

ABSTRACT

of the dissertation work by Bakhtiyar Satkulov on the topic «Formation and development of mathematical literacy and 21st-century skills in students in the context of PISA studies», submitted for the degree of Doctor of Philosophy (PhD) in the educational program 8D01501-«Mathematics».

According to the requirement of the State Educational Standard of Secondary Education, schoolchildren should not only have high-quality knowledge, but also have the skills to solve practice-oriented problems that model real phenomena. At the same time, the development of a well-thought-out plan for the process of teaching schoolchildren methods of solving practice-oriented educational problems, their justified choice occupies a special place in the implementation of school educational programs in mathematics.

The rapid development of the economy, the introduction of innovative technologies in production, aimed only at maximum profit, led to the depletion of natural resources, the complete degradation of the social environment, the disappearance of folk traditions, a positive spiritual environment. The solution to these problems led to a revision of views and attitudes towards the world around us, led to the recognition of the importance of the issue of sustainable development.

In the official UN document "Agenda for Sustainable Development" of 2015, 17 main goals of sustainable development were formulated. Among them, one can highlight such a fundamental issue as: ensuring free access to high-quality, developing education. Since high-quality education contributes to the achievement of each goal of sustainable development.

In this regard, in 2018, the Organisation for Economic Co-operation and Development (OECD) at the UN formulated its programme concept "The Future of Education and Skills: Education 2030" [1]. In this programme, special attention was paid to the following questions: what should be the content of the school educational programme; what knowledge, skills and abilities will be in demand in the future?

Such formulation of questions, the above-mentioned problems led to the need to revise and select the content of school education in the direction of strengthening the applied focus, improving the quality of knowledge, skills and abilities of the student, which will be in demand in the future.

Problems of the applied focus of teaching mathematics, issues of forming schoolchildren's mathematical knowledge, skills and abilities, choosing and developing the content of practice-oriented educational tasks, have been studied by many domestic and foreign authors.

For example, in the works of V.S. Lednev, V.I. Mishin, Yu.K. Babansky, V.V. Kraevsky, J. Lee, D. Park, Michelle Stephan, A.E. Abylkasymova, A.K. Kagazbaeva and others, the problems of school education, the formation of mathematical knowledge, skills and abilities, the choice of content, the essence, the structure of mathematical education, the general theory and methods of teaching schoolchildren are studied.

The theoretical foundations of the applied focus of teaching mathematics in secondary school, the methodological features of the implementation of practice-oriented teaching are reflected in the studies of A.N. Tikhonov, Yu.M. Kolyagin, N.A. Tereshin, V.V. Firsov, R.A. Sadvakasova, A.E. Abylkasymova, E.A. Tuyakov, S.M. Seitova, A.K. Bekbolganova et al.

Modern studies have proposed effective approaches to the development of educational content and methods of teaching schoolchildren to solve practical problems (Zabelina S.B., Pinchuk I.A., Karpechenko A.S., Petrova T.Yu., Postnikova K.R., Ivanov D.I., Abylkasymova A.E., Umiralkhanov A.N., Zhadrayeva L.U., Tuyakov E.A., Kenzhebek Kh.T., Dauletkulova A.U., Serikbay S., and others).

An analysis of scientific research by domestic and foreign authors has shown that the content of practice-oriented educational tasks should reflect more modern, applied, relevant educational material within the framework of natural science knowledge set out in standard curricula. Therefore, in the PISA-2021 program document (“Program for International Student Assessment” [2]), special attention was paid to solving applied problems, the concept and development of mathematical literacy, and 21st century skills. Since the ability to think creatively, systematically, the ability to reason, prove logically, convincingly formulate arguments, evaluate the results obtained, demonstrate communication skills, and decision-making skills are skills that are becoming increasingly important in modern society every day. Mathematical literacy is a student’s skills in formulating a mathematical problem, applying and interpreting mathematics in the process of solving problem situations. 21st century skills include: critical, systematic, creative thinking; research, communication skills, assessment skills, self-regulation, leadership, persistence, reflection, and use of information.

