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METHODOLOGICAL APPROACHES TO OVERCOMING LEARNING LOSSES IN THE TOPIC "LOGARITHMIC FUNCTION" THROUGH INTERACTIVE LEARNING TOOLS

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The article analyzes methodological approaches to overcoming students' learning losses in the topic "Logarithmic Function" through interactive learning tools. In the context of the pandemic, remote and blended learning, as well as war and constant stress, there has been a significant decline in students' motivation and knowledge, especially in mathematics, where the abstractness of concepts complicates the process of mastering the material. The literature review highlights considerable learning losses in understanding logarithmic functions, difficulties in grasping the definition of logarithms, graphical interpretation of functions, and applying knowledge to practical problems. Traditional teaching methods are insufficient to overcome these losses. The aim of the study is to develop a unified system and methodological recommendations to address learning losses through the use of interactive technologies. A comprehensive approach is proposed, combining knowledge diagnostics, identification of typical learning losses, construction of individual learning trajectories, use of interactive technologies and digital tools (GeoGebra, PhET, Google Forms, AhaSlides), problem-based and case tasks, differentiated reinforcement, self-analysis, and reflection. The use of interactive technologies promotes increased engagement and motivation, development of logical thinking, and the formation of practical skills in applying logarithms. The developed model allows consideration of students' individual needs and the creation of adaptive learning trajectories. Further research involves experimental verification of the effectiveness of interactive technologies in reducing learning losses and improving learning outcomes in the topic "Logarithmic Function." The proposed approaches can also be adapted for other abstract mathematical topics, increasing their universality and practical value for pedagogical practice

Keywords: *learning losses, logarithmic function, interactive learning, differentiation, adaptive learning, interactive technologies, digital technologies, function graphs, practical problems, reflection*

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1. Introduction

In 2025, the education system continues to be influenced by various factors that contribute to learning loss. The pandemic, remote and blended learning, war, constant stress, and limited access to quality education have all led to a decline in students' motivation and academic performance [1].

These problems are evident across all educational areas and subjects, especially in mathematics, where new concepts, unfamiliar terminology, and stress related to upcoming exams (such as entrance interviews or the National Multidisciplinary Test) pose significant challenges.

Traditional approaches, based on cognitive activity and classical teaching models, fail to ensure the expected level of understanding and retention of material [2]. These substantial learning losses lead to poor comprehension of various topics, especially the "Logarithmic Function," which has broad practical applications [3].

These challenges pose a fundamental question for educators: *"What tools/methods/resources should be used to stimulate student learning and overcome learning losses?"*

2. Literature Review

Researchers, such as Michael Frketic A [4], Donnelly R., Patrinos H. A. [5], Díaz-Berrios T., Martínez-Planell R. [6], and Lukyanova S. M. [1], have highlighted significant learning losses in students' understanding of the topic "Logarithmic Function." However, methodological approaches based on interactive learning remain under-researched.

In [4], the authors identified difficulties students face in learning the "Logarithmic Function" but emphasized the lack of studies, focused on improving instruction of this topic or addressing specific student difficulties and corresponding strategies.

In [5], Donnelly and Patrinos explored the issue of student learning losses, caused by school closures during the COVID-19 pandemic. Their research revealed a decline in knowledge and motivation due to disruptions and the transition from traditional to remote or blended learning. Key challenges included lower academic performance, lack of tools to address learning losses, and a shortage of comprehensive studies to evaluate the problem fully. They concluded that the pandemic introduced new challenges in education that require further research and the development of appropriate tools.

In [6], the authors investigated through the APOS theory how high school students understand exponential and logarithmic functions. They identified difficulties with the concept of logarithms, noting that traditional instruction often focuses on algorithmic procedures rather than applied meaning and conceptual understanding. The proposed “genetic decomposition” method requires further study for effectiveness and adaptation.

In [1], Lukyanova S. and Filon L. studied the impact of prolonged remote learning during the COVID-19 pandemic and the subsequent challenges, caused by the Russian aggression. The authors noted that state-proposed measures were not fully implemented due to insufficient resources and support for teachers. This highlights the need for effective pedagogical tools to overcome learning losses. They also suggest using intra-subject connections to build a unified system of mathematical knowledge and overcome fragmented learning. However, they point to the necessity of further research into the methodology of forming and applying such connections and evaluating its effectiveness.

In conclusion, the modern education system is continuously facing new challenges and requires a flexible structure to support student adaptation and prevent learning losses.

Additionally, students face difficulties with understanding the logarithmic function due to its abstract nature. There is a need for methodologies that can address this issue.

3. Research aims and objectives

The aim of our study is to design and justify an effective system with methodological recommendations for overcoming students' learning losses on the topic of “Logarithmic Function” through the implementation of interactive learning tools.

To achieve the goal, the following tasks were set:

1. Analyze the learning losses in the topic "Logarithmic Function" and identify the challenges, faced by students and teachers.
2. Develop methodological recommendations for using interactive tools to overcome common student difficulties in this topic.
3. Summarize the research findings and provide practical guidance for mathematics teachers on organizing interactive learning for the topic "Logarithmic Function."

