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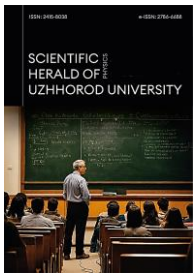

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Assessing schoolchildren's 21st century cognitive and behavioural development

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Abstract

Relevance. The study of effective methods for developing cognitive skills among schoolchildren is extremely relevant. This is crucial to ensure their proper preparation for the challenges of the modern world, which is characterized by rapidly changing transformations and the dominance of digital technologies.

Purpose. The purpose of the research is to determine the degree of effectiveness of approaches to formative assessment of the development of cognitive skills among schoolchildren of the 21st century.

Methodology. A system of scientific research methods was used, including analysis, synthesis, comparison, surveys, mathematical statistics, and observations.

Results. The study showed that using the results of residual, activity, local, and modular assessment contributes to improving the quality of education and developing students' communicative and reflective abilities. Model examples of item-by-element assessment of tasks for schoolchildren during formative assessment are provided. An algorithm for conducting formative assessment within one academic period has been developed. The analysis of tasks performed by schoolchildren during formative assessment showed that test tasks must be developed differently for each content component.

Conclusions. The results obtained during the research should be used in developing methodological materials for teachers. These materials should address the organization of the educational process and approach to the formative assessment of the cognitive skills of schoolchildren.

Keywords: final certification; academic results; quality learning; mental skills.

Introduction

International exams of the Program for International Student Assessment (PISA) every three years measure the mathematical literacy of schoolchildren, the effectiveness of learning and the development of educational systems in different countries of the world. It is obvious that the effectiveness of the research on the level of mathematical literacy among schoolchildren directly depends on the evaluation work to establish the formation of the signs of mathematical literacy at each stage of the lesson and the algorithm for solving practice-oriented problems, which should be a necessary part of the process of everyday education of schoolchildren. In this regard, to measure the quality of education and mathematical literacy in different national educational systems, various assessment technologies are used, in particular, in many countries of the world, criterion-based assessment of students' educational achievements is used. For example,

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J. Threlfall [1] explores the commonalities between assessment-based and "contingent" approaches to learning in the UK. In their studies, X.T. Meng et al. [2] and Q.X. Chen [3] propose introducing an adapted formative assessment system and creating a corresponding blended learning model in China. I. Clark [4] describes the basic principles of formative assessment and identifies the structural elements of formative assessment. In addition, he argues that formative assessment is an educational and psychological process to which authors in many countries have devoted their research.

J.J. Cumming et al. [5] emphasizes that the use of formative assessment results in Australian schools to improve learning requires ongoing teacher training and professional development. L. Allal [6] describes the specifics of engaging students in various forms of formative assessment, namely self-analysis, mutual analysis, and discussion of descriptors. A.L. Hondrich et al. [7] assessed the effectiveness of German teachers' implementation of formative assessment embedded in the science curriculum. W.Y. Guo and Z. Yan [8] explore how Hong Kong school students can develop an informed understanding of formative and summative assessment. D. Štefanc and M.K. Šebart [9], and M. Taras [10] explore questions about the possibility of integrating summative and formative assessments and the relationship between formative and summative assessments.

In recent years, the research of many authors has been aimed at determining the goals of assessment, developing the theory of assessment, developing innovative assessment methods, determining the differences between summative and formative assessment, determining the priority of conducting formative assessment in the context of improving the quality of education [11; 12; 13]. Several studies examine assessment issues in school mathematics education [14; 15]. The studies of Zh.A. Abekova et al. [16], R.K. Iskakova et al. [17] and M. Leenknecht et al. [18] are devoted to identifying effective methods of formative assessment of students' educational achievements.

The PISA 2021 program concept places special emphasis on mathematical reasoning and 21st century skills – these are thinking and behavioural skills that are becoming increasingly important in everyday human life [19]. The national strategy for improving the education system in Kazakhstan provides for the introduction of the latest approaches to assessing the academic progress of students in general educational institutions [20]. The program provides for the creation of a content base of criterion evaluation to determine the level of competence and the level of development of thinking, which corresponds to the thinking skills of the PISA-2021 concept. The scientific and methodological basis of this approach to assessment is the work of B.S. Bloom et al. [21], which was developed in the studies of P. Black and D. Wiliam [22], P.E. Newton [23], M. Weurlander et al. [24].

To objectively check the learning results and establish the dynamics of students' mastery of new knowledge, a criterion evaluation of students' learning abilities was organized in all schools of the Republic of Kazakhstan. Currently, Nazarbayev Intellectual Schools of the Republic of Kazakhstan, together with the International Examination Council of the University of Cambridge, have developed the basic requirements for criteria-based assessment of students' educational achievements:

– the primary focus of assessment is exclusively the student's intellectual efforts to process the content, not his traits or personality;

– the student's work should be directly related to the reference sample of the performance of a certain task, determined in advance;

– the developed criteria serve as a basis for determining the level of mastery of the material by students, forming a multi-level evaluation system. It provides an accounting of educational achievements with subsequent transfer to a traditional 5-point rating scale. This allows each student to personally track their progress and grades;

– the criteria for evaluating the educational achievements of students are inextricably linked with the educational goals for mastering the relevant content.

However, these requirements and these studies do not provide answers to the questions:

1. What components of current assessment contribute to increasing the effectiveness of the educational process and improving the quality of education in general?

