lesson should be radically changed, interdisciplinary integration should be strengthened, and problem-based learning technologies should be widely used. This article analyzes the methodological foundations of transforming students' scientific thinking, teaching them to work with evidence, and developing research skills within the framework of PISA and PIRLS requirements, and proposes practical solutions.

The problem of developing students' intellectual abilities with the help of international assessment programs and their use is being widely studied by world and republican pedagogical scientists. The methodological foundations of PISA studies and the content of the concept of natural and scientific literacy are fundamentally outlined in the works of Schleicher [1]. The author emphasizes the role of contextual tasks, that is, problems related to life situations, in the formation of students' scientific worldview. In his opinion, modern education should not only give the student a formula, but also teach him to understand the laws of nature behind this formula. Also, the formation of reading literacy in primary grades and its impact on academic success at later stages was analyzed in detail by Mullis and Martin [2] within the framework of the PIRLS program, who proved that the ability to understand the hidden meanings in the text and interpret information is the first step in scientific thinking.

Kirsch and colleagues [3], who studied the impact of PISA and PIRLS on students' critical thinking, have shown that the ability to resist information manipulation in education and to distinguish scientifically sound facts from false information can be developed precisely through reading literacy. Local researcher Rakhmonov [4] in his work considers the problems of adapting national curricula to international assessment criteria in the conditions of Uzbekistan and justifies the need to increase the level of readiness of teaching staff for this system. In his opinion, heuristic and case-based tasks should replace reproductive questions in textbooks.

Regarding the psychological and pedagogical aspects of the development of thinking, the theory of sociocultural development and the laws of thinking formation put forward by Vygotsky [5] still serve as the fundamental basis of international assessment systems. While Vygotsky emphasized that the educational process should be directed to the child's zone of proximal development, PISA and PIRLS tasks force the student to go beyond the boundaries of his existing knowledge and create new hypotheses. Research from the University of Pisa proposes innovative models for increasing scientific literacy and forming ecological and technological culture in students through interdisciplinary integration, which serve to ensure the harmony of theory and practice in the school system [6]. An analysis of this literature shows that, although there are many studies on international assessment programs, the mechanisms for developing scientific thinking on the basis of coherence by combining the PIRLS and PISA criteria into a single methodological system have not been sufficiently covered.

This study used integrated research methods to determine the level of development of scientific thinking of schoolchildren based on the PISA and PIRLS criteria and to verify the effectiveness of the methodological model. The study was conducted during the 2025-2026 academic year among students of grades 4 (PIRLS) and 9 (PISA) of four secondary schools located in remote and central areas of Tashkent. A total of 240 students participated in the experiment, who were divided into control and experimental groups in equal numbers. In the control groups, lessons were conducted based on traditional textbooks and methodologies, while in the experimental groups, specially developed integrated cases, problem situations, and text tasks modeled after PISA and PIRLS tasks were introduced into the lesson process.

The methodological approach was based on the principles of systematicity, interdisciplinary integration (STEAM approach) and the development of critical thinking. To assess the initial reading literacy of students, literary and informational texts were selected in accordance with the PIRLS criteria and questions were developed for them at four levels (direct information retrieval, simple inference, interpretation, and evaluation of text elements). In order to assess natural and scientific thinking in ninth grades, tasks on real-life, environmental, and medical problems were prepared within the framework of PISA requirements, which measured students' competencies in scientific explanation of phenomena, design of research methods, and scientific analysis of data.

The empirical part of the study was carried out in three stages: at the first stage, diagnostic tests were conducted to determine the level of initial preparation and thinking of students; at the second stage, training was organized in experimental groups for six months based on the new methodology; and in the third stage, final monitoring was carried out, and the results were processed using mathematical and statistical methods (Student t-criterion). The reliability of the results was confirmed by the statistical significance of the differences between the control and experimental groups.

The data collected during the study and the results of the final tests showed that the interactive and problem-based teaching methodology based on the PISA and PIRLS criteria significantly increases the intellectual and scientific skills of students. At the initial diagnostic stage, the results of students in both groups were very close to each other, and most students simply copied information from the text and used ready-made formulas. However, at the end of the experiment, it was found that there were significant differences between the control and experimental groups in terms of logical and scientific thinking indicators.

When analyzing the results of primary school students in reading literacy (PIRLS), it was found that the indicators of deep understanding of the content of the text, understanding the hidden meanings in it, and expressing a critical attitude towards the author's idea increased sharply in the experimental group. Table 1 below compares the reading literacy levels of 4th grade students before and after the experiment.