The PISA research is aimed at establishing the level of mathematical literacy development in 15-year-old students. The results of the international PISA exams contributed to an increase in research interest in the formation and development of mathematical literacy and 21st century skills in schoolchildren.

For example, in the studies of E. Lukicheva, T. Avdeeva, I. Avdeev, M. Yarina, T. Ivanova, O. Simonova, J. Jailani, H. Retnawati, H. Djidu, A. Abylkasymova, A. Dauletkulov. M. Yesenova, S. Abueva, B. Kaskataeva, A. Kokazhaeva, Z. Kazybek. B. Zhaukenova, D. Toybazarov, the methodological features of the formation and development of mathematical literacy, and the issues of choosing tools to improve students' mathematical literacy were studied. D.Zhilin, M. Pinskaya, A. Mikhailova, O. Rydze, L. Denishcheva, K. Krasnyanskaya, N. Avdeenko, Abu Bakar, N. Ismail, B.S. Haug, S.M. Mork, R. Lavi, M. Tal, Y.J. Dori, R. Bazakanova, N. Ospanova, E. Smagulov investigated the didactic foundations, pedagogical conditions for the formation of logical thinking and 21st century skills in students.

However, these and other studies do not consider the issues of teaching the solution of practice-oriented problems in the context of PISA research, the

development of a model for organizing the process of teaching students mathematical literacy, the specifics of composing assignments and questions for a problem situation, the development of a methodology for the formation and development of mathematical literacy and 21st century skills. In order to improve the formation of mathematical literacy in schoolchildren, some national education systems implement the teaching of mathematical literacy to schoolchildren as part of their teaching mathematics (J. Lee, D. Park; M.A. Abu Bakar, N. Ismail; E. Alekseeva).

However, the introduction of the practice of teaching mathematical literacy to schoolchildren in the educational system, as part of studying the program subject, has not found wide application in many educational systems of the world. The reason for this attitude to teaching mathematical literacy, developing 21st century skills is the lack of a separate textbook on mathematical literacy, the unpreparedness of teachers to teach schoolchildren mathematical literacy, the lack of need to form and develop 21st century skills in schoolchildren. The unpreparedness of teachers to teach mathematical literacy is manifested by the lack of formation of interdisciplinary knowledge in them.

The process of teaching mathematics from the position of forming interdisciplinary knowledge, 21st century skills has been the subject of research by a number of authors (M. Braskén, K. Hemmi, B. Kurtén; I. Osmolovskaya, L. Krasnova; Z. Zhumabaeva, B. Amirkhanova). The basis of teaching mathematical literacy is the context of a practice-oriented problem, mathematical reasoning applied by the student in the process of solving this problem. Therefore, mathematical, interdisciplinary knowledge, the ability to formulate a mathematical problem, the skills of applying mathematics, the skills of interpreting the solution are the main substantive components of mathematical literacy.

However, in the scientific and educational space, the problems of using the main characteristics of the components of mathematical literacy in the formation and development of mathematical literacy in schoolchildren, the skills of the 21st century, remain little studied. According to pedagogical didactics, in the process of teaching mathematical literacy, it is also necessary to take into account the results of measuring the formation of mathematical literacy.

Checking the formation of mathematical literacy in students has the most important educational and upbringing significance. Checking the level of knowledge acquisition in the Republic of Kazakhstan is carried out on the basis of a criteria-based assessment of students' academic achievements.

The problems of criteria-based assessment of students' academic achievements, issues of developing requirements for achieving the development of knowledge, skills and abilities, and constructing a methodological system of tasks designed to monitor and record the results of teaching mathematics are reflected in the studies of L. Allal, H. Torrance, D. Cisterna, A.W. Gotwals, M. Taras, L. Bozhenkova, E. Sokolova, V. Dalinger, A. Abylkasymova, L. Iskakova, Z. Abekova, A. Oralbaev, M. Ermakhanov, A. Dzhakipova, D. Nurgabyl.

However, in psychological and pedagogical research, the issues of measuring the level of development of mathematical literacy skills and the problems of determining the development of 21st century skills remain almost unexplored.