2. Do formative assessments contribute to the development of students' mathematical reasoning and 21st century skills?

Thus, the analysis of the above and other works determines to change views on the significance of practice-oriented tasks, the content of scientific and educational materials, educational and formative goals, to revise the goals and objectives of assessment, to develop new effective assessment methods, to take into account the roles of the student and teacher in assessment practice. This view, as well as the modern practice of assessing mathematical literacy, allows us to conclude in favour of using a new paradigm of criterion-based assessment in the process of teaching schoolchildren. Thus, there is a need for further study of the essential components of current assessment in order to clarify their potential for the formation and development of key competencies of students.

Materials and Methods

Research is based on empirical, and theoretical methods, as well as on the method of mathematical statistics. The empirical method was based on the use of analysis, comparison of mathematics classes conducted by teachers (11 lessons), the results of conversations with mathematics teachers of secondary schools (13 teachers), the results of formative assessment (134 works), and the organization of diagnostic activities.

The theoretical research method was based on the use of the results of a comparative analysis of scientific publications from the Scopus and Web of Science databases. The method of mathematical statistics was based on the use of the results of written work of schoolchildren.

The starting points for this study are the theoretical foundations of formative assessment, the OECD concept, the PISA 2021 studies and the results of experimental assessment and learning. Criterion evaluation of

educational results and mental skills of students is an inseparable component of continuous educational process. It serves as a tool for identifying the individual abilities of each student to improve the educational process, contributing to a deeper mastery of the content and the development of cognitive and thinking skills. Both the criterion-referenced assessment of educational achievements and the assessment of student's mental abilities require the establishment of a two-way dialogue and mutual understanding between the teacher and the student. This is achieved by using clear assessment criteria or indicators of the formation of thinking skills.

The analysis method was applied in the study to evaluate existing theoretical approaches, methods and tools for formative assessment. It was used to determine their ability to assess students' cognitive and behavioral skills by the concept of 21st century skills. In addition, based on a thorough analysis of qualitative and quantitative data from the pedagogical experiment, the results of observations, questionnaires, written works, as well as conversations with teachers were investigated. Also, in the process of research, an analysis of the level of formation of individual competencies in different groups of students during the application of various forms of formative assessment was carried out.

The synthesis method provided for the identification of the optimal complex model of formative assessment of cognitive and behavioural skills of the 21st century. Accordingly, the synthesis ensured the generalization of the results of the analysis of empirical data, theoretical developments, and concepts of OECD, and PISA. This method was also used to form conclusions regarding the conducted pedagogical experiment, namely, the results of interviews with mathematics teachers of secondary schools and the results of the formative assessment were synthesized.

The comparison method was used in the study when establishing the level of effectiveness of different types of formative assessment, namely activity, local and modular. With its help, it was determined common and distinctive features between them, are revealed in the process of development of individual cognitive and behavioural competencies in modern students.

The purpose of the study is to determine and expand the scope of the functional capabilities of formative assessment and develop tools and content components for formative assessment of students' educational achievements, aimed at the formation and development of quality knowledge, cognitive abilities, and behavioural skills of the 21st century.

Results

Statement of the problem

The PISA study measures the effectiveness of national education systems by how prepared students are to apply mathematics in matters of solving problems arising in their environment. The PISA 2021 program concept describes the relationship between mathematical reasoning and the three familiar stages of practice-oriented problem solving (formulation, application, interpretation and evaluation). The modern concept of key competencies for life and activity in the 21st century includes eight key skills: critical thinking, creativity, research skills, self-regulation, initiative and persistence, information literacy, systems vision, communication skills and reflection. The analysis proved that cognitive processes and behavioural patterns are the foundation for the development of mathematical thinking and mastery of skills needed in the present century.

Cognitive activity is the mental activity of a person that leads to the understanding and formulation of a problem. It involves interpreting the problem in a form that is understandable to the individual. This activity includes solving and generalizing the problem, as well as evaluating and interpreting the solution. It encompasses the acquisition or reproduction of knowledge through the use of information, research, and study. Additionally, cognitive activity involves systematic and creative thinking. Behavioural activities include communication, reflection, self-regulation, initiative and perseverance, and also a value attitude. Cognitive abilities are mainly formed and developed mainly through solving problem-oriented problems. Skills such as reflection, self-regulation, initiative and perseverance are formed and developed when discussing solutions to problems, communication when carrying out joint educational work, and a value attitude through understanding the content of the task and when carrying out joint educational activities.

Thus, the issues of formation and development of quality knowledge, cognitive abilities, value attitudes, and behavioural skills of the 21st century are the key tasks of school education. Therefore, in the modern school education system, identifying signs of well-formed cognitive abilities in schoolchildren, communication skills, reflection, self-regulation, initiative and perseverance is of no small importance. To formulate research questions, a series of ascertaining experiments was organized in five secondary schools of the city of Taldykorgan, Republic of Kazakhstan. The purpose of these studies was to study how the results of criterion-referenced assessments of students' educational achievements affect the level of their assimilation of new knowledge in mathematics, and the development of their cognitive abilities. The experimental work used teachers' analysis of the results of assessing students' educational achievements, experimental data on the analysis of the content and results of tests completed by schoolchildren.

The analysis of the research results showed that the mathematics teachers in the studied schools did not conduct a systematic analysis of the results of the assessment of the student's educational activities. This analysis should be aimed at studying the impact of assessment on the formation and development of the cognitive abilities of children. To identify such a negative attitude of teachers towards the analysis of assessment results, additional conversations were held, and a questionnaire was proposed that included 8 questions. The results of the interviews, analysis of responses to questionnaire questions, and study of the work practices of mathematics teachers allowed us to establish the main problem in using assessment results – the inability to recognize, distinguish, and use the functionality of the content components of formative assessment. The study also revealed several contradictions:

1. Insufficient development of educational and methodological tools. There are clearly defined

requirements for knowledge, abilities and skills that students of secondary schools should have. At the same time, there is not a sufficient number of educational and methodological tools and technologies that would ensure the successful formation of these knowledge, abilities and skills. This makes it difficult for teachers to fully use the results of criterion evaluation to improve the educational process.

