# Chapter IV. PROBLEMS OF EDUCATION AND UPBRINGING OF CHILDREN IN EDUCATIONAL INSTITUTIONS OF MOUNTAIN REGIONS

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# ALGORITHMS WITH AN APPEALING OUTCOME AS A MEANS OF ENHANCING MOTIVATION AND QUALITY OF MATHEMATICAL KNOWLEDGE CONSOLIDATION IN GRADES 5-6

**Abstract**. The article examines the problem of maintaining the learning motivation of 5th–6th grade students while performing routine mathematics exercises. The relevance of the study is determined by the need to improve the effectiveness of consolidating mathematical knowledge within the framework of competency-based and activity-oriented approaches in modern education. Repeated completion of similar exercises, which is necessary for developing computational skills and mastering mathematical algorithms, often leads to a decline in students' interest in learning, thereby highlighting the need for new methodological solutions.

The purpose of the study is to provide a theoretical justification for the psychological, pedagogical, and methodological feasibility of using algorithms with appealing outcomes as a means of organizing the consolidation of mathematical knowledge among 5th–6th grade students and to identify the conditions for their effective implementation. To achieve this goal, a set of theoretical research methods was employed, including the analysis, synthesis, and systematization of psychological-pedagogical and methodological literature, comparative analysis of contemporary educational approaches, theoretical modeling of algorithm-based tasks, and instructional design.

The scientific novelty of the study lies in the substantiation and systematization of algorithms with appealing outcomes as a distinct methodological tool for consolidating mathematical knowledge. The proposed approach involves a sequence of mathematical actions that leads students to an aesthetically or intellectually meaningful result in the form of an ornament, drawing, cipher, palindrome, maze, or geometric composition.

The findings indicate that the use of such algorithms contributes to enhancing intrinsic motivation, developing self-monitoring skills, sustaining cognitive interest, and fostering a positive attitude toward mathematics. Examples of algorithms for various topics in the mathematics curriculum for grades 5–6 have been developed and systematized, and the key methodological conditions for their effective application have been identified. The practical significance of the study lies in the creation of a set of ready-to-use algorithm-based exercises that can be employed by mathematics teachers when organizing students' learning activities during the knowledge consolidation stage.

**Keywords**: mathematics teaching methodology, learning motivation, mathematical algorithms, knowledge consolidation, game-based learning, algorithmic learning, aesthetic component of learning.

# АЛГОРИТМИ З ПРИВАБЛИВИМ РЕЗУЛЬТАТОМ ЯК ЗАСІБ ПІДВИЩЕННЯ МОТИВАЦІЇ ТА ЯКОСТІ ЗАКРІПЛЕННЯ МАТЕМАТИЧНИХ ЗНАНЬ УЧНІВ 5-6 КЛАСІВ

**Анотація**. У статті досліджено проблему підтримки навчальної мотивації учнів 5–6 класів під час виконання рутинних вправ з математики. Актуальність дослідження зумовлена необхідністю підвищення ефективності закріплення математичних знань в умовах компетентнісного та діяльнісного підходів сучасної освіти. Багаторазове виконання однотипних вправ, необхідне для формування обчислювальних навичок і засвоєння математичних алгоритмів, часто супроводжується зниженням інтересу до навчання, що актуалізує пошук нових методичних рішень.

Метою дослідження є теоретичне обґрунтування психолого-педагогічної та методичної доцільності використання алгоритмів із привабливим результатом як засобу організації закріплення математичних знань учнів 5–6 класів та визначення умов їх ефективного застосування. Для досягнення мети використано комплекс теоретичних методів дослідження: аналіз, узагальнення та систематизацію психолого-педагогічної і методичної літератури, порівняльний аналіз сучасних освітніх підходів, теоретичне моделювання алгоритмізованих завдань та педагогічне проєктування.

Наукова новизна дослідження полягає в обґрунтуванні та систематизації алгоритмів із привабливим результатом як окремого методичного засобу закріплення математичних знань. Запропоновано підхід, за якого виконання послідовності математичних дій приводить учня до отримання естетично або інтелектуально значущого результату у вигляді орнаменту, малюнка, шифру, паліндрому, лабіринту чи геометричної композиції.

