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Formation and development of mathematical literacy in the context of evaluative – Study tasks of PISA

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Abstract

To identify the level of education of schoolchildren in different countries of the world, the OECD conducts international studies in the field of education. Comparative results of these studies make it possible to determine the effectiveness of national educational systems contributing to adapting programs for modernization and reform of educational systems. This study aims to develop mathematical literacy among 15-year-old students of the Republic of Kazakhstan by developing the basic skills of the 21st century in solving practice-oriented problems. An experimental study was conducted to determine teachers' attitudes toward the formation of mathematical literacy among schoolchildren. The study involved 32 teachers. The Analysis of the results of the survey revealed that the majority of teachers had a negative attitude towards the formation of mathematical literacy among schoolchildren, substantiating their points of view by the fact that the formation and development of mathematical knowledge and skills by itself contributed to the development of skills in the 21st century. Only 11% of teachers could accurately indicate those tasks, out of the seven tasks presented for consideration, in the solution of which schoolchildren had shown critical, systemic thinking. An analysis of geometry textbooks used in schools of the Republic of Kazakhstan showed that out of the total number of educational tasks studied in geometry lessons, the share of practice-oriented tasks comprised less than 3%. Based on the results of the experimental study, it is concluded that it is necessary to develop appropriate methodological approaches that contribute to the formation of mathematical literacy among schoolchildren using the learning tasks of the school geometry course.

Keywords: 21st Century Skills, Lesson System, Math Literacy, Math Reasoning, PISA, Thinking

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The OECD (Organization for Economic Cooperation and Development) has published the concept "The Future of Education and Skills, Education 2030" (2018). Many researchers emphasize that the OECD, in recent years, has strengthened its position in the global governance of education. For example, Niemann and Martens (2018), based on an analysis of international studies conducted under the auspices of the OECD, observe that such a special, informal approach to education management through the results of international assessments can become a generator of imitation for other educational systems. Rutkowski and Rutkowski (2016) describe the influential position and significance of the PISA International Study Program in Education in their study while offering a balanced approach to using, analyzing, and interpreting PISA results. The essence of the Organization for Economic Cooperation and Development is to facilitate economic progress, social advancement, and cooperative solutions to global issues by providing an international forum for member countries to compare data, exchange ideas, identify best practices, coordinate policies, and collaborate with other nations and organizations to promote evidence-based standards and recommendations that aim to improve economic prosperity along with the overall well-being and welfare of people everywhere. In this concept, special attention is paid to the following questions: what should be the essence of the school educational program, what should be the content of the curriculum of school disciplines, and what skills are in demand in the future? Indeed, intending to improve student achievement in math literacy through PISA exams, there is a growing global research interest in 21st-century skills and their possible incorporation into their educational systems (The Future of Education…, 2018). For example, various scientific communities in the United States propose developing a practice-oriented educational concept for secondary and higher education to integrate mathematical, polytechnical and natural knowledge, technology, art, and engineering (Wang et al., 2020; Lee & Park, 2014).

The study by Abu Bakar and Ismail (2020) discusses the skill levels of teachers of metacognitive regulation and student achievement according to the introduction and implementation of teaching in the context of 21st-century skills and the Malaysian curriculum. Furthermore, Saarela and Karkkainen (2017) describe the educational system in Finland and conclude how essential the skills of trusting cooperation between a teacher and a student are in the process of achieving success in Finnish schools in the PISA tests. In his work, Bi (2018) gave an original classification of the effectiveness of PISA cycles, a new understanding of learning to prioritize teacher teaching to improve student performance in some countries seeking to increase productivity. Lastly, Lee and Park (2014) compare key school reform policies and outcomes in the US and Korea over the past three decades based on TIMSS and PISA data analysis.

The problem-based learning (PBL) is often characterized as the most effective method of implementing practice-oriented learning that promotes the development of 21st-century thinking skills in the scientific literature (Suhirman & Prayogi, 2020; Prabawanto & Susilo, 2020; Brassler & Dettmers, 2017). In particular, Problem-based learning focused on increasing motivation was considered by Tang et al. (2020). An analysis of the results of PISA studies revealed that in many schools and secondary vocational educational institutions in some countries of the world, the issues of developing 21st-century skills in schoolchildren, improving the skills of teachers to identify manifestations of 21st-century skills of the students in the process of solving learning problems, has not been explored yet (Semilarski et al., 2021; Karatepe & Akay, 2020; Haug & Mork, 2021). The issues of the formation of the skills of the 21st century among schoolchildren of the middle and senior level also still need to be explored. For example, it was discovered that many teachers do not know how to consciously use the main meta-skills of the 21st century in the learning process, and students mainly use only learning skills in their educational practice (Erten, 2022; Lavi et al., 2021; Abu Bakar & Ismail, 2020).

The studies of Retnawati and Wulandari (2019) and Jailani et al. (2020) describe the dynamics of the development of the basic skills of mathematical literacy of schoolchildren, depending on their class membership and school level. Some issues were discussed to increase the level of formation of mathematical literacy among schoolchildren based on the effective use of educational material. However, some researchers note that in the context of implementing the PISA concept in educational systems, there might be a very narrow framework of educational values that only sometimes considers the complexity of the learning process (Addey, 2017). This analysis, as well as a review of the results of other studies related to the formation of mathematical literacy among 15-year-old schoolchildren, allows us to make a conclusion that it is necessary to develop a methodology for teaching schoolchildren to solve practice-oriented problems and appropriate didactic materials that contribute to the formation of mathematical literacy among schoolchildren. Based on the analysis of the content of educational tasks of school mathematics offered in the textbooks of the Republic of Kazakhstan, it is concluded that if the text of educational tasks is supplemented with assessment and training tasks in the context of PISA test tasks, then they can be effectively used in the process of developing mathematical literacy among students.

Comparative results of international studies in the field of education make it possible to determine the effectiveness of national educational systems contributing to the adaptation of modernization programs and reform educational systems. Its most influential Program for International Students Assessment (PISA). One of its main areas is the assessment of the level of mathematical literacy of 15-year-old schoolchildren and college students. Mathematical literacy in PISA-2021 is considered the ability of a student to think mathematically, formulate mathematical problems, apply and interpret mathematics in various phenomena. Thus, mathematical literacy is considered as the ability to carry out mathematical reasoning apply mathematical knowledge to describe, interpret, and predict various phenomena (PISA 2021…, 2018). According to the PISA-2021 concept, reasoning (thinking) is the main component of mathematical literacy.