2. Insufficient development of criteria assessment tools. Teachers should use criterion-referenced assessments to assess student achievement. However, there are not enough tools and techniques that would allow them to effectively assess such important aspects as cognitive abilities and 21st century skills. This makes criterion-referenced assessment less effective because it cannot cover all important aspects of the student's development.

In addition, assessment practice and the analysis of a wide range of theoretical and empirical studies on formative assessment indicate that its implementation and use are subject to various difficulties. One challenge is identifying meaningful components of formative assessment. This is particularly important in the context of using assessment results for the formation and development of knowledge, cognitive abilities, and behavioural skills necessary for the 21st century.

The established problem of using assessment results and the identified contradictions determined the relevance of the research problem, which lies in the insufficient development of tools and structural elements of formative assessment of student's educational achievements and methods of its use in the process of formation and development of quality knowledge, cognitive abilities, and behavioural skills of the 21st century.

Identifying the content components of criteria-based assessment of students' educational achievements

Identification of the functional capabilities of formative assessment that contribute to the formation and development of knowledge, cognitive abilities, and behavioural skills of the 21st century, and motivation for knowledge is closely related to knowledge of the essence of the assessment itself. The essence of assessment is learned through identifying (by some criterion) the substantive components of this assessment and cognition of each substantive component separately. On the other hand, the advisability of identifying content components stems both from the need to improve school practice and from the need of methods of teaching mathematics as a science. Given the above and the purpose of the study, the authors leave before themselves the task of determining the means and content components of the criterion-referenced assessment of students' educational achievements.

Depending on the purpose of the test, criterion-based assessment of students' educational achievements is divided into two main types: formative and summative assessment. Summative assessment can be final or intermediate. At the end of each academic period (year, quarter, half year) a final assessment is conducted. Its purpose is to assess the knowledge and skills acquired by students during this period. The results of the final assessment must correspond to the levels of formation of thinking skills defined by the educational program. After studying the main training modules, an interim summative assessment can be organized. Its purpose is to test the knowledge, skills and abilities acquired by students during these modules. Evaluation is based on criteria defined for each module. Depending on the content of the learning material, different forms of assessment may be used, such as tests, projects or research papers. Research has shown that summative assessment is an effective tool for evaluating learning outcomes and helping to improve the learning process.

Formative assessment of student's educational achievements is one of the main factors in improving the quality of education, allowing you to quickly identify gaps in knowledge, and errors in mathematical reasoning, and adjust the process of teaching schoolchildren educational material. Analysis of research by domestic and foreign scientists shows that formative assessment is used to organize effective training. However, the authors interpret the forms and content of formative assessment in different ways. This shows that there is no single approach to its use. Teachers in Kazakhstan have considerable freedom in choosing the forms and frequency of use of formative assessment tools. However, practice shows that simple approval or objection from the teacher is not enough. For effective formative assessment, it is important to conduct a detailed discussion of the results of the students' work, record the assessment results, and use a variety of assessment forms and methods. Using these approaches will help develop students' abilities, increase their interest in learning, and make the learning process more effective.

It is important to note that formative assessment is not just knowledge control, but also a tool for student development. Therefore, it should aim to help students understand what they have already learned and what they need to do to improve their performance. The analysis of various forms of control of students' knowledge indicates the need to develop new components and means of formative assessment. These components and tools should take into account the functionality of different assessment methods, improve the quality of learning, and shape and develop cognitive abilities and skills of the 21st century. A content analysis of educational and methodological works, the practice of mathematics teachers, and the purpose of formative assessment used at different stages of the learning process allowed to identification of the following content components of formative assessment: residual formative assessment, modular formative assessment, activity-based formative assessment, local formative assessment.

At the beginning of each academic period (year, half-year, quarter) it is recommended to carry out control and analytical work, which the authors call "residual formative assessment". The purpose of this work is to determine the residual knowledge of students and to evaluate the formed cognitive abilities and behavioural skills of the 21st century. Based on the obtained results, it will be possible to update the knowledge of students, to correct knowledge where necessary. In addition, they will influence the provision of quality planning of the educational process for the next period. Thus, residual formative assessment is an important tool that helps make learning more effective and efficient. The authors call such a test a residual formative assessment:

1. Residual assessment is a tool used by the teacher at his discretion. It is necessary to determine the level of knowledge and skills of students at the beginning of the new academic period, as well as to make adjustments to the planning of the educational process. Various methods can be used for residual assessment, such as tasks, tests, record sheets, observations, and analysis of learning achievements.

2. The main indicators of residual formative assessment of students' educational activities are: possessing systematic knowledge, which is evident in solving systems of typical problems. Demonstrating cognitive abilities, which are shown in the ability to clearly express thoughts and prove a point of view while solving heuristic and research problems. Having the skills to apply mathematical knowledge in solving and modelling practice-oriented problems. At the discretion of the teacher, the results of residual formative assessment, identified based on these signs, can be registered in the specified tables of fixation, correction of student achievements (correction, development of educational achievements and thinking skills of students), and errors made by students are highlighted.

3. When carrying out residual assessment, the following methods are most often used: thematic general or individual control work, testing, and questionnaires. Such an assessment is usually carried out at the beginning of each half-year, based on the results of which residual knowledge for the past half-year is established.