У результаті дослідження встановлено, що використання таких алгоритмів сприяє підвищенню внутрішньої мотивації, розвитку навичок самоконтролю, підтримці пізнавального інтересу та позитивного ставлення до математики. Розроблено та систематизовано приклади алгоритмів для різних тем курсу математики 5–6 класів і визначено основні методичні умови їх ефективного застосування. Практична значущість роботи полягає у створенні комплексу готових алгоритмізованих вправ, придатних для використання вчителями математики під час організації навчальної діяльності учнів на етапі закріплення знань.

**Ключові слова**: методика навчання математики, навчальна мотивація, математичні алгоритми, закріплення знань, ігрове навчання, алгоритмізація навчання, естетичний компонент навчання.

**INTRODUCTION**

**The problem formulation.** Modern mathematics education is aimed not only at developing subject knowledge and skills but also at fostering students' intrinsic motivation to learn, their ability for independent thinking, reflection, and application of knowledge in various life situations (Ministerstvo osvity i nauky Ukrainy, 2016). This issue becomes particularly relevant for students in grades 5–6, who are transitioning from primary to lower secondary education. At this stage, a significant portion of mathematical content requires systematic consolidation through numerous practice exercises aimed at developing stable computational skills and mastering problem-solving algorithms (Sliepkan, 2006; Burda et al., 2015).

At the same time, educational practice shows that performing a series of similar exercises is often accompanied by a decline in students' cognitive interest, attention, and learning motivation. The routine nature of such activities frequently leads to the mechanical execution of actions without understanding their meaning and significance, which negatively affects both the quality of learning outcomes and students' attitudes toward mathematics in general. Therefore, there is a growing need for methodological solutions that combine the necessity of practicing mathematical skills with maintaining interest, emotional engagement, and a positive learning experience.

One promising way to address this issue is the use of algorithms with appealing outcomes, where the execution of a sequence of mathematical actions leads students to an aesthetically or intellectually meaningful result in the form of a drawing, ornament, cipher, symmetrical figure, palindrome, or numerical pattern. In such cases, practice activities acquire additional meaning for students, while the final result performs not only a motivational but also a control function, enabling learners to identify mistakes independently and evaluate the correctness of their work.

The scientific novelty of the study lies in the theoretical substantiation of an approach to organizing the consolidation of mathematical knowledge through algorithm-based exercises with appealing outcomes and in the systematization of examples of their application for various topics in the mathematics curriculum for grades 5–6. The practical significance of the study lies in the development of methodological recommendations and a set of algorithms that can be directly used by mathematics teachers when organizing students' learning activities during the knowledge consolidation stage.

**Analysis of recent research and publications**. The problem of developing learning motivation and improving the effectiveness of mathematics education remains the focus of attention of both Ukrainian and international researchers. The methodological foundations of mathematics teaching, the organization of students' mathematical activities, and the implementation of the competency-based approach have been discussed in the works of Z. I. Sliepkan (Sliepkan, 2006), as well as in the collective work of Ukrainian scholars on competency-based mathematics teaching methodology (Burda et al., 2015).

An important contribution to understanding the mechanisms of learning motivation is provided by Self-Determination Theory, according to which effective learning is ensured through satisfying learners' needs for autonomy, competence, and social relatedness (Tadieieva, 2012). The role of self-regulation and intrinsic motivation in education is also emphasized by Kolchyhina A., and Zaitseva O. (2021), who consider motivation to be one of the key factors determining successful learning.

Contemporary international educational research pays considerable attention to the concept of productive struggle, which involves engaging students in solving manageable intellectual challenges and viewing mistakes as an important resource for cognitive development (Hiebert & Grouws, 2007). These ideas were further developed by Russo J. et al. (Russo et al., 2022), who demonstrated that overcoming challenges consciously contributes to a deeper understanding of mathematical content and enhances learning motivation.