The concept of mathematical literacy aims to determine the ability of students to apply mathematical objects and at researching and predicting phenomena through mathematical thinking. When considering practice-oriented problems, the transition from a problematic situation to a specifically formulated problem requires mathematical thinking. The choice of a method, an algorithm for solving a problem, the process of solving it, interpreting the solution obtained in the language of a real phenomenon are manifestations of mathematical and interdisciplinary thinking (PISA 2021…, 2018). The ability to think mathematically is a skill that is becoming increasingly important in the 21st century. In this regard, the most important skills of the 21st century were added to the PISA-2021 concept for the first time, namely: critical thinking; system thinking; creativity; research and study; initiative and perseverance; use of information; communication; reflection (The Future of Education…, 2018). Obviously, mathematical reasoning contributes to the formation and development of the above-mentioned set of essential skills of the 21st century. In general, mathematical literacy is formed and developed on the basis of mathematical reasoning and the skills of the 21st century, manifested in each cycle of solving a problem situation. In the PISA assessment technology, it is not supposed conducts to assess the various components of mathematical literacy separately, since the solution of real problems involves the complex use of many different mathematical skills and abilities. In the PISA study, math literacy assessment relies on the following interrelated components:

- task context, which describes the situation;
- the context of test tasks with mathematical content, while the task contains elements of the assessment of mathematical knowledge in interconnection with certain skills of the 21st century;
- mathematical reasoning (thinking), stages of problem solving (formulation, application, interpretation and evaluation).

Thus, task context, context of test tasks, mathematical thinking, the stages of solving the problem (the modelling process), and individual skills of the 21st century are closely interconnected and are interdependent. In the context of the task, the essence of the situation under study, which is related to the practical and everyday activities of a person is described. Assessment mainly uses contexts that are easily perceived by the student: personal, public, professional, and scientific (The Future of Education…, 2018).

Depending on the mathematical content of the test tasks, the following classes of PISA mathematical tasks are distinguished: tasks for change and relationships; quantity tasks; tasks for uncertainty and data; tasks on space and forms. Solving problems on change and relationships is intended to assess the competence of schoolchildren to establish connections between variables to design and use mathematical models. Solving problems for quantity is intended to assess the competence of schoolchildren in interpreting and substantiating data, determining the formation of computational thinking, and understanding units of measurement. Solving problems for uncertainty and data is intended to assess the competence of schoolchildren in determining and substantiating probabilistic and static phenomena in predicting processes. Thus, PISA studies are of particular importance in determining the readiness of 15-year-old students for their practical activities. Therefore, the comparative results of these studies are used by many countries of the world to improve the content of secondary education and the learning process.

METHODS

To determine teachers' attitudes to the formation of mathematical literacy among schoolchildren, a survey was conducted among mathematics teachers of secondary schools and colleges in the Zhetysu region of the Republic of Kazakhstan (32 men in total). The analysis of the survey results revealed that over 70% of teachers had a negative attitude towards forming mathematical literacy among schoolchildren. The tasks in the solution of which schoolchildren manifest critical, convergent, divergent, and systemic thinking include practice-oriented tasks of school geometry. In this regard, an experimental study was conducted to establish teachers' skills to identify the expression of critical, convergent, divergent, algorithmic, and systemic thinking in schoolchildren when schoolchildren solve seven tasks in geometry of an average level of complexity. Divergent thinking involves generating multiple creative solutions or ideas, emphasizing originality and exploration. In contrast, critical thinking entails systematic analysis and evaluation of information to make well-reasoned, evidence-based judgments or decisions. Divergent thinking fosters creativity and innovation, often used in brainstorming and creative fields, while critical thinking is applicable in various contexts, ensuring objective assessment and informed decision-making based on evidence and analysis. In this regard, a meaningful analysis of textbooks on geometry has been held.

In addition, the modeling method was used to form a system of lessons in various directions aimed at assimilation, consolidation, and systematization of the abilities and skills of schoolchildren. The analysis method was used to reveal the main approaches to the vectors of educational classes proposed by the authors. Thus, on its basis, four types of lessons, posted in a particular sequence and also characterized by specific features, were revealed. Thus, the system in the relationship between the theoretical and practical skills of students, as well as their ability to develop the existing level of knowledge, is observed. The research used the deduction method, which was essential in forming its structure and plan. At the beginning of the research, general data about Kazakhstan, about the peculiarities of mathematical tasks, and the success of their performance by schoolchildren were described. Next, specific approaches were defined, namely a system that provides an in-depth analysis of the researched topic and its future development. It is essential that this approach made it possible to reveal ways to improve the process of students' implementation of acquired theoretical knowledge in real life or in the course of performing tasks.

The research was divided into several stages. In the first stage, Kazakhstan students' current state of mathematical literacy development was analyzed. In particular, it was determined based on which approaches and tools its implementation took place, and the main advantages and disadvantages were established. The second stage characterized a system of lessons with different didactic goals. In addition, the main types of geometric problems aimed at deep consolidation and the primary use of acquired skills from various topics were revealed. In the third stage, a discussion was held, which made it possible to compare the author's views with the positions of other scientists regarding the research topic. Conclusions were drawn up, and the main results of the work were presented in them. All procedures performed in the study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments.

RESULTS AND DISCUSSION

An analysis of the results of the assignments revealed that only 15% of the respondents could accurately determine the tasks in the solution in which divergent thinking is manifested in schoolchildren. Only 11% of teachers could indicate the tasks in the solution of which schoolchildren manifested critical, systemic thinking correctly. Over 35% of teachers could accurately identify tasks in the solution of which the schoolchildren were expressing algorithmic thinking. This allowed us to conclude that out of the total number of educational tasks considered in geometry lessons, the share of practice-oriented tasks is less than 3%. Some standard school geometry topics are mainly studied in depth in various optional classes. In addition, practice-oriented geometric tasks need to be more present in didactic materials used to assess students' educational achievements. Hence, there is a growing necessity for developing approaches for the creation of appropriate educational and methodological materials that contribute to the formation of specific practical skills for schoolchildren to apply the acquired polytechnic knowledge in practice, the need to make comprehensive changes in the teacher's pedagogical activity, aimed at developing mathematical literacy among schoolchildren. Thus, it is concluded that in matters of the formation of mathematical literacy among students in the schools of the Republic of Kazakhstan, the potential of geometric problems could have been more used.

The Republic of Kazakhstan assessed the quality of school education under the PISA program from 2009 to 2022. According to the results of a comparative study, in 2009, Kazakhstan was ranked 59th among 75 participating countries. In 2012, an increase in academic performance in all subjects was shown. Overall, the overall rating of the academic performance of schoolchildren in the Republic of Kazakhstan increased as well—overall result: 45th place out of 65 participating countries. Kazakhstan's performance for 2015 continued its positive growth, and it was ranked 42nd out of 72 participating countries. According to the international study PISA-2018 results, the Republic of Kazakhstan became 69th out of 79 participating countries. This is the lowest result for the entire time of Kazakhstan's participation in the international PISA study.