4. This form belongs to the category of system-forming, as it forms the conditions for teaching students to systematize knowledge, and the teacher to teach differentiated remedial learning, recovery and consolidation of educational knowledge, and formation of formed cognitive abilities following the results of educational achievements of students (2-3 hours). With residual formative assessment, analysing the results of solving all problems helps establish the systematic nature of knowledge. Solving problems related to ecology aids in assessing the student's well-formed value attitude towards the environment. Problems with multiple-valued answers contribute to assessing the formation of critical thinking, while research problems help gauge the development of creative thinking.

5. Among the approaches that develop the evaluative, corrective, and mental activity of schoolchildren is the discussion by the whole class on the blackboard of the solution to the same problem by several schoolchildren, followed by the selection of the most successful solution. In addition, for discussion, it is useful to offer students problems in which there is a deliberate error (no more than one error). This approach allows to establish that students have developed the skills of systematic, critical thinking, and making corrective decisions.

The examination of students' academic performance, which is conducted (no more often than three times per quarter) at the end of the educational module, will be called modular formative assessment:

1. Modular formative assessment is instrumental and can be carried out within one lesson at the discretion of the teacher using the following tools: tasks, assignments, expected results, written work, and model examples. The teacher can enter the results of the residual assessment in the table to monitor the achievements of the students and make corrections in the educational process.

2. Residual assessment prepares students for summative assessment by correlating expected results with summative assessment criteria. This helps both the teacher and the students to better understand what knowledge and skills they need and motivates the students to learn.

3. The basis of modular assessment is a system of pedagogical assessment methods, including control work, case method, project method, portfolio, testing, and catanotests.

4. Modular formative assessment is preceded by lessons, where special attention should be paid to systematizing knowledge and establishing connections between the studied concepts from a given module. Since, during modular assessment, the student's systemic understanding skills of the educational module are tested (the ability to identify connections between concepts and properties presented in the conditions and solutions of various problems), to justify each action performed, its ability to construct a whole from several parts that are in a certain semantic connection (synthesize). With modular assessment, the level of cognitive abilities of schoolchildren is established: to understand a problem, formulate mathematical models, apply mathematical knowledge, interpret a solution, and determine the ability to evaluate their educational achievements.

5. Modular formative assessment is reflective and creates conditions for students to systematize the knowledge acquired by students, self-control of mastering new knowledge self-regulation of learning, and development of thinking skills.

For example, a modular formative assessment on any topic can be carried out using a test, designed for 1-2 hours, consisting of several options, each option is a system of tasks related thematically. The tasks included in the text of the control work must be formulated mathematically correctly. This assessment uses research tasks, environmental tasks, understanding tasks, formulation, application, analysis, and synthesis, the solution of which ensures the assimilation and consolidation of new knowledge in the educational module, contributes to the development of creative thinking, cognitive abilities, and a value-based attitude towards the environment. The analysis of the results of a modular assessment contributes to the development of students' systems thinking skills, assessment skills, and making corrective decisions.

Determining the presence or absence of developed thinking skills in schoolchildren (understanding, formulation, application, analysis, synthesis), carried out in the process of independent presentation, assimilation, consolidation of the content of educational material, the solving practice-oriented problems the framework of one topic, authors will be called activity-based of formative assessment:

1. Activity-based formative assessment provides continuous basic preparation for the implementation of modular formative assessment within the framework within one training content and is implemented at the discretion of the teacher using the following tools: written and oral tasks for class and homework, refutation tasks, and problematic environmental tasks.

2. Activity-based formative assessment is correlated with the goals of the lesson and is carried out under the guidance of the teacher using criteria, signs of assessing the mastery of the educational module, the completed educational task and determining the well-formed thinking skills based on model examples.

3. Activity-based formative assessment can be implemented in the process of activity-based, problem-oriented teaching methods equally for all students in the class, and differentiated, with attention paid to specific students selected depending on their cognitive abilities. When implementing activity assessment, the method most often used is oral questioning (individual, frontal). This form of assessment can also be implemented through the educational and assessment work of students in dynamic pairs of shift personnel, designed for initial study and problem-solving. In the process of such assessment, schoolchildren and teachers are convinced of the effectiveness of learning and determine whether learning goals have been achieved.

4. Activity-based formative assessment is cognitive and creates conditions for students to assimilate, consolidate, systematize knowledge and form and develop cognitive abilities and behavioural skills of the 21st century. Activity-based formative assessment is preceded by a presentation of a new topic, where, depending on the content of the educational material, the following lesson objectives can be distinguished: formation in schoolchildren of the ability to solve problems with practical content. The process of solving practical problems involves several cycles of mental activity. Initially, tables and graphs are used to highlight the data and missing components of the task. Next, relationships among unknown components are established using available data. The laws governing the problem are then described mathematically, applying relevant mathematical knowledge. Solutions are interpreted within the context of the problem. This process fosters critical thinking in schoolchildren and emphasizes the importance of monitoring and evaluating their work results. To this end, after presenting a new topic, schoolchildren should be offered tasks that develop their need for control and scrupulous verification of the results of their work. An excellent method for developing a critical attitude towards educational material is provided by refutation tasks, which develop students' ability to construct counterexamples and critical thinking skills.

5. In the assessment process, which occurs during oral surveys and educational activities where students work in dynamic pairs, various communications are established. These interactions include constructive connections between participants in the learning process, as well as reflection, self-assessment, mutual assessment, and analysis of educational effectiveness. These activities collectively contribute to the development and enhancement of cognitive abilities and behavioral skills relevant to the demands of the 21st century.