Particular interest in recent years has been directed toward game-based approaches in mathematics education. The meta-analysis conducted by Tokac U. et al. (Tokac et al., 2019) demonstrated a positive impact of game-based learning on students' mathematics achievement. Similar conclusions were reached by Vankъlъ P. (Vankъlъ, 2021), whose systematic review showed positive effects of educational games on students' motivation, engagement, and emotional attitudes toward learning. Recent review studies confirm these findings. Pan Y. et al. (Pan et al., 2022) highlighted the considerable potential of educational games for increasing students' interest in mathematics, while Hui H. et al. (Hui et al., 2023) demonstrated the positive influence of game-based learning on both cognitive and affective learning outcomes. Similarly, Troussas C. et al. (Troussas et al., 2023) showed the effectiveness of combining gamification elements with adaptive learning, whereas Sбnchez-Cruzado C. et al. (Sбnchez-Cruzado et al., 2024) emphasized the role of digital game-based environments in supporting students' motivation and persistence in learning mathematics.

An important aspect of this study is the aesthetic dimension of mathematical activity. According to Sinclair N. (Sinclair, 2004), aesthetic experiences can serve not only as a consequence of mathematical understanding but also as an independent factor stimulating cognitive activity. This perspective makes it possible to consider an appealing outcome as a means of maintaining students' interest in learning and encouraging perseverance in completing educational tasks.

In recent years, the Ukrainian educational context has also witnessed growing interest in innovative technologies and activity-based approaches to teaching. Nedilskyi S. (Nedilskyi, 2025) emphasizes the significant potential of digital technologies as a means of modernizing the educational process, while Hainiuk I. (Hainiuk, 2025) highlights the importance of integrating creative, research-oriented, and practice-based forms of activity within STEM education.

Slyvka L. (Slyvka, 2025) additionally confirms the effectiveness of content-rich and motivationally attractive educational constructs for enhancing learners' educational activity.

The analysis of scientific sources indicates that issues of learning motivation, productive mathematical activity, and the use of game-based technologies are widely represented in contemporary research. However, the use of algorithms with appealing outcomes as a specific methodological tool for organizing the consolidation of mathematical knowledge among students in grades 5–6 remains insufficiently explored. This circumstance determines both the relevance and the necessity of the present study.

**AIM AND TASKS OF THE RESEARCH**

The purpose of the study is to provide a theoretical justification for the psychological, pedagogical, and methodological feasibility of using algorithms with appealing outcomes as a means of organizing the consolidation of mathematical knowledge among students in grades 5–6, to develop and systematize corresponding algorithm-based exercises, and to determine the conditions for their effective implementation in mathematics lessons.

In accordance with this purpose, the following research objectives were formulated:

1. To analyze the problem of student motivation during the performance of routine mathematics practice exercises in grades 5–6.
2. To reveal the psychological and pedagogical foundations of organizing knowledge consolidation through algorithms with appealing outcomes, drawing on Self-Determination Theory, the concept of the New Ukrainian School, and game-based learning.
3. To determine the role of the aesthetic component in mathematical practice activities and its influence on learning motivation and persistence.
4. To develop and systematize examples of algorithms with appealing outcomes for various topics in the mathematics curriculum for grades 5–6.
5. To formulate methodological conditions for the effective use of algorithm-based exercises with appealing outcomes in mathematics lessons in grades 5–6.
6. To identify possible risks associated with the proposed approach and outline ways of overcoming them through methodological support.

**RESEARCH METHODS**

To achieve the stated purpose, a set of theoretical research methods was employed, including the analysis and synthesis of psychological-pedagogical and methodological literature on motivation in mathematics learning; comparative analysis of scientific approaches to knowledge consolidation; theoretical modeling of algorithms with appealing outcomes for various topics in the mathematics curriculum for grades 5–6; instructional design of educational tasks; and the systematization and generalization of research findings.

**RESULTS OF THE RESEARCH**

As a result of the theoretical study, the feasibility of using algorithms with appealing outcomes as a means of organizing the consolidation of mathematical knowledge among students in grades 5–6 was substantiated. It was established that combining routine mathematical actions with the achievement of an aesthetically or intellectually meaningful result creates additional motivational incentives for completing educational tasks and contributes to sustaining students' interest in mathematics.

It was shown that the psychological and pedagogical foundation of the proposed approach is based on the principles of Self-Determination Theory concerning the importance of intrinsic motivation in learning, the concept of productive struggle, which involves overcoming manageable intellectual challenges, and contemporary approaches to game-based and activity-based learning. The appealing outcome of an algorithm serves as both an intermediate and final goal of activity, increasing students' engagement in mathematical exercises and fostering a positive emotional attitude toward learning.