Analysis of psychological and pedagogical research allows us to conclude that teaching mathematical literacy should be carried out taking into account the following factors: the level of development of mathematical reasoning skills in schoolchildren; the student's readiness to perceive and understand the problem statement; professional training and positive motivation of the teacher; compliance of the task content with the level of achievements of modern science. Taking these factors into account helps to create the framework of a model for organizing the process of teaching mathematical literacy, the formation and development of 21st century skills.

In schools of the Republic of Kazakhstan, teaching mathematical literacy is mainly carried out within the framework of teaching mathematical disciplines, without taking into account the level of acquired interdisciplinary knowledge, the requirements of modern pedagogy and psychology.

Thus, the study of the problem of organizing the teaching of mathematical literacy to schoolchildren, the issues of formation and development of 21st century skills allowed us to identify the following contradictions between:

- the applied focus of the training content and the lack of designed practice-oriented tasks reflecting the processes of the environment, corresponding to some sections of the school course of algebra and geometry.
- the provisions of the State Educational Standard of Basic and General Secondary Education, defining the basic requirements for the knowledge, skills, and abilities of students and the inadequacy of the developed approaches that contribute to the successful development of this knowledge, skills, and abilities of the 21st century;
- the need to use successful practices for the formation and development of 21st century skills, mathematical literacy in schoolchildren and the insufficient development of the methodology for teaching mathematical literacy to schoolchildren and the development of 21st century skills.
- the need to measure the level of development of mathematical literacy, determination of the development of 21st century skills and the lack of tools for measuring mathematical literacy and establishing the development of 21st century skills.

The identified contradictions and insufficient study of the problems of formation and development of mathematical literacy, 21st century skills determined the directions of the study and the relevance of the research problem - the development of a methodology for the formation and development of mathematical literacy and 21st century skills in schoolchildren.

The need to resolve the above contradictions and the relevance of the study determined the choice of the topic of the dissertation research: "Formation, development of mathematical literacy and 21st century skills in schoolchildren in the context of PISA research."

The aim of the study is the psychological and pedagogical substantiation and development of a methodology for organizing the process of formation and development of mathematical literacy, 21st century skills.

Research objectives:

- study of the psychological and pedagogical basis of the process of teaching schoolchildren mathematical literacy in the context of international PISA studies, identification of problems in teaching mathematical literacy;
- establishment of logical connections of mathematical reasoning with the stages of solving practical problems, their significance in solving practice-oriented problems;
- development of an algorithm for constructing assessment and training tasks for practice-oriented problems in the context of PISA studies;
- development of systems of practice-oriented problems and tasks for them, aimed at developing mathematical literacy in students, 21st century skills in the context of PISA studies; - development of a model for teaching mathematical literacy, development of a model for the process of step-by-step formation and development of mathematical literacy in students within the framework of studying the relevant section of mathematics,
- development of a methodology for the formation and development of mathematical literacy in schoolchildren, 21st century skills in the context of PISA research;
- development of a methodology for measuring the development of mathematical literacy skills, establishing the development of 21st century skills;
- conducting an experimental study to determine the degree of development of the theoretical and methodological foundations of methods for teaching mathematical literacy to schoolchildren, establishing the effectiveness of the developed methodology for the formation and development of mathematical literacy and 21st century skills.

Research methods:

- a) theoretical: analysis of psychological and pedagogical literature, analysis of mathematics textbooks used in schools of the Republic of Kazakhstan, in the context of the formation and development of mathematical literacy in students, skills of the 21st century; analysis of educational, methodological and regulatory documents;
- b) empirical: conversations with teachers in order to study the readiness of teachers to teach schoolchildren mathematical literacy; questionnaires, surveys of teachers; analysis of the results of written tests of schoolchildren; analysis of the results of assignments by teachers;
- c) mathematical processing, comparison of experimental data using statistical research methods.