Here, special attention should be paid to establishing interaction in the "task-student" system. Since tasks are objects of mental activity for both the student and the teacher. And, therefore, in this assessment, tasks are used that develop mental activity in schoolchildren. Here authors mean tasks for of observation, comparison, analogy, understanding, formulation, application, research, analysis and synthesis. Formative assessment (current check) of the level of students' assimilation of educational material within one lesson will be called local formative assessment.

With the correct organization of local formative assessment, the teacher receives prompt information about the presence of gaps in students' knowledge and the skills they have acquired, which should be immediately used to eliminate gaps in knowledge and to correct the learning process. Local formative assessment provides continuous preparation for activity-based formative assessment of student's knowledge and skills within the framework of the educational material being studied:

1. Local formative assessment is carried out at the discretion of the teacher, while it is based on various means of assessment (for example, using an oral test, mathematical dictation with an assessment of the truth or falsity of statements, an individual study map) using words that motivate learning.

2. Local formative assessment is carried out directly under the guidance of the teacher using indicators that correspond to the assessment descriptors and lesson objectives provided for the given educational material. Such assessment promotes memorization and polishing of new knowledge. With the help of this approach, teachers, parents and students can monitor according to an individual map of students' learning of educational material with the help of local assessment indicators. An individual learning map and a table for recording and correcting student achievements are tools that motivate students to learn.

3. Among the methods of local assessment, one can highlight mathematical dictations, quick surveys, refutation tasks, critical discussion of the results of homework with the whole class, and information and communication technologies: Plickers, and Kahoot. At this stage of training, it will also be possible to use interactive learning.

4. This type of evaluation is characterized by operational features, and therefore ensures the dynamic organization of the educational process of students for the acquisition, development, and verification of acquired knowledge from the selected educational material.

5. Local formative assessment is preceded by a presentation of a new topic, where, depending on the content of the educational material, the following lesson objectives can be distinguished: mastering a new concept. To master new concepts, the following sequence of lesson stages can be distinguished: motivation for introducing the concept; identification of essential properties of the concept; mastering the definition of a concept; and mastering the content of the theorem. To master the content of the theorem, the following sequence of lesson stages can be distinguished: highlighting the conditions and conclusion of the theorem; constructing a drawing of modelling conditions and derivation of the theorem; choose an algorithm for proving the theorem.

Here, special attention should be paid to the assimilation of concepts, properties, theorems and to consolidating the knowledge acquired by schoolchildren. This assessment uses tasks for understanding, formulation, and application, the solution of which ensures the

formation and development of schoolchildren's thinking skills (deductive, algorithmic, critical thinking).

Thus, a reasonable choice of the content of test work, completing tasks, solving problems, discussing the results of test work, the use of activity-based, problem-oriented teaching methods contribute to the formation and development of cognitive abilities and behavioural skills of the 21st century.

Model examples

By the above, authors will give examples of the implementation of criterion-based assessment in the context of using assessment results in the formation and development of knowledge, cognitive abilities and behavioural skills of the 21st century. Thus, modular formative assessment can be carried out, for example, by checking the written work of schoolchildren. A careful analysis of the results of written work provides quality results regarding the weaknesses and strengths of individual students and their typical mistakes. Based on this, it is possible to outline ways to eliminate them. The algorithm for element-by-element analysis of the implementation of each test task is developed in different ways. For example, let us say a written assignment includes the following task:

Problem 1. Solve the equation (1):

$$\sqrt{1 + cos\, 2\, x} = \sqrt{2}\, sin\, 2\, x. \quad (1)$$

First, an optimal way to solve the problem is compiled:

1. The domain of definition of this equation is given by the inequality $sin\, 2\, x \geq 0$, whence (2):

$$\pi k \leq x \leq \frac{\pi}{2} + \pi k. \quad (2)$$

2. By squaring both sides of this equation, authors obtain (3, 4):

$$1 + cos\, 2\, x = 2\, sin^2\, 2\, x, \quad (3)$$

$$2\, cos^2\, 2\, x + cos\, 2\, x - 1 = 0. \quad (4)$$

3. Let's introduce a new variable$y = cos\, 2\, x$, then $2y^2 + y - 1 = 0$. Where do authors find from (5):

$$y_1 = -1; y_2 = \frac{1}{2}. \quad (5)$$

4. Thus, this problem has been reduced to the simplest trigonometric equations: $cos\, 2\, x = -1;\ cos\, 2\, x = \frac{1}{2}$. From the first equation authors find $x = -\frac{\pi}{2} + \pi n$, from the second authors get (6):

$$x = \pm\frac{\pi}{6} + \pi k. \quad (6)$$

5. Authors used the squaring transformation, then extraneous roots of this equation may appear among the found values. Let's check the values of $x = -\frac{\pi}{2} + \pi n, x = \frac{\pi}{6} + \pi k$. It is easy to verify that the numbers $x = -\frac{\pi}{2} + \pi n$ and $x = \frac{\pi}{6} + \pi k$ satisfy the inequality $\pi k \leq x \leq \frac{\pi}{2} + \pi k$, and therefore are solutions to this equation. The numbers $x = -\frac{\pi}{6} + \pi k$ do not belong to the domain of definition.

6. So, this equation has two groups of solutions (7):

$$x = -\frac{\pi}{2} + \pi n, x = \frac{\pi}{6} + \pi k. \quad (7)$$

Now, to assess educational achievements and well-formed schoolchildren's thinking skills, you can draw up the following plan for testing the solution to the problem:

1. Correctly established the domain of definition of this equation: established that the domain of definition of this equation is given by the inequality $sin\, 2\, x \geq 0$; solved the found inequality.
2. He squared both sides of the given equation.
3. Introduced a new variable. Solved a quadratic equation.
4. Obtained the simplest trigonometric equations. Solved a found trigonometric equation.
5. Eliminated extraneous roots.