Theoretical analysis made it possible to determine that the use of algorithm-based exercises with appealing outcomes potentially provides:

- increased intrinsic motivation to perform mathematics practice tasks;
- enhanced attention and responsibility during the execution of individual algorithmic steps;
- development of self-monitoring and self-assessment skills through an embedded feedback mechanism;
- improved emotional perception of mathematics through the combination of logical and aesthetic components of learning activities;
- preservation of the full mathematical content of exercises without replacing educational goals with entertainment.

The proposed approach is consistent with the key principles of the New Ukrainian School Concept (Ministerstvo osvity i nauky Ukrainy, 2016), particularly competency-based, activity-based, and learner-centered approaches. In this framework, students act not as passive performers of isolated exercises but as active participants who, through the sequential execution of mathematical actions, create an intellectual or visual product that serves both as the outcome of a mathematical algorithm and as a means of self-checking the correctness of completed actions.

Within the study, examples of algorithms were developed and systematized for various topics in the mathematics curriculum for grades 5–6, including "Addition of Multi-Digit Numbers," "Factors and Multiples," "Coordinate Plane," "Fraction Reduction," "Operations with Decimal Fractions," "Percentages," "Linear Equations with One Variable," "Line Segment and Midpoint of a Segment," and "Angle Measurement and Construction." For each topic, algorithms were

proposed that combine the practice of specific mathematical skills with obtaining an appealing outcome in the form of a palindrome, maze, cipher, ornament, geometric composition, or visual image.

The analysis of the developed algorithms made it possible to identify several types of appealing outcomes:

- ***numerical*** (palindrome);
- ***quest-based*** (maze);
- ***graphic*** (drawing);
- ***ornamental*** (pattern or ornament);
- ***linguistic*** (word decoding or encryption);
- ***exploratory*** (research-oriented result).

The proposed classification is not exhaustive and may be expanded depending on the content of the educational material and the age characteristics of students.

The developed algorithms demonstrate that routine mathematical exercises can be transformed into meaningful and engaging activities without reducing the educational value of the mathematical content. In this way, the attractive outcome becomes not an end in itself but a pedagogical tool for increasing students' motivation, engagement, and persistence in learning mathematics.

***Examples of algorithms for various mathematics topics in grades 5–6***

I. Topic: "***Addition of multi-digit numbers***" (grade 5).

Algorithm: ***"The palindrome hunter"***

1. Select a natural number (a two-digit or three-digit number).
2. Write down the number formed by reversing the order of its digits.
3. Add both numbers together.
4. If the resulting sum is a palindrome, terminate the algorithm.
5. If not, repeat the procedure with the newly obtained number.

Example: 48+84=132, 132+231=363.

Routine operations: writing a number in reverse order; column addition (written addition); palindrome verification.

Aesthetic outcome: A visually appealing, symmetrical number.

II. Topic: ***"Divisors and multiples"*** (Grade 5).

Algorithm: ***"The Divisor Labyrinth"***

1. There are several numbers on the sheet that need to be connected with arrows (Fig. 1).
2. The task begins from a given starting number.
3. Transitions can only be made to a number that is a divisor of the current number.
4. Subsequently, move to a divisor of the new number.
5. The objective is to reach the number 1 via the shortest path.

Legend: a black arrow indicates a possible transition; a green arrow denotes the correct path.

Routine operations: divisibility checks; finding divisors; attentiveness.

Aesthetic outcome: Navigating the numerical labyrinth successfully.

III. Topic: ***"The Coordinate Plane"*** (Grade 6).

Algorithm: ***"The secret drawing by two traits"***

On a worksheet with a printed coordinate plane template:

1. Plot the given points (Fig. 2).

2. If the sum of the coordinates is even, connect the point to the previous one with a solid line; if odd, use a dashed line.