In 2018, compared to 2015, the result in mathematical literacy of Kazakhstani schoolchildren worsened by 37 points: 2015 – 460 points, 2018 – 423 points. In particular, it was clearly shown by the low level of formation of spatial thinking among schoolchildren, which depends directly on the formation of knowledge and skills in geometry (Programme for International…, 2019). An analysis of the results of these studies revealed some problems in the system of school mathematical education in the Republic of Kazakhstan, for instance, the issues of forming polytechnic knowledge among schoolchildren, developing thinking and abilities to apply the mastered mathematical knowledge in solving practical problems. Thus, the last assessment was conducted in 2018. Kazakhstan was ranked 69th in the country ranking. The actual data is not yet known, as the last assessment was conducted in 2022, and its results will be known in December 2023.

This problem is related to the peculiarities of the learning process in Kazakhstani schools, which is mainly aimed at mastering fundamental mathematical knowledge and solving standard mathematical problems included in the class of tasks for final exams. Solving problems on space and forms is intended to assess the competence of schoolchildren in visualizing spatial figures in recognizing various quantities and patterns from various geometric shapes, tables, and diagrams. Mathematical reasoning encompasses several essential competencies, including reproduction, which involves recognizing, understanding, and utilizing mathematical objects; establishing connections by identifying relationships between different concepts and objects; and engaging in reasoning processes such as generalization, abstraction, interpretation, application, and the identification of patterns. These competencies collectively form the foundation for practical mathematical thinking, enabling individuals to navigate mathematical concepts and problems with clarity and depth.

According to the PISA concept, to identify the “reproduction” competence, students are offered tasks of two types: those with the choice of an unequivocal answer and those with the reproduction of the answer (the answer is written as a number, expression, word), while it is not required to describe the solution algorithm. In this case, it is assumed that students have the skills to apply known methods and solution algorithms, perform calculations, and work with standard formulas. Competence, “establishing a connection,” is formed by solving problem situations in real-world tasks but not requiring a complex level of mathematization. Competence “reasoning” is formed with the help of tasks in which students formulate a problem, make up a mathematical model of the situation, solve the problem, and give an interpretation of the solution to the problem. Mathematical reasoning is carried with the help of the following structural objects of school mathematics:

- quantity, numerical expressions, their algebraic properties, number systems;
- symbolic, graphic representation, abstraction;
- algebraic structures, geometric objects, their regularities;
- functional dependencies between quantities;
- mathematical models;
- characteristics of the dispersion of samples.

The uniqueness of this international study lies in determining the knowledge and skills of schoolchildren that will ensure the readiness of a school graduate to successful implementation himself as a person and as a professional in his practical and daily activities. In general, the technology of international assessment of mathematical literacy for 15-year-old schoolchildren and college students provides for six levels of achievement. Students who have shown the skills of critical thinking, comprehension, justification and interpretation of the solution to the problem, have the ability to analyse, generalize (completed tasks of the 5th and 6th levels) are considered mathematically literate and receive the highest marks. Students who have the ability to apply the acquired knowledge and skills to obtain a new statement, new information receive grades corresponding to levels 3 and 4. Level 2 corresponds to the ability to apply the acquired knowledge and skills in the simplest (non-educational) situations that are related to practical and everyday activities person. Students who were able to complete only level 1 tasks are considered mathematically illiterate. The subject of assessment of mathematical literacy in PISA is not the educational achievements of students, but the quality of the formation of their key competencies. At the same time, the assessment tasks of the international exam not only allow assessing the achievements and abilities (learning, thinking) of schoolchildren, but also have an educational character in the form of a controlled integration of interdisciplinary knowledge.

Therefore, the modern assessment technology of the international PISA study (The Future of Education…, 2018) was chosen as the methodological basis for the development of educational and methodological materials for the formation of mathematical literacy among schoolchildren. In the international PISA exams, a tool for assessing mathematical literacy is a sequence of tasks at various levels, through which the knowledge and skills of schoolchildren are assessed. At the same time, PISA task developers emphasize the importance of 21st century skills, but so far, they have not developed purposeful tasks for them in accordance with these abilities and skills. In addition, today, in the professional and daily activities of a person, the tasks of choosing the most appropriate solution from a variety of options for solving this problem exist. In the process of making certain decision, a person expresses divergent, as well as convergent thinking. In this regard, divergent and convergent thinking can be included in the set of essential skills of the 21st century. Thus, the main components of mathematical literacy, in addition to critical and systemic thinking, include divergent, convergent thinking.

The critical thinking of middle-level students is chaotic, temporary, their critical reasoning is generally not substantiated or is argued erroneously. A necessary condition for the formation of critical thinking in middle school students is the knowledge and application of the rules of mathematical logic. Divergent thinking is manifested in middle and senior schoolchildren’s behaviour in the process of identifying a set of solutions, and in the subsequent choice of a suitable solution, and convergent thinking is also shown in the algorithm for finding the exact solution to the problem under consideration. Systemic thinking is expressed by senior schoolchildren when the student analyses, synthesizes the data of a certain problem, integrates various knowledge, and presents them in the form of one general model, in the form of a dynamic system, makes a decision based of system analysis.

Based on the need to develop mathematical literacy among 15-year-old schoolchildren, and in accordance with the goal of consolidating and systematizing the content of the educational material for the section, authors will build a system of lessons aimed at assimilation, consolidation, systematization of knowledge, at the development of schoolchildren's thinking skills. At the same time, in the system of lessons, each lesson differs in its main didactic goals:

1. Lessons of familiarization and assimilation of new educational material.
2. Lesson to consolidate and apply the studied educational material of the module of the training program.
3. Lesson for testing knowledge, skills, and mental skills of students according in the module of the training program.
4. Lessons of systematization of the totality of knowledge at the section of the training program.

Lesson of Familiarization and Assimilation of New Educational Material

In accordance with the main goal of teaching schoolchildren, a lesson to familiarize students with new educational material is being singled out. A very common teaching method, usually used when presenting new material, is problem-based learning. This approach will be also relevant for the lesson of familiarization and assimilation of new educational material with an emphasis on the development of thinking.

The main element of such a lesson is the stage of teaching students with new educational material. At this stage, the teacher first introduces the students to the essence of the problem; together, they discuss how to formulate the condition and statement of the problem in a different way, break the problem into small tasks, and what knowledge is needed to solve it. Further, discussions are held on the joint search for a solution to the problem and the choice of a solution algorithm. After that, the solution of the mathematical problem is carried out. The resulting solution is interpreted. At this stage, it is essential to establish not only the basic knowledge necessary to teach new educational material to students effectively but also a set of exercises that should be indicated, during which both acquired, and new knowledge will be updated.