Based on the study of the specified plan, it is possible to most fully test schoolchildren's knowledge of theoretical material, the ability to apply it to problem-solving, determining the well-formed cognitive abilities (understanding, formulation, application, analysis, critical thinking, decision-making skills – choosing the appropriate solution), highlight isolated and typical mistakes, draw up a plan for correcting the knowledge acquired by schoolchildren. For example, to implement activity-based of formative assessment, you can offer the following homework.

Task 1. For a warehouse 9 m wide, you need to build a gable roof. The length of one of the slopes is $4.5\sqrt{3}$ m, and the second slope forms 60 m with the horizontal plane of the roof. What should be the angle of the roof ridge and the length of the second slope?

To obtain information about the presence of knowledge gaps in schoolchildren and to assess the knowledge they have acquired and the developed cognitive abilities and behavioural skills of the 21st century, the following educational activities can be distinguished:

1. Construction of a model drawing of the problem under consideration $BC = 9\, m;\ AC = 4.5\sqrt{3}\, m;\ \angle B = 60^0, AB = ?;\ \angle A = ?$ (Figure 1).

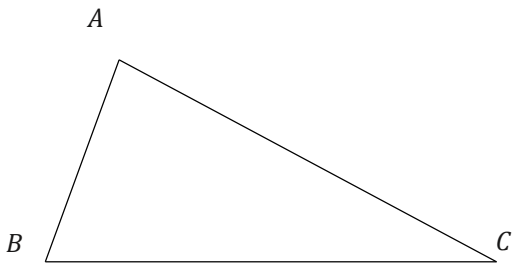

Figure 1. Construction of a model drawing of the problem under consideration

2. Comparison of data and missing components of the problem under consideration: $BC = 9\,m;\ AC = 4.5\sqrt{3}\,m;\ \angle B = 60^0, AB = ?;\ \angle A = ?$.

3. Establishing the relationship of unknown components using data. In this triangle, opposite the side AC lies a known angle $\angle B$, BC lies an unknown angle $\angle A$. Let $\angle A = x$.

4. Establishing the dependencies of the task at hand (using the theorem of sines) in the form of a mathematical object (equation) (8):

$$\frac{9}{\sin x} = \frac{4.5\sqrt{3}}{\sin 60^0}, \qquad (8)$$

from here authors get the equation $\sin x = 1$.

5. Finding a solution to the equation and problem. Therefore, $\angle A = x = 90^0$. $\angle C = 180^0 - (90^0 + 60^0) = 30^0$. Then $AB = \frac{BC}{2} = \frac{9}{2} = 4.5$.

Using an algorithm for solving this problem, it is possible to determine the ability of schoolchildren to apply mathematical knowledge when solving practical problems, and isolating data, identifying missing components, and establishing the pattern of the problem being solved by a student allows one to determine knowledge of theoretical material. An oral discussion of the results of homework provides an opportunity to establish the well-formed cognitive abilities (understanding, formulation, application, analysis, synthesis, creative, critical thinking), and behavioural skills of the 21st century (reflection, value-based attitude towards others).

Activity-based formative assessment can also be implemented during the lesson. For example, a lesson on the topic "The simplest trigonometric equations" can be taught using the "Task Exchange" technique. This technique is implemented through the work of students in dynamic pairs of shift composition and is designed for initial study and problem-solving. For the work of dynamic pairs, the teacher prepares special cards. Each card consists of two problems that are solved using the same method. As an example, here are two tasks from the section "Methods for solving trigonometric equations:

Assignment 1 (9):

$$\begin{aligned} &2\sin^2 x + \sin x = 0, \\ &\cos x - \sin 2x = 0. \end{aligned} \qquad (9)$$

Assignment 2 (10):

$$\begin{aligned} &\sin^2 x + 6\sin x - 16 = 0, \\ &\cos^2 x - 4\cos x + 3 = 0. \end{aligned} \qquad (10)$$

Here the teacher, separately with the first student, works through the algorithm for solving task 1, with the second student, task 2. At the same time, students obtain a solution to a problem of type A) through joint work with the teacher, and problems of type B) are solved by the student independently. In primary classes, the teacher checks the student's justification for solving each problem. Next, you should organize the exchange of tasks between the students of the primary pair. In pairs, students explain to their partner the solution to problem A) from their assignment. Further, the algorithm for working in pairs is the same as when a teacher and student work together. In the next pair, the student must already teach the student from the other pair to solve the problem obtained in the primary pair. This algorithm continues until the student submits solutions to all tasks.

In the process of completing these tasks, you can evaluate the student's educational achievements: the ability to solve the simplest trigonometric equations, and knowledge of the basic methods for solving trigonometric equations. The described methodology allows you to assess the student's cognitive ability, such as observation, comparison, analogy, application, analysis and synthesis, generalization. In particular, when performing these tasks, they develop communicative abilities: to build a dialogue learning algorithm for solving a problem; the ability to answer questions; pose questions to solve the problem; correctly write down the necessary statements and formulas in notebooks; evaluate the educational work of a student partner. When carrying out the activity-based formative assessment, students can also be offered a task to find errors in the algorithm for solving the problem: "Check the correctness of the given solution for the equation $\cos 5x + \cos x = 1 - 2\cos^2 x$".