Hypothesis of the dissertation research. If we develop and implement into the educational process a psychologically and pedagogically sound methodology for the formation and development of mathematical literacy and 21st century skills in basic school students with the enhancement of the content of the program material with targeted practice-oriented tasks and tools for measuring the level of mathematical literacy, establishing the formation of 21st century skills, then the proposed

methodology will improve the quality of knowledge and skills of schoolchildren; develop their critical, systemic, creative thinking, form research, communication, evaluative, reflective skills. Analysis of the results of 15-year-old schoolchildren of the Republic of Kazakhstan, obtained in international PISA exams, psychological and pedagogical studies of domestic and foreign authors revealed the need for research in the field of developing the choice of methods and technologies for teaching schoolchildren mathematical literacy. In this regard, in 2020 - 2024, experimental studies were conducted in schools in the city of Taldykorgan, which consisted of three stages.

At the initial stage, a diagnostic (ascertaining) experiment was conducted (2020-2021), which consisted in establishing the degree of development of the psychological and pedagogical basis of the methods and processes of teaching schoolchildren mathematical literacy in the context of PISA research.

At this stage, the problems of teaching mathematical literacy, the formation and development of 21st century skills, the degree of their study in pedagogical theory and practice, the psychological and pedagogical basis of the process of teaching schoolchildren mathematical literacy in the context of international PISA studies were identified. The purpose of the study, the objectives of the theoretical and experimental research were determined. The object and subject of the study were established, a hypothesis was formulated.

At the intermediate stage, an exploratory experiment was conducted (2021-2022). At this stage, in order to select the method, technology for teaching schoolchildren mathematical literacy, another questionnaire was offered to mathematics teachers. The analysis of the responses to the relevant questions of the questionnaire and the results of scientific research by domestic and foreign authors allowed us to select the most suitable teaching method and technology that would effectively form and develop mathematical literacy and 21st century skills in schoolchildren. These turned out to be the problem-oriented teaching method and the modular teaching technology. The analysis of the algorithm for solving problem problems and the experimental study allowed us to identify the algorithm for compiling assessment and training tasks for problem problems; logical connections between mathematical reasoning and the stages of solving practical problems were established; problem problems and tasks for them were identified and compiled, aimed at forming and developing mathematical literacy and 21st century skills in schoolchildren; a model was built for organizing the process of forming and developing mathematical literacy and 21st century skills within the framework of studying the corresponding section of mathematics; a methodology for forming and developing mathematical literacy and 21st century skills in schoolchildren was developed; a methodology for measuring the development of mathematical literacy skills and establishing the development of 21st century skills was developed.

The final stage of the study was a formative pedagogical experiment (2022-2024), the main purpose of which was to determine the effectiveness of the developed methodology for the formation and development of mathematical literacy in students, 21st century skills and measuring the formation of their mathematical literacy. Based on the results of the pedagogical experiment, based on the Student's

t-test, it was proven that the level of formation of mathematical literacy in schoolchildren in the experimental class is higher than in the control class. Which confirmed the hypothesis about the success of experimental learning.

In order to compare the results of measuring mathematical literacy, the levels of formation of mathematical literacy in schoolchildren were determined in the context of criteria-based assessment of student achievement. Using the same experimental data, it was proven that mathematical literacy in students of the control class is formed at an average level ($0,5 < K_{cont} < 0,7$), and the mathematical literacy of a student of the experimental class is formed above the average level ($0,7 < K_{exp} < 0,9$).

Thus, it was proven that the proposed criteria approach to measuring mathematical literacy in schoolchildren correlates with the obtained results of the Student's t-test. At the same time, it was confirmed that the criteria approach to measuring mathematical literacy in schoolchildren is more universal, since this method establishes the level of development of mathematical literacy skills and 21st century skills.

The following provisions are submitted for defense:

1. Methodology of teaching schoolchildren based on the idea of organizing search activities by the teacher, aimed at developing target, content (practice-oriented tasks and assignments for them) and activity (methodology for the formation and development of mathematical literacy skills) components of training.

2. Model of the process of step-by-step formation, development of mathematical literacy in students, facilitating the implementation of connections between mental activity and the stages of solving practice-oriented problems.
3. Methodology for the formation and development of mathematical literacy skills and 21st century skills in schoolchildren, the substantive component of which consists of an invariant (content of standard educational material) and variable (designed system of practical tasks and assignments for them) parts aimed at problem-oriented learning and the use of a cognitive-activity method for discussing the results of completing assignments.