The next stage of this lesson is the primary consolidation of educational material at the playback level. At this stage, the simplest educational tasks are solved by recognizing a new concept, reproducing the formulation of a theorem or its proof, and reproducing a method, an algorithm for solving a model problem; students develop convergent and critical thinking in interconnection through the justified application of a specific method for solving a problem, compliance with the rule’s mathematical logic. The final stage of the lesson of familiarizing and assimilating new educational material is the performance of independent work (in the form of homework or other forms of independent work). When performing independent work, students develop mathematical reasoning. Such lessons, i.e., lessons of familiarization and assimilation of new educational material, preceding the lessons of consolidation and application, should be no more than 2-3 lessons.

Lessons for Consolidating and Applying the Studied Educational Material According to the Module of the Training Program

The expediency of highlighting such a lesson follows from the need to form and develop mathematical literacy in 15-year-old students. Considering the lesson of consolidation and application of the studied educational material from the point of view of observing the logic of the learning process, the concept of "Didactic structure of the lesson of consolidation and application" will be reached, the stages of which are seen from the following diagram: actualization of knowledge – consolidation of knowledge – application of knowledge.

Thus, in this lesson, the studied educational material is not only updated, but also deeply consolidated by solving practice-oriented problems, as well as non-standard mathematical problems. When solving such problems, the student learns to apply mathematical knowledge to practical needs, to prepare for professional activities in the future, and to solve problems put forward by the practice of everyday life. When solving applied and non-standard problems, convergent, critical, divergent, algorithmic thinking, and some other skills of the 21st century are formed. Thus, in the lessons of consolidation and application, students' mathematical literacy is formed and developed.

The analysis of the PISA problem solutions showed that assessment questions 1 and 2 of the PISA a problem are reproducing in nature, the questions 2 and 3 of the PISA a problem are cognitive in nature and are designed for deep consolidation and application of the acquired knowledge according to the module of the curriculum, to achieve the appropriate primary and secondary level of mathematical literacy. To consolidate and apply the acquired knowledge, the PISA problem structure will be used: a situation is described (introduction to for tasks under consideration), and it is proposed from one to four tasks related to the situation. The introduction to the tasks is a short explanatory text that is motivating.

The following assessment demonstrates – study tasks designed for deep consolidation and application of the acquired knowledge in the module “Mutual arrangement of straight lines on a plane.” Exercise A—mutual arrangement of straight lines on a plane (Figure 1).

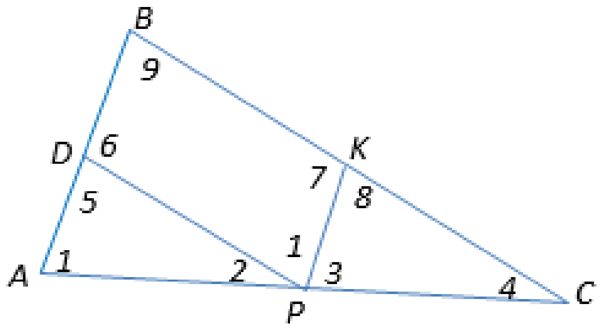

Figure 1. Exercise A. Mutual arrangement of straight lines on a plane

An arbitrary triangle ABC is given. An arbitrary point P is taken on the base AC, and from the point P, draw two straight lines parallel to the lateral sides.

Task 1: Is the condition of Exercise A correctly graphically depicted in Figure 1?
Evaluation of the answer to Task 1:
The answer is accepted in full:
Code 1: Yes. Since PD||BC, PK||AB
Answer not accepted:
Code 0: Other answers.
Code 9: No response.
Task 2: Indicate all pairs of adjacent angles.
Assessment of the answer to Task 2:
The answer is accepted in full:
Code 1: 5 and 6; 7 and 8.
Answer not accepted:
Code 0: Other answers.
Code 9: No response.
Task 3: Indicate all pairs of equal corresponding angles at the secant AC.
Assessment of the answer to Task 3:
The answer is accepted in full:
Code 1: 1 and 3; 2 and 4.
Answer not accepted:
Code 0: Other answers.
Code 9: No response.
Task 4: Determine the sum of the interior angles of triangle ADP.
Assessment of the answer to task 3:
The answer is accepted in full:
Code 1: 180˚.
Answer not accepted:
Code 0: Other answers.
Code 9: No response.

Contents of tasks 1,2, 3, 4:

Area of mathematical content: space and form;

Context: scientific;

Cognitive and mental activity: reproduction, graphic representation, mathematical reasoning.

With the help of these tasks, educational materials “Angles formed at the intersection of two parallel lines of a secant”, and “The sum of the internal angles of a triangle” are reproduced, consolidated, disciplinary knowledge is integrated within, such thinking abilities as: polytechnical thinking (graphic thinking), critical thinking (justified choice of parallel lines and secant, application of knowledge). In the process of performing these tasks, middle-level schoolchildren develop objective operational thinking (direct action with a specific model of an object). When considering the graphical representation of the problem, abstract, non-operational subject thinking is manifested.

Exercise B. Airplane Flight. The length of the aircraft flight path from the place where the aircraft was lifted to the highest peak of the mountain, located in front of the aircraft flight path, is 2 km. Before the plane took off, the navigator, using an altimeter, determined that the height of that mountain's highest peak was 1000 m (Figure 2).

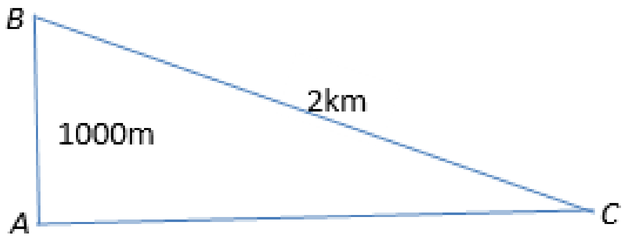

Figure 2. Exercise B. Airplane Flight

Let’s compose assessment-study tasks through which the integration of such interdisciplinary knowledge is controlled as: the length of the path of the aircraft, the angle of elevation of the aircraft, the altitude of the aircraft, the altimeter, and the properties of a right triangle.

Task 1 for Exercise B. Determine the angle of the aircraft.

The answer is accepted in full:

Code 1: 30˚. Uses the property of a right triangle: if the leg is equal to half of the hypotenuse, then the angle opposite this leg is 30˚.