Solution. Since $\cos 5x + \cos x = 2\cos 3x \cos 2x, 2\cos^2 x = 1 + \cos 2x$, this equation will take the form $2\cos 3x \cos 2x = -\cos 2x$. Let $\cos 2x \neq 0$. Let's divide both sides of the equation by $\cos 2x$. As a result, the authors obtain the equation $\cos 3x = -\frac{1}{2}$. From this equation, authors find a family of solutions $x = \pm\frac{2\pi}{9} + \frac{2\pi k}{3}$. After reflection, students find an error in the solution (this is dividing both sides of the equation by $\cos 2x$), and they are convinced of the loss of the root of $x = \frac{\pi}{4} + \frac{\pi n}{2}$. With the help of such a task, you can test students' knowledge of trigonometric formulas, their ability to carry out identical transformations, solve the simplest trigonometric equations, and determine the well-formed student's skills in critical attitude to the results of completing assignments. Local formative assessment on the topic "The simplest trigonometric equations $\sin x = a,\ \cos x = a$" can be carried out, for example, using a mathematical dictation for 7-10 minutes, consisting of two options, which is a system of tasks related thematically. The dictation text can be written in advance on the back of a regular board, projected onto the board using a projector, or presented using an interactive whiteboard.

The dictation can be checked right here in the class by asking one of the students who wrote the first version to read their answers to the assignments, and then the second version, discussing their correctness. The correct answers must be spoken out loud and written on the board. Each participant in the discussion is then given points on an individual learning map. Discussion of the correctness of the results promotes the development of working memory, and the application of the simplest, fundamental concepts, properties, and provisions of the educational material.

Discussion

In the scientific doctrine, more and more studies are appearing, which prove the priority of the development of cognitive skills in schoolchildren, as a mandatory

requirement of the modern educational process. Thus, C. Lin [25] substantiated the importance of integrating social-emotional learning into the teaching of certain disciplines, particularly mathematics. Accordingly, within the framework of this study, attention was also focused on the specifics of learning and students' mastery of mathematics. The researcher managed to single out the key areas of social-emotional learning that should be integrated into mathematics lessons. These are: creating a favourable emotional climate, developing self-awareness and self-regulation, teaching empathy, and practising attentiveness and cooperation. It should be noted that a negative conclusion was obtained within the framework of this study. In particular, what is common between the articles is the definition of methods and exercises aimed at the implementation of social-emotional learning in mathematics lessons.

C. Lin [25] also managed to develop recommendations for teachers on the effective integration of social-emotional learning into the process of teaching mathematics. In the system of these activities, the researcher included: exercises for recognizing emotions based on mathematical images, group projects with elements of gamification, as well as interactive exercises on empathy using images of geometric shapes. Thus, the results of both studies have in common that they reveal not only methods of forming students' mathematical literacy, but also the development of important life skills, including emotional intelligence, empathy, and cooperation.

The development of students' cognitive activity is a key factor in the formation of their educational competence and life skills. This conclusion was reached by B. Ozcakir and E. Cakiroglu [26], who defined the structure of the cognitive activity of a modern schoolboy, which includes motivational, operational, emotional-volitional, and control-evaluative components. The role and influence of cognitive activity on students' academic performance were also considered within the framework of this study. The researchers revealed the specifics of the development of cognitive activity in mathematics lessons through solving problems, problem situations, and applying research methods. Based on this, the researchers managed to develop a set of methods and techniques for activating students' cognitive activity at various stages of the mathematics lesson, including motivation, assimilation of new knowledge, application, and control. Common to the results of this research is the provision of examples of problem tasks, research projects, and interactive exercises to activate cognitive interest and involve students in active mental activity.

In turn, R. Sugianto et al. [27] conducted his pedagogical experiment on the implementation of his method of cognitive development of students in mathematics lessons. It should be noted that a similar approach was used in this study. The results obtained by the researchers testify to the positive dynamics of the development of all components of cognitive activity in the experimental groups of students compared to the control groups. In this way, the researchers managed to prove the effectiveness of the developed methodology for increasing cognitive interest, mental activity, independence, and creativity of students during mathematics education. The commonality of the results of this study is that both of them offer a well-founded methodology for the development of student's cognitive activity in mathematics lessons, which demonstrates successful results in the course of pedagogical experiments.

Sutama et al. [28] revealed the specifics of the use of problem-based learning technology in mathematics lessons for the development of critical and creative thinking, and cognitive activity of students. The researchers managed to reveal the essence and structure of problem-based learning, its main stages and techniques, in particular, problem-based presentation, partly research activity, and independent research activity. During this study, the principles of problem-based learning were also considered, which, accordingly, is quite common in the process of learning mathematics. The researchers defined the requirements for the selection and construction of problem situations during the presentation of mathematical material. Dolidnyk established that an effective technological model of problem-based learning of mathematics should include the purpose, content, forms, methods, as well as means of learning. Common to both studies are the approach to the formation of specific methodological recommendations for the implementation of the problem-based approach, which varies depending on the stage of the mathematics lesson. In addition, the researchers created an educational and methodological complex necessary for the implementation of problem-based learning technology in mathematics lessons. Thus, common to the results of the research is confirmation of the priority of activation of cognitive activity, and formation of subject and meta-subject competencies of students in mathematics lessons in modern learning conditions.

E. Yayuk et al. [29] studied the issue of the development of cognitive skills in modern schoolchildren from the other side, namely the formation of clip thinking. The researchers established that in modern conditions there is an objective need to rethink traditional approaches to teaching mathematics given the specifics of clip thinking and the peculiarities of the perception of information by students of the 21st century. A similar conclusion was made during this study, namely in the context of determining the characteristic features of clip thinking. These include fragmentation, illogicality, distracted attention, and preference for visual information over textual information. The researchers were able to distinguish the benefits and risks of the clip's perception for students' mastery of mathematics, which are directly related to mathematical thinking. Based on this, the scientists formulated methodological recommendations aimed at reforming teachers' approaches to the construction of mathematics lessons, taking into account the clip-like nature of students' cognitive processes. Common to the results of the research is that the proposed learning techniques and methods are based on such principles as visibility, visualization, multimedia, and fragmentary presentation.