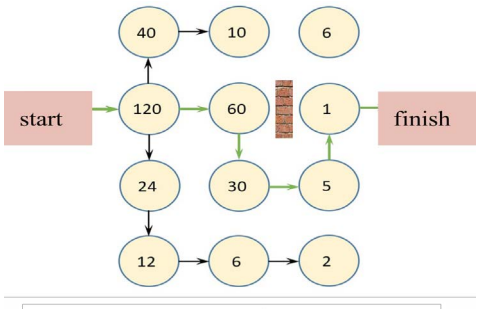



*Fig. 1.*

| (x; y) | |
|---|---|
| (0; -2) | (-4,5; -4,5) |
| (-6; -4) | (-5; -6) |
| (-6; -8) | (-3; -6) |
| (-1; -7) | (0; -1) |
| (0; -2) | (-8; -1) |
| (-8; -2) | (-8; 5) |
| (-10; 0) | (-4; 5) |
| (-10; 8) | (0; -1) |
| (-9; 7) | (-7; 2) |
| (-5; 7) | (-5; 4) |
| (-2; 6) | (0; -1) |
| (0; 2) | (0; -4) |
| (0; -2) | (0; 4) |
| | (-1; 8) |
| | (-2; 9) |

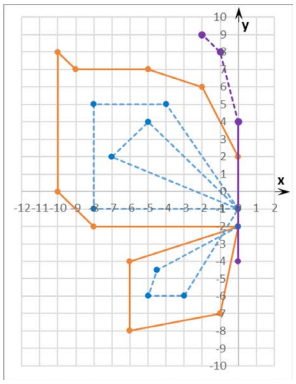



*Fig. 2.*

Skills developed: plotting points on a plane; calculating the sum of numbers; attentiveness.

Aesthetic outcome: The exact same set of points can yield not only the outline of a shape but also an intricate internal pattern.

IV. Topic: ***"Reduction of fractions"*** (Grade 5).

Algorithm: "***The Fractional Pattern"***
Students are presented with a set of fractions arranged in a circle (Fig. 3).
1. Reduce each fraction to its simplest form and determine its value.
2. Record the resulting fractions in the table cells in ascending order of their values (from smallest to largest).
3. Color each fraction according to its specific fractional value:

- from 0 to 0.24– red;
- from 0,25 to 0,49 – yellow;
- 0,5 – green;
- from 0,51 to 0,75 – orange;
- from 0,76 to 1 – black.

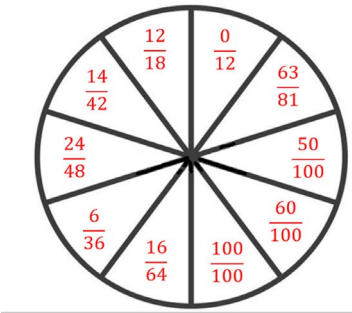



*Fig. 3.*

4. Compare the resulting sequence of colors with the pattern of a traditional Hutsul carpet. If all calculations have been performed correctly, you will obtain a characteristic color stripe:



Skills developed: reducing fractions, comparing and ordering fractions, converting fractions into decimals, mapping numerical intervals to specific colors.
Aesthetic outcome: A vibrant mathematical ornament that reflects the ethnic motifs of traditional Hutsul carpets (Fig. 4)



*Fig. 4.*

V. Topic: ***"Arithmetic operations with decimals"*** (Grade 5).
Algorithm: ***"Decode the word"***
Each letter of the alphabet corresponds to a specific number.
The worksheets present sample tasks involving operations with decimals (Fig. 5).

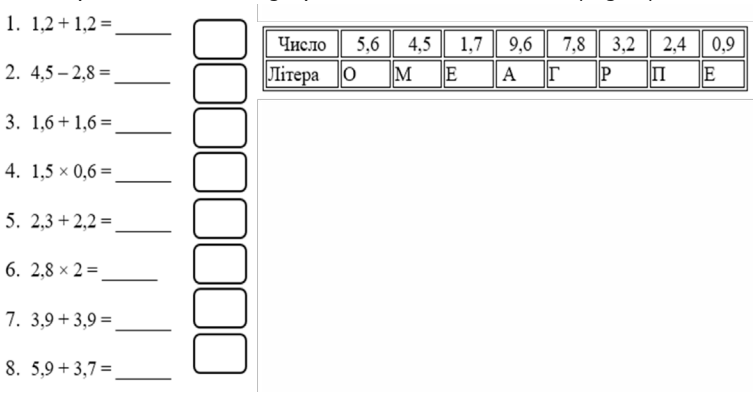



*Fig. 5.*

Upon performing the operations, each correct result is mapped to a specific letter according to a pre-defined conversion table.
The letters are then assembled to form a word or a phrase.
Skills developed: addition, subtraction, and multiplication of decimals; computational attentiveness.
Aesthetic outcome: The process culminates in the disclosure of a word, a motto, or a proverb.
VI. Topic: ***"Percentages"*** (Grade 5).
Algorithm: ***"The financial detective"***
1. The student is given an initial monetary amount.
2. Subsequently, the student sequentially performs the following operations:

an increase of 10%,
a decrease of 20%,
an increase of 25%,
a decrease of 10%.