4. Methodology for criteria-based assessment of the development of mathematical literacy skills, establishing the development of 21st century skills contributes to an increase in the educational motivation of schoolchildren, an objective determination of the level of development of mathematical literacy.

The scientific novelty of the study lies in the fact that:

- logical connections between mathematical reasoning and the stages of solving practical problems have been established and their significance in solving practice-oriented problems has been revealed;

- an algorithm for constructing assessment and training tasks for practice-oriented problems in the context of PISA research has been developed;

- systems of practice-oriented problems and tasks for them have been developed, aimed at forming and developing mathematical literacy and 21st century skills in schoolchildren;

- a model for teaching mathematical literacy has been compiled, a model for organizing the process of step-by-step formation and development of mathematical literacy and 21st century skills within the framework of studying the corresponding section of mathematics has been built;

- a methodology for forming and developing mathematical literacy and 21st century skills in schoolchildren in the context of PISA research has been developed;

- a methodology for measuring the development of mathematical literacy skills and establishing the development of 21st century skills has been developed.

In addition, the following tasks were solved:

- the psychological and pedagogical foundations of the process of teaching schoolchildren mathematical literacy in the context of international PISA studies were studied, the problems of teaching mathematical literacy were identified;

- experimental studies were conducted to determine the degree of development of the theoretical and methodological foundations of methods for teaching schoolchildren mathematical literacy, the effectiveness of the developed methodology for the formation and development of mathematical literacy and 21st century skills was established.

The theoretical significance of the study lies in the fact that:

- the proposed approach to the design of assessment and training tasks for practice-oriented problems that form and develop mathematical literacy in students makes a certain contribution to the theory of developing practice-oriented problems;

- the developed, classified systems of problems aimed at the formation and development of mathematical literacy in schoolchildren within the framework of studying the program educational materials of school mathematics, partially complement the content of pedagogical didactics;

- the constructed model of the process of formation and development of interdisciplinary knowledge, mathematical literacy, 21st century skills within the framework of studying the contents of the mathematics section contributes to the development of the theory of constructing a system of lessons; - the established interactive connections of mathematical reasoning with the stages of solving practical problems complement the theory of educational psychology.

The practical significance of the research results is that the research results can be successfully used by teachers, researchers, and educators in compiling new generation textbooks and teaching aids for secondary education, in teaching schoolchildren mathematical literacy, in the process of forming and developing 21st century skills (confirmed by implementation acts, see Appendix 8).

The validity and reliability of the pedagogical research results are ensured by: a retrospective analysis of psychological and pedagogical literature, the use and combination of adequate research methods that correspond to the goals, objectives and hypothesis of the research; practical confirmation of the research results through the use of mathematical and statistical research methods.

Testing of the research results:

- the main provisions and results of the research were reported and discussed at scientific and methodological seminars of the Department of Mathematics and Physics of the Zhetysu University named after Ilyas Zhansugurov, Department of

Mathematics of the Women's National Pedagogical University (2022 and 2023), Department of Mathematics of the Aktobe Regional University named after K. Zhubanov, Faculty of Pedagogy and Humanities of the University named after S. Demirel (2024), at training seminars for advanced training of school teachers in the city of Taldykorgan.

- Some research results were discussed at international conferences: "Science, Society, Culture: Problems and Prospects of Interaction in the Modern World" (Petrozavodsk, 2023); "In the World of Science and Education (Almaty, 2025); "Global Science And Innovations 2023: Central Asia" (Astana, 2023). – the main results of the dissertation are presented in journals included in the list of peer-reviewed scientific publications determined by the Committee for Quality Assurance in Science and Education of the Ministry of Higher Education and Science of the Republic of Kazakhstan (3 articles), in an indexed scientific journal from the Scopus database (1 article), in the materials of international scientific and practical conferences (3 articles) and 1 article in a university journal.

Structure and content of the dissertation. The work consists of an introduction, two chapters, a list of references and appendices.