In turn, A. Bicer et al. [30] focused on the expression and analysis of ways of structuring material, types of tasks, and forms of control, taking into account the peculiarities of clip thinking. Based on this, the researchers formed their own selection of interactive online resources, services and software tools for visualizing mathematical material. In

addition, the researchers developed a system of mathematics tasks in the format of clip perception. An important component of his research is conducting a pedagogical experiment using clip technologies in mathematics lessons in experimental groups. As a result, the researchers proved that during the use of the developed methodical support, an increase in motivation, activity and involvement of students in performing mathematics tasks was found. Thus, common to the results obtained in this study is the conclusion about the need to adapt approaches to teaching mathematics to modern cognitive realities, which is possible through the implementation of practical tools to take into account the clip thinking of students.

Based on the above, it should be noted that researchers in their works reveal various methods and tools for assessing the cognitive and behavioural development of schoolchildren. At the same time, they all adhere to the position that the formation of these skills is necessary not only for the acquisition of subject knowledge, in particular in mathematics, but also for the general personal development of the student.

Conclusions

The identified content components of the criteria-based assessment of schoolchildren's educational achievements, along with assessment methods, make it possible to quickly objectively assess the knowledge of schoolchildren, as well as effectively carry out corrective actions in the process of schoolchildren mastering educational material, and determine in schoolchildren's the well-formed of cognitive abilities and behavioural of skills of the 21st century. The results and assessment methods contribute in schoolchildren to the formation and development of motivation, cognitive abilities and behavioural skills of the 21st century.

The results obtained contribute to new research in the field of assessing students' educational achievements and will be useful in drawing up a map of the implementation of criterion-based assessment and the well-formed schoolchildren's thinking skills. Note that the complexity of drawing up criteria and descriptors for schoolchildren to determine their level of mastery of educational materials introduces corresponding difficulties and restrictions in the formation of the student's skills of a critical attitude towards the results of completing his task. Using the described content components of formative assessment, it is possible to determine the target function characterizing the general educational and mental achievements of the student, which is the goal of future research. Therefore, the content components of formative evaluation are: residual, modular, activity, and local evaluation, and the content components of summative evaluation are: final and intermediate evaluation.

The basis of the criteria-based assessment tools for students' educational achievements is the following tools: tasks, problem situations assignments, methods, criteria, assessment descriptors; Expected results; individual learning maps; and tables for recording and correcting student achievements. The developed knowledge of schoolchildren in mathematics was taken as the main factor reflecting the effectiveness of using the identified content components of formative assessment in the learning process. Since the developed mathematical knowledge ensures determine had developed of cognitive abilities in students. In this regard, at the final stage of the study, written work was carried out to establish that schoolchildren from the control (81 students) and experimental (86 students) groups had developed knowledge and skills to solve educational problems.

Calculation of empirical values of Student's t-test showed that $t_{emp} = 3.8$. By determining the $t_{crit} -$ criterion at a given level of significance $\alpha = 0.05$ and the number of degrees of freedom $k = 165$, authors found that $t_{crit} = 3.3$ and $t_{emp} > t_{crit}$. Thus, the authors were convinced that at the final stage of the study, the differences in the distribution of schoolchildren in the experimental and control groups according to the level of development of the ability to solve educational problems were statistically significant. Thus, the identified tools and content components of formative assessment serve several purposes: they allow for the objective evaluation of educational achievements, help in determining developed cognitive abilities and 21st-century behavioural skills, facilitate analysis of educational content, enhance student motivation, and contribute to improving the quality of education. Overall, these aspects aid in fostering the development and enhancement of cognitive abilities and behavioural skills among schoolchildren in the 21st century.

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Conflict of Interest

None.

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Оцінка когнітивного та поведінкового розвитку школярів 21 століття

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Анотація

Актуальність. Вивчення ефективних методів розвитку когнітивних навичок у школярів є надзвичайно актуальним. Це має вирішальне значення для забезпечення їх належної підготовки до викликів сучасного світу, який характеризується швидкими трансформаціями та домінуванням цифрових технологій.

Мета. Метою дослідження є визначення ступеня ефективності підходів до формувального оцінювання розвитку когнітивних навичок у школярів 21 століття.

Методологія. Використано систему методів наукового дослідження, зокрема аналіз, синтез, порівняння, опитування, математичної статистики, спостереження.

Результати. Дослідження показало, що використання результатів залишкового, діяльнісного, локального та модульного оцінювання сприяє підвищенню якості освіти та розвитку комунікативних і рефлексивних здібностей студентів. Наведено модельні приклади поелементного оцінювання завдань для школярів під час формувального оцінювання. Розроблено алгоритм проведення формувального оцінювання протягом одного навчального періоду. Аналіз завдань, виконаних учнями під час формувального оцінювання, показав, що тестові завдання мають бути розроблені по-різному для кожного змістового компонента.

Висновки. Результати, отримані в ході дослідження, доцільно використовувати при розробці методичних матеріалів для вчителів. Ці матеріали мають стосуватися організації навчального процесу та підходів до формувального оцінювання когнітивних умінь школярів.

Ключові слова: підсумкова атестація; навчальні результати; якість навчання; розумові уміння.