Answer not accepted:

Code 0: The answer is incorrect. The argument is wrong.

Code 9: The answer is incorrect. The argument is missing.

Task 2 for Exercise B. At what angle should the plane rise so as not to touch the tops of the mountain?

The answer is accepted in full:

Code 21: More than 30˚. If the pilot climbs at an angle of 30˚, then the plane may hit the top of the mountain. If the angle of rise of the aircraft is more than 30˚, then the flight path of the aircraft will pass above the top of the mountain. Since, with an increase in the value of angle C, the true flight altitude of the aircraft along the entire flight path will also increase.

The answer is accepted in part:

Code 11: More than 30˚. Contains a solution, however, contains inaccuracies in mathematical reasoning.

Answer not accepted:

Code 01: The answer is incorrect. The argument is wrong.

Code 02: The answer is incorrect. The argument is missing.

The content of tasks 1 and 2:

Area of mathematical content: space and form;

Context: professional;

Cognitive and mental activity: reproduction, graphical representation, mathematical reasoning, calculations.

When performing these exercises, the learned knowledge on the educational material “Properties of a right triangle” is reproduced, consolidated, and applied. With a graphical representation of the condition of the problem under consideration, schoolchildren develop spatial imagination; in the process of completing tasks, they form interdisciplinary and polytechnical knowledge skills for interpreting the solution of the problem. In the process of finding an answer to the question: “At what angle should the plane rise in order not to hit the tops of the mountain?” students develop critical and divergent thinking.

Lesson for Testing the Knowledge, Skills, and Abilities of Students in the Module “Mutual Arrangement of Straight Lines on a Plane”

At most, 4-5 lessons should precede this lesson. The expediency of singling out such a lesson follows from the need to determine the quality of assimilation of program material by students, diagnosing their knowledge and skills of mental activity. The lesson of checking the formation of knowledge, skills and abilities of students is an important part of the learning process. The definition and study of educational achievements, mental and cognitive abilities of students is a necessary component of the learning process, a component of the internal content of each stage of learning. Checking the formation of knowledge and mathematical thinking among students is a very complex process, both in a psychological and pedagogical sense and in terms of organizing training. This is because the test is entrusted with obtaining objective information for effective learning management and the formation and development of mathematical literacy among students. One of the tools for such verification is written work. Using this type of verification allows you to provide all schoolchildren with independent work at the same time. There are several types of such work: to provide everyone with independent work:

- work on solving problems and exercises;
- work on the interpretation of tables, diagrams, and graphs;
- work on establishing dependencies;
- work to determine the characteristics of the dispersion of samples.

The practice has shown that the PISA assessment tasks of the initial and intermediate levels of complexity can be used to check the level of assimilation of the module of the curriculum to determine the formation of skills of mental activity. These tasks are compiled at the level of assessment and training exercises, designed to consolidate and apply the acquired knowledge in the module “Mutual arrangement of straight lines on a plane.”

Lesson on the Systematization of the Body of Knowledge in the Section of the Training Program

The appropriateness of highlighting such a lesson follows from the training program's general structure and the PISA tasks' characteristics. The systemic knowledge among students will stand for the total volume of their acquired knowledge, including meaningful and logical connections. At the same time, the integral structure of this set corresponds to the core of scientific theory. Considering the lesson of systematizing the body of knowledge by section from the point of view of the logic of building a scientific theory, authors will come to the concept of "Didactic structure of the lesson of systematizing the body of knowledge by section," the stages of which are seen from the following diagram: actualization of knowledge – establishing a connection between the elements of educational material – solving problems for systematizing the body of knowledge. The highest level of systematization of knowledge is carried out through mental operations such as comparison, analysis, synthesis, and generalization, which can be achieved in implementing interdisciplinary communications. By establishing these links, the formation of schoolchildren's systematic knowledge of mathematics and the development of applied knowledge about the most important phenomena of the world around us, modern production technologies are being contributed.

Comparison is a logical method of thinking through which the analogy and difference of compared objects, or their properties, are revealed. Generalization is the mental selection of some common essential mathematical problems and phenomena properties. Generalization is also understood as a mental operation that transitions from single elements to the general, from the less general to the more general. Analysis is a logical method of thinking, a research method, consisting of the fact that the object under study is mentally divided into separate elements (features, properties, relationships), each of which is studied separately. Synthesis is a logical method of thinking, with the help of which individual elements are combined into a single whole. The sequence of assessment tasks 1, 2, 3, and 4 PISA orients the teacher to achieve the systemic nature of the acquired interdisciplinary knowledge in the minds of students by identifying and establishing links between the elements of the general structure of the studied educational material by of training program section. In general, the PISA assessment and training tasks at the high complexity level are systematized and designed to achieve a high level of mathematical literacy. Tasks at the high complexity level can be used to check the level of mastery of knowledge and the formation of mental abilities by the training program section.

Let's consider examples illustrating the described approach to organizing a knowledge systematization lesson. Task A. During the construction of the subway of the city of Almaty, the design engineer designed an escalator, which has 90 completely identical steps from the ground vestibule to the floor of the underground station (Figure 3). The width of the step is $20\sqrt{3}$ cm and the height is 20 cm.

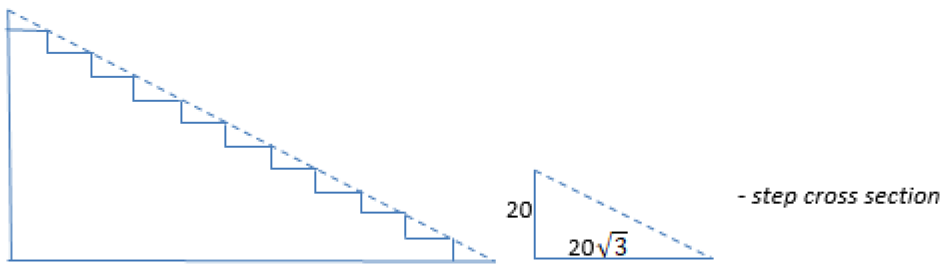

Figure 3. Escalator

In the process of knowledge actualization, various elements are considered, including the properties of a right triangle, the characteristics of angles formed by corresponding parallel sides, the components of escalators, and the depth of a station. Establishing connections within this general problem structure involves recognizing that the steps and the escalator collectively form a right triangle, with the sum of step heights equaling the escalator's height and the sum of step widths representing the base of the escalator. Furthermore, the escalator's angle of inclination depends on the lengths of its height and base. Finally, this interconnected knowledge framework enables the determination of station depth based on the height of the escalator, illustrating the interplay of these elements within the problem context.