3. Consecutively, the following questions must be answered:
Has the amount increased or decreased?
By how much (both in monetary terms and as a percentage)?
Could this outcome have been predicted?
Skills developed: percentages; working with multipliers such as (1,1), (0,8), (1,25), (0,9).
Aesthetic outcome: Students discover that a 20% increase ("+20%") and a 20% decrease ("-20%") do not mutually cancel each other out.

VII. Topic: ***"Linear equations in one variable"*** (Grade 6).
Algorithm: ***"The equation labyrinth"***

1. The root of a correctly solved equation indicates the number of the subsequent equation.
2. If the solutions are correct, the student navigates through the labyrinth and reaches the "exit" (Fig. 6).

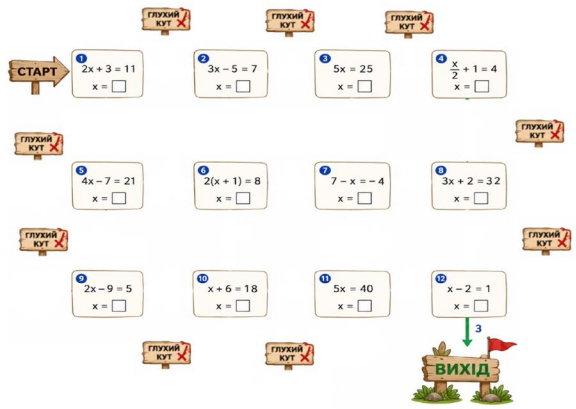



*Fig. 6.*

3. If an error is made at any stage, the path leads to a dead end.
Correct path: 1 → 4 → 6 → 3 → 5 → 7 → 11 → 8 → 10 → 12.
Skills developed: solving equations; verification (checking solutions); attentiveness.
Aesthetic outcome: The exercise is transformed into an immersive educational quest.

VIII. Topic: ***"The line segment and its midpoint"*** (Grade 5).
Algorithm: ***"Geometric ornament from midpoints"***

1. Construct a square.
2. Mark the midpoints of all its sides.
3. Connect these midpoints (Fig. 7).

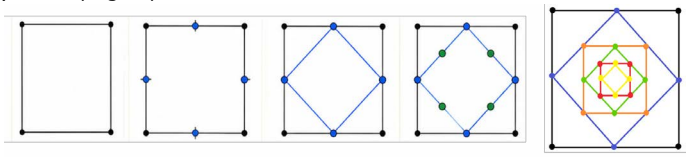


*Fig. 7.*

4. Within the newly formed square, find the midpoints of the sides again.
5. Repeat steps 3 and 4 three to four times.
6. Color the resulting figure as desired.
Routine operations: drafting (drawing); finding the midpoint; drawing line segments.
Aesthetic outcome: A regular geometric ornament.

IX. Topic: ***"Angle measure. Measuring and constructing angles"*** (Grade 5).
Algorithm: ***"The angle mosaic"***

1. The student is provided with two grids: one containing drawings and another blank grid of the same dimensions (Fig. 8).
2. In each cell of the diagram, the student measures the unknown angle using a protractor.
3. Based on the measurements:
if the angle is less than 60°, the corresponding cell of the blank grid is colored yellow;

if it is from 60° to 90°, the cell is colored green;
if it is greater than 90°, the cell is colored blue.