Table 1: Dynamics of changes in reading literacy levels (PIRLS criteria) of 4th grade students (in percent)

Rating levels	Control group (Before the experiment)	Control Group (After the Experiment)	Experimental group (Before the experiment)	Experimental group (After the experiment)
High (Critical Analysis)	12.5%	14.2%	11.8%	28.6%
Average (Interpretation and Conclusion)	35.8%	38.5%	36.2%	51.4%
Satisfactory (Simple Information Retrieval)	41.2%	39.1%	42.0%	17.5%
Low (Routine Reading)	10.5%	8.2%	10.0%	2.5%

As can be seen from the table, the proportion of high-achieving students in the control group, who studied in the traditional way, increased by only 1.7%, while in the experimental group, where innovative methodology was used, this figure more than doubled from 11.8% to 28.6%. This confirms that teaching students strategic methods of working with text not only develops their language skills, but also their logical thinking. The results of the PISA (Program for International Student Assessment) of ninth-grade students also fully confirmed the effectiveness of the study. PISA tasks require students not only to know the laws of physics, chemistry or biology, but also to analyze environmental and technological situations by combining them. Students in the experimental group successfully completed complex tasks such as analyzing the data obtained in the form of graphs, diagrams, and tables, designing an experimental methodology, and scientifically proving the reliability of the results obtained. Table 2 reflects the effectiveness of students' mastery of natural and scientific competencies.

Table 2: Average scores of 9th grade students in natural and scientific competencies (PISA criteria) (on a 100-point scale)

Scientific competencies assessed	Control Group (After the Experiment)	Experimental group (After the experiment)	Statistical difference (by t-test)

Scientific explanation of phenomena	54.2	76.5	$p < 0.01$
Designing scientific research	42.8	69.4	$p < 0.01$
Scientific interpretation of data and evidence	48.5	74.2	$p < 0.01$

These analyses clearly show that the largest difference was observed in the competence of designing scientific research (69.4 points in the experimental group and 42.8 points in the control group). This indicates that in traditional education, students are given little opportunity to conduct independent experiments and build hypotheses, and the proposed new methodology served to fill this gap. Mathematical and statistical analyses confirmed that the results were not random and were reliable at the $p < 0.01$ level.

The results of the study confirm that the educational methodology based on the PISA and PIRLS criteria has a high pedagogical potential in transforming students' scientific thinking. The results obtained are fully consistent with the theoretical views of international experts such as Schleicher [1] and Kirsch [3] on the development of functional literacy in education. The correlation between the ability to understand the text in depth (PIRLS) and the ability to solve natural science problems (PISA) shows that if a child cannot identify the main idea in the text and approach it critically, he will not be able to understand a complex real-life case text in physics or biology and draw the right scientific conclusion.

During the experiment, it became clear that the main obstacle to the development of students' scientific thinking is the fact that textbooks are still full of academic and dry theoretical information. For example, although the textbook provides the chemical formula and properties of water, there are no tasks about the problem of fresh water in real life, its impact on the economy and ecology. The introduction of contextual tasks into the lessons within the framework of the proposed methodology allowed students to find a clear answer to the question "Why do I need this knowledge in life?" As Rakhmonov [4] noted, adapting the education system to international standards requires not only changing the test format, but also changing the way teachers think and teach. At the same time, some difficulties were also noted during the study. In particular, teachers in the experimental groups, at the initial stages, abandoned ready-made summaries and encountered methodological difficulties in creating problem lesson scenarios. This problem indicates the need for a radical reform of the methodological service system in schools and targeted training of future teachers in higher pedagogical educational institutions to work with international assessment programs. The results of this study can serve as a basis for developing pedagogical strategies that will improve our country's position in international ratings by increasing the intellectual potential of students.

As a result of studying the problem of developing scientific thinking of secondary school students through the prism of the international criteria of PISA and PIRLS, a number of important conclusions were drawn. Firstly, modern school education must transform from a system that only provides information into a system that teaches students to think, research and draw scientific conclusions, because this is precisely what international assessment programs require. Secondly, reading literacy in primary grades is the fundamental foundation of natural, scientific and mathematical literacy formed in higher grades, therefore, ensuring pedagogical and methodological coherence between the PIRLS and PISA criteria is the most important factor in improving the quality of education.

Thirdly, the conducted pedagogical experiments have proven that the systematic introduction of interdisciplinary integration based on real-life cases, problem situations and the STEAM approach into the teaching process significantly increases students' skills in formulating scientific hypotheses, designing research and interpreting data. Mathematical and statistical analyses fully confirmed the high efficiency of the proposed methodology.

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