In the next stage, authors will compose training tasks for problem A, through which the integration of interdisciplinary knowledge is being implemented, such as the main parameters of the escalator, the cross-section of the escalator steps, and the properties of a right triangle.

Task 1 for Problem A. Determine the depth of the station.

The answer is accepted in full:

Code 21: 18 m. Contains correct reasoning. The sum of the heights of the steps is the height of the escalator, i.e., station depth.

Code 22: 1800 cm. Contains correct reasoning. The sum of the heights of the steps is the height of the escalator, i.e., station depth.

The answer is accepted in part:

Code 11: 18 m. There are inaccuracies in the reasoning.

Code 12: 1800 cm. There are inaccuracies in the reasoning.

Answer not accepted:

Code 01: The answer is incorrect. The argument is wrong.

Code 02: The answer is incorrect. The argument is missing.

Task 2 for Problem A. Determine the base of the escalator.

The answer is accepted in full:

Code 21: $1800\sqrt{3}$ cm Contains correct reasoning. The sum of the widths of the steps is the base of the escalator. Then the length of the base of the escalator is defined as $20\sqrt{3}*90 = 1800\sqrt{3}$ (cm).

Code 22: $18\sqrt{3}$ m. Contains correct reasoning. The sum of the widths of the steps is the base of the escalator. Then the length of the base of the escalator is defined as $20\sqrt{3}*90 = 1800\sqrt{3}$ (cm) = $18\sqrt{3}$ (m).

The answer is accepted in part:

Code 11: $1800\sqrt{3}$ cm. There are inaccuracies in the reasoning.

Code 12: $18\sqrt{3}$ m. There are inaccuracies in the reasoning.

Answer not accepted:

Code 01: The answer is incorrect. The argument is wrong.

Code 02: The answer is incorrect. The argument is missing.

Task 3 for Problem A. Determine the length of the escalator.

The answer is accepted in full:

Code 21: 36 m. Contains the correct reasoning: Part of the entire length of the escalator corresponding to one step is determined by the formula $lk = \sqrt{400+3*400} = 40$ (cm). Then the length of the entire escalator is $l = lk*90 = 40*90 = 3600$ (cm) = 36 (m).

Code 22: 3600 cm. Contains the correct reasoning: Part of the entire length of the escalator corresponding to one step is determined by the formula lk = √400+3*400 = 40 (cm). Then, the length of the entire escalator is l = lk*90 = 40*90 = 3600 (cm) = 36 (m).

Code 23: 36 m. Contains the correct reasoning: The length of the base of the escalator is 18√3 m, and the height is 18 m. Then, the length of the entire escalator is determined by the formula √182+3*182 = 36 (m).

Code 24: 3600cm. Contains the correct reasoning: The length of the base of the escalator is 1800√3 cm, and the height is 1800 cm. Then, the length of the entire escalator is determined by the formula √18002+3*18002 = 3600 (cm).

The answer is accepted in part:

Code 11: 36 m. There are inaccuracies in the reasoning.

Code 12: 3600 cm. There are inaccuracies in the reasoning.

Answer not accepted:

Code 01: The answer is incorrect. The argument is wrong.

Code 02: The answer is incorrect. No reasoning.

Task 4 for Problem A. Determine the angle of inclination of the escalator to its base. To do this, use Table 1.

Table 1. The angle of inclination of the escalator to its base

a/b	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
φ	6°	11°	17°	22°	27°	31°	35°	39°	42°	45°

Note: a – he legs opposite to the angle φ; b – the leg adjacent to the angle φ.

The answer is accepted in full:

Code 21: 31˚. Contains correct reasoning: a = 20, b = 20, a/b ~ 0.6, φ = 31˚. Uses the statement: the angles of the corresponding parallel sides are equal. And so, the desired angle is 31˚.

The answer is accepted in part:

Code 11: 31˚. There are inaccuracies in the argument.

Answer not accepted:

Code 01: The answer is incorrect. The argument is wrong.

Code 02: The answer is incorrect. No reasoning.

The content of tasks 1, 2, 3 and 4:

Area of mathematical content: space and form;

Context: professional;

Cognitive and mental activity: reproduction, graphic representation, mathematical reasoning, calculation.

Problem B. Bridge.

One of the largest reservoirs of the globe – Lake Balkhash, is situated in Kazakhstan. One of the unique features of this lake is that its Western basin is fresh, while the eastern one is brackish. It is required to build a DF bridge across the strait of Lake Balkhash, separating its Western and Eastern basins. To build this bridge, the topographer, having carried out measuring work using computer technology, drew a topographic map of the location of the DF Bridge (Figure 4). On the map DE = 2 cm; AB = 5.5 cm.

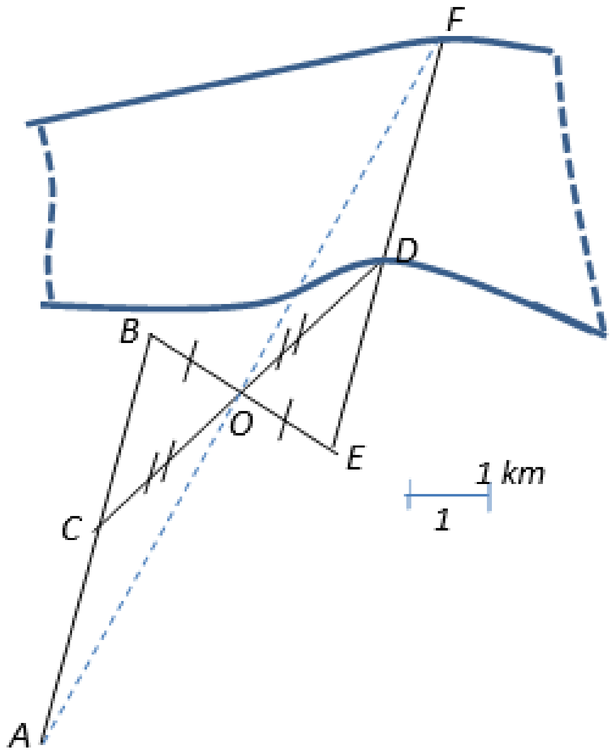

Figure 4. Topographic map of the location of the bridge

Now, let's formulate the assignments, with the help of which the stages of the lesson of systematizing the body of knowledge are implemented using the following elements of the general structure of the problem under consideration: the length of the bridge; topographic map; possibilities of computer technology; unique property of Lake Balkhash; properties of equal triangles, equality of internally cross lying angles, map scale.

Assignment 1 to Problem B. Indicates equal internal cruciform angles formed by the secant BE.

The answer is accepted in full:

Code 21: ∠B = ∠E. Uses the sign of equality of triangles and the equality of the corresponding angles in equal triangles.