4. Once all cells are colored, a distinct ornament emerges.

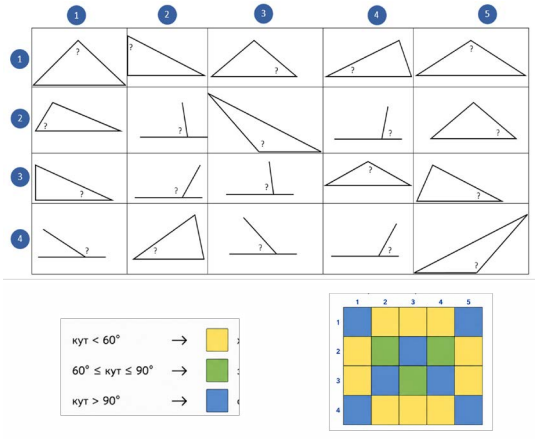



*Fig. 8.*

Routine operations: measuring angles.

Aesthetic outcome: A vibrant, multicolored geometric mosaic.

***Methodological Conditions for Effectiveness***

For algorithm-based knowledge consolidation with an appealing outcome to fulfill its didactic function, several methodological conditions must be met.

The first condition is the ***transparency of the mathematical objective***. Students should clearly understand which skill they are practicing, which rule they are applying, and why the algorithm is mathematically valid. Otherwise, the activity risks becoming a game for the sake of the game itself.

The second condition is the ***step-by-step nature and clarity of instructions***. Algorithms designed for students in grades 5–6 should be transparent, consistent, and free from excessive conditions or cognitive overload.

The third condition is the ***attainability of the outcome within a lesson***. If the final result is too distant, the motivational effect weakens. Students should perceive a realistic opportunity to achieve the expected outcome within a relatively short period of time.

The fourth condition is the inclusion of a ***reflective conclusion***. After completing the algorithm, it is advisable to conduct a brief discussion addressing which mathematical rule was applied, where mistakes could have occurred, and why a particular result was obtained. This prevents the activity from being reduced to merely “reaching” an attractive final product.

The fifth condition is ***differentiation***. The same algorithm can be easily adapted to different levels of difficulty by varying the number of steps, the size of numbers, the complexity of constructions, or the inclusion of intermediate verification tasks.

An objective analysis of the proposed approach requires acknowledging potential risks. First, there is a danger of excessive emphasis on entertainment: if the attractive outcome completely overshadows the mathematical work, students may remember the picture but not the underlying mathematical rule. This risk can be mitigated through reflective discussion and follow-up questions after completing the task. Second, overly complex ciphers or overloaded instructions may distract students from the educational objective. This can be addressed by strictly adhering to the principle of cognitive accessibility. Third, not all students feel equally comfortable working with visual or multi-step algorithms, which necessitates differentiated versions of the same activity. This challenge can be overcome by developing several levels of complexity for each algorithm.

**CONCLUSIONS AND PROSPECTS OF FURTHER RESEARCH**

The study theoretically substantiated the feasibility of using algorithms with appealing outcomes as a means of enhancing motivation and improving the effectiveness of consolidating mathematical knowledge among students in grades 5–6. The analysis of psychological-pedagogical and methodological literature demonstrated that combining routine mathematical exercises with aesthetically or intellectually meaningful outcomes is consistent with the principles of Self-Determination Theory, the concept of productive struggle, activity-based learning, and contemporary game-based learning approaches.

It was established that algorithms with appealing outcomes perform not only a motivational but also a didactic function, as they contribute to increasing students’ attention, developing self-monitoring skills, encouraging the conscious execution of mathematical actions, and fostering a positive emotional attitude toward mathematics learning. At the same time, the appealing outcome serves as an additional incentive to complete the task and as a mechanism for verifying the correctness of completed actions.

Within the study, examples of algorithm-based exercises were developed and systematized for various topics in the mathematics curriculum for grades 5–6. These examples demonstrate the practical applicability of the proposed approach in teaching arithmetic, algebraic, and geometric content. The findings show that such algorithms make it possible to preserve the full mathematical content of learning activities without replacing educational objectives with entertainment elements.

The methodological conditions for the effective implementation of algorithms with appealing outcomes were formulated, and potential risks associated with the approach were identified together with strategies for minimizing them.

Prospects for further research include conducting pedagogical experiments to evaluate the impact of algorithms with appealing outcomes on students' learning motivation, cognitive engagement, and academic achievement in lower secondary school; developing digital and interactive versions of such algorithms using modern educational technologies; creating systems of algorithm-based exercises for other sections of the school mathematics curriculum; and investigating possibilities for integrating this approach into STEM education and interdisciplinary learning.

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