The answer is accepted in part:

Code 11: ∠B = ∠E. Contains correct reasoning related to the sign of equality of two triangles but does not contain information about why ∠B = ∠E.

Code 12: ∠B = ∠E. The reasoning is missing important arguments, or there are inaccuracies.

Answer not accepted:

Code 01: The answer is incorrect. The argument is wrong.

Code 02: The answer is incorrect. The argument is missing.

Assignment 2 to Problem B. On the map DE = 2 cm; AB = 5.5 cm. Determine the length of the bridge.

The answer is accepted in full:

Code 21: 3.5 km. Uses the sign of equality of triangles and the equality of the corresponding segments in equal triangles.

The answer is accepted in part:

Code 11: 3.5 km. It contains correct reasoning related to the sign of equality of two triangles, but there is no justification for using the scale indicated in the topographic map.

Code 12: 3.5 km. There are no critical arguments in the reasoning, or there are inaccuracies in the reasoning.

Answer not accepted:

Code 01: The answer is incorrect. The argument is wrong.

Code 02: The answer is incorrect. The argument is missing.

Assignment 3 to Problem B. Determine if the bridge length found in task 2 is sufficient to build a real bridge.

The answer is accepted in full:

Code 21: No. The found length of the bridge does not include the length of the supporting (boundary) parts of the bridge.

The answer is accepted in part:

Code 11: No. The argument is wrong.

Answer not accepted:

Code 0: Yes. The argument is wrong.

Code 9: Yes. The argument is missing.

The content of tasks 1, 2, and 3:

Area of mathematical content: space and form;

Context: professional;

Cognitive and mental activity: reproduction, graphical representation, mathematical reasoning, calculations.

With the help of these tasks, through mathematical reasoning, the acquired knowledge is reproduced, consolidated, and systematized according to the educational materials “Properties of equal triangles”, and “Properties of right triangles”. With a graphical representation of the conditions of problems A and B, schoolchildren develop polytechnical knowledge and abstract thinking. In solving problems, interdisciplinary knowledge is formed, the problem's solution is interpreted, and critical thinking is used. Finding the answer to the question: “Is the length of the bridge found in task 2 sufficient to build a real bridge?” develops students' critical and divergent thinking. This study is based on a 2-year pilot study that aims to build math literacy in 15-year-old students. A survey of math teachers, consisting of 67 people, believes (82%) that the form of presenting problems from school textbooks does not contribute to the effective work of teachers in developing 21st-century skills in schoolchildren in a professional sense, at the same time teachers (96%) consider themselves competent in questions teaching mathematics.

In this regard, a system of lessons was developed in order to assimilate, consolidate and systematize the content of the educational material for the section, to form professional knowledge in 15-year-old schoolchildren, critical, divergent and convergent thinking, which are the main components of mathematical literacy. To identify the usefulness of the developed system of lessons in teaching mathematical literacy among schoolchildren of the experimental (30 students) and control (28 students) classes, a written work was carried out. As criteria, the ability of schoolchildren solve practice-oriented tasks were chosen as follows:

- tasks corresponding to levels 5 and 6;
- tasks corresponding to levels 3 and 4;
- tasks corresponding to levels 2 and 1, in accordance with the PISA mathematical literacy scale of

formation.

The analysis of written works, which determines the effectiveness of the developed methodology for teaching mathematical literacy to schoolchildren, showed that 20% of schoolchildren haven't reached the 2nd level, 70% have reached the 2nd level, 7% have reached the 3rd and 4th levels, and 5, 6 levels have reached 3% of schoolchildren from the experimental class. In the control class, 60% haven't reached the 2nd level, 37% have reached the 2nd level, 3% of schoolchildren have reached the 2nd level. These data testify the correctness of the approach to teaching mathematical literacy to schoolchildren in the experimental class and confirms the need for research in this area. Thus, the developed system of lessons, designed tasks based on the standard tasks of the school textbook contribute to the assimilation of new educational material by schoolchildren, the application of mathematical knowledge in specific problem situations, and the formation of skills of the 21st century.

In the concept of PISA-2021, the most important skills of the 21st century hold special place, namely: critical thinking; systems thinking; reflection. Therefore, the research on the methodological base of the PISA assessment tasks, assessment of thinking skills is relevant (Prabawanto & Susilo, 2020). Also, the article by Sjoberg and Jenkins (2022) argues that the statistical aspects of PISA have attracted a lot of attention from researchers, however, some elements and methodological bases of PISA are largely left out of the attention of researchers. These include methodological problems of designing tasks, pedagogical measurement of thinking skills in the context of PISA exam tasks. Dingler et al. (2017) highlights methodological challenges in determining the effectiveness of teamwork measurements team performance over time, discusses the foundations of the Program for International Student Assessment (PISA), the content of the Assessment and Teaching 21st Century Skills (ATC21S) project, and compares assessment results obtained on the basis of these programs.

Yusupova and Skudareva (2020), studied the essence of the PISA category, in particular, revealed in her research its properties and aspects on which it is based. Thus, it established that the above-mentioned mechanism should be understood as the international evaluation activity coordinated by the representatives of the OECD (Organization for Economic Cooperation and Development). The significance of this research is that it aims to obtain comparative information about the level of knowledge and skills of their practical use in practice, among the subjects of the educational process. In addition, it includes the establishment of priority vectors for the development and modernization of international educational programs, which definitely has a positive effect on the degree and number of educational achievements of students in different countries. Based on this, she established that there is a dynamic increase in the quality and level of training of teachers for their teaching of educational material, as well as the organization of the education system. In addition, she managed to analyze the main areas of PISA tasks. Thus, they are aimed at establishing the level of preparation of students for the implementation of the acquired knowledge and skills that they acquired in the educational institution. For example, the establishment of such a conclusion regarding mathematical skills is formed on the basis of a system of tasks, which consist in determining the ability of a teenager to apply knowledge and skills in mathematics during everyday life, as well as when solving problems related to this area.

In turn Hwang and Ham (2021), defined the meaning and content of the concept of "mathematical literacy". She managed to investigate and reveal it as a human possibility to form, implement and modernize mathematics from different angles and under different conditions. Thus, mathematical literacy includes mathematical reasoning that is formed in a schoolchild as a result of the mathematical concepts he has learned. In addition, this component also includes a number of procedures, facts, and tools designed to analyze, interpret, and model various phenomena in accordance with established factors. Thus, the researcher established that due to the development of mathematical literacy, the role of mathematics in society is consolidated and increased. This results from the fact that the acquisition of such skills by the subjects of the educational process allows the latter to form logical conclusions and express effective solutions that affect the modernization of mathematical sciences, in accordance with the challenges that are necessary for people as creative, active, and thinking citizens.

Particular attention was paid to Narimo's scientific work, in which the researcher modelled the priority questions that should be the basis of the PISA mathematical tasks (Narimo et al., 2020). Thus, she focused her research on the substantive part of surveying students and determining their level of knowledge. The researcher asserts the need to base this process on tasks that will allow schoolchildren not only to reveal their practical skills, but also to demonstrate their attitude to mathematics as a whole. For this, it is worth asking teenagers about what skills a person needs to have in order for him to be able to act rationally in cases related to mathematics. More concrete is the question of what the meaning of mathematical competence for a teenager is who studies at school and plans to enter a higher educational institution in order to acquire professional skills. Having considered such examples, the author believes that they are effective, as they allow revealing not only the level of actual mathematical knowledge of schoolchildren, but also the possibilities of interpreting mathematics in their future life.

In addition, Federiakin et al. (2021) notes that the concept of mathematical literacy allows for the formation of a quality foundation for the modernization of students' competence, as well as deepening their understanding and familiarization with established mathematical concepts. Based on this, the researcher emphasizes the advantage of students who are able to carry out qualitative cognition and expand abstract views on mathematics. PISA tasks make it possible to pay attention to the need to improve the existing level of skills of schoolchildren regarding the implementation of mathematics and related tools in real life. Precisely because of this, it becomes necessary to reveal to teenagers the importance of mathematics and ways of using it in their future professional activities. The author agrees with the stated position, while noting that the motivation and desire of a significant number of schoolchildren to continue studying mathematics and deepen their knowledge increases, provided they can establish a connection between their theoretical and practical skills. Accordingly, they get the opportunity to compare mathematics with other educational disciplines and the immediate environment, which in turn reveals and increases the priority of the first.

Attention was also drawn to the work of Ozkale and Ozdemir (2020) which he establishes that the process of forming mathematical literacy among students during the PISA assessment consists of several constructs. The author noted that mathematical aspects are encountered quite often in the context of everyday issues, as well as challenges of the real world. At the same time, he divides such aspects into two types. The first are contextual categories related to the field of activity, based on which acute problem cases can be formed. The next type of problem can be a category of social challenges, which to a greater extent relate to the local level, that is, to a specific community, as well as professional or scientific ones, which respectively relate to the application of mathematics during a specific type of employment of a schoolchild. The author agrees with the presented position and also adds that the PISA tasks are designed to develop the mathematical abilities of teenagers to solve such context-centered challenges, due to mathematical thinking and special approaches.

Wu et al. (2020) managed to describe the process based on which the process of completing the tasks provided for by PISA should take place. Thus, first of all, a schoolchild should be based on the content of various mathematical concepts and acquired knowledge and skills directly during the exercises. Already at this stage, the development of mathematical literacy takes place, since the person models and implements a mathematical strategy based on what he has information Next, the teenager should focus attention on the quality of the wording of the problem, namely the questions related to it. Accordingly, the author believes that in this case it is advisable to use special mathematical procedures to achieve a rational mathematical solution, as well as to establish the true answer. In addition, agreeing with the proposed approach, he notes that even at the last stage, the activation of mathematical thinking and the formation of new skills takes place.

The discussion made it possible to establish that mathematical literacy has several features, as well as the vectors in which it develops. It is important that, to a greater extent, the positions of scientists have a number of common features with the ideas of the author, so this may indicate the priority of acquiring mathematical skills by schoolchildren and their demonstration during the performance of PISA tasks.

CONCLUSION

Despite the free availability of the results of PISA research to a wide range of researchers, analysts of the learning process, academic research on the methodological problems of learning is surprisingly very small. This study might contribute to addressing the part of this gap that relates to the formation of mathematical literacy, by examining the cause of this problem and developing appropriate teaching approaches.

One of these issues is the correspondence of the contents of textbooks to the problem of the formation of mathematical literacy. An analysis of the textbooks used in the Republic of Kazakhstan shows that the mathematical problems of the textbook are preferably aimed at the formation of mathematical concepts, statements, and computational skills, less used: mathematical formulation of situations, identification and development of skills of 21st century. According to the levels of mathematical literacy in these textbooks, among the tasks that are mandatory for studying, there are no tasks of levels 5 and 6, they mainly contain tasks of the 2nd level, occasionally tasks of the 3rd and 4th levels. The reason for this distribution of tasks is explained by the lack of time for schoolchildren to study tasks of levels 3-6. In addition, it was found that in textbooks the greatest number of tasks has a scientific context, and practice-oriented tasks that have social, professional contexts do not support the development of mathematical literacy. Whereas the tasks compiled by PISA experts for the problem situation provide a consistent accessible study of the problem situation from different positions. In order to eliminate such a discrepancy, a system of lessons was proposed, aimed at developing the mathematical literacy of schoolchildren. The developed system of lessons, designed tasks based on standard tasks of the textbook, allowed schoolchildren to master new educational material, apply mathematical knowledge in specific problem situations, and form some skills of the 21st century.

An analysis of the results of experimental written work indicates the correctness of the approach to teaching mathematical literacy to schoolchildren in the experimental class and that increasing the mathematical literacy of students can be implemented by integrating the formation of mathematical reasoning and mathematical knowledge. The results of a survey of school mathematics teachers revealed that the level of formation of mathematical literacy of schoolchildren directly depends on scientific and methodological preparedness, motivation of mathematics teachers, and the quality of teaching materials. The proposed structure of the system of lessons, formulated tasks for problem situations, illustrating approaches to compiling tasks for standard tasks of the textbook can be used when compiling new generation textbooks in the Republic of Kazakhstan and other countries.

All the lessons listed are similar in that they are built in accordance with the basic requirements for the lesson, and that in each lesson, along with the main goal, secondary goals (sub goals) are set and solved. To select approaches for developing a methodology for the formation of mathematical literacy in 15-year-old schoolchildren, authors highlight the main features of the construction of these types of lessons. The analysis showed that the PISA problems are mainly practice-oriented, and the tasks for these problems, in addition to the evaluation functions, and are educational in nature. In this regard, for each lesson, depending on its purpose, the corresponding practice-oriented problems and assessment – study tasks for the students will be composed. When compiling these tasks, the focus will be placed on the wording of the tasks of the international program for assessing student learning achievements PISA and on problem-based learning.

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Author Contribution	:	DN: Conceptualization, Methodology, Data Curation, and Writing-Original Draft Preparation. BS: Visualization, Investigation, Writing-Original Draft Preparation, and Supervision. AK: Software, Validation, Writing-Reviewing, and Editing. All authors read and approved the final manuscript.
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