4. Materials and Methods

This study employed the following methods: analysis of scientific, methodological, and educational literature; synthesis; comparison; systematization; generalization; and modeling.

The didactic basis of the model includes textbooks, author-developed interactive exercises and presentations, ICT tools, modern educational resources, interactive platforms, and services.

The research relied on educational materials, such as the current curriculum and technical tools like PhET, GeoGebra, Google Forms, AhaSlides, and artificial intelligence tools.

5. Research Results and Discussion

Based on the literature analysis and existing issues in the education system, we can identify the main problems students face in understanding the concept of the "Logarithmic Function":

1. Abstractness of the Logarithm Concept.

The lack of students’ understanding of this concept is documented in [7, 8]. According to a report by the Ukrainian Center for Educational Quality Assessment (UCEQA), most students poorly understand logarithmic properties and cannot apply theoretical knowledge in practice. Fewer than 25% of test-takers correctly solved problems involving evaluating logarithmic expressions, even when the answer was a simple integer [8].

2. Difficulties with Graph Construction and Interpretation.

Although the research in the field of physics demonstrates that students struggle with graphical interpretations of mathematical expressions, these findings are comparable in mathematics, particularly in interpreting logarithmic function graphs [9].

3. Lack of Practical Applications.

Due to abstract problems in chemistry or physics (e.g., sound measurement), it is essential to use applied problems and practical case studies to show the real-world use of logarithms [10].

This analysis reveals a decline in the quality of education, a lack of feedback (teacher-student-parent communication), excessive theoretical instruction, and reduced learning motivation. According to N. Kreydun [11], major factors contributing to learning losses include low digital competence, unstable communication in digital environments, and reduced motivation due to new teaching and interaction formats.

We propose using existing interactive technologies and integrating them into a unified system to overcome learning losses and improve student motivation.

Interactive technologies can be integrated into the learning process to enhance cognitive activity and engage students as active participants [12]. These technologies are based on collaboration, communication, inquiry-based learning, reflection, and various forms of interaction, increasing student involvement [13].

Based on practical experience teaching mathematics at School No. 190 in Kyiv, the following advantages of using interactive technologies in teaching the “Logarithmic Function” were identified:

1. Engaging students in independent research of logarithms and their properties through interactive apps and ICT tools.
2. Enhancing comparison and analysis skills, as well as logical thinking, through visualization and transformation of logarithmic functions.
3. Increasing motivation through project- and research-based approaches.
4. Individualization and differentiation of the learning process according to students’ needs.

In order to develop a unified educational system that overcomes learning losses when teaching the “Logarithmic Function”, we propose that the initial phase should involve selecting an appropriate platform to serve as a comprehensive repository for all educational materials – this could be a website, Google Classroom, chatbot, or another option. Selection should be based on criteria, such as usability, accessibility, clarity, and available features.

Each such service has its own advantages and disadvantages that need to be investigated before platform selection."

Once a platform is selected, populate it with relevant materials. These may include:

1. Problem-based tasks:

Using PhET [14] and real-world problems to show the practical use of logarithmic functions and engage students.

2. Digital tools and online resources:

Platforms like GeoGebra and Desmos can help visualize and manipulate the logarithmic function, supporting deeper understanding of its properties and limitations.

3. Project-based research:

Such tasks promote cognitive and analytical skills. However, they should be limited to maintain the focus on learning objectives.

4. Case-study method:

Encourages students to analyze and model real-life situations, such as pH level calculation or complex financial calculations, to apply mathematical tools in context.

5. Reflection and self-assessment:

Teachers can introduce learning journals, mind maps, self-analysis cards, and other tools to detect learning gaps and foster responsibility in students.

We propose a **comprehensive algorithm** for overcoming learning losses in the topic *"Logarithmic Function"*:

Systematic Diagnostic and Lesson Design Using Interactive Tools

1. Systematic diagnostics of students’ knowledge level on the topic through testing or surveys. Tools: Kahoot!, Classtime, Google Forms, ClassMarker.

2. Identifying typical structures of learning losses and developing individual or group learning trajectories to overcome them. Determine the level of learning losses, choose the type (individual, group, adaptive), and select tools for overcoming.

3. Develop interactive lessons using digital and interactive tools.

4. Engage students in various types of learning activities, considering their individual learning styles (based on the VARK model).

5. Regularly monitor students’ academic progress, maintain open communication, and provide support when necessary.

6. Encourage self-assessment and reflection among students.

Let us present an example of a lesson on the topic “Logarithmic Function”, which integrates the diagnosis of learning losses, the development of an individual learning trajectory, and the use of interactive technologies.

Artificial intelligence (AI) [15] can be used to design such a lesson; however, the AI-generated lesson plan should be carefully reviewed and edited to ensure it aligns with the specific objectives of the lesson.

Objective:

To overcome learning losses related to students’ understanding of the logarithmic function, its properties, and graph construction.

1. Knowledge Diagnostics

Start the lesson by diagnosing what material students are struggling with. Use platforms, such as **Kahoot!**, **Google Forms**, or **Classtime**. Design diagnostic test questions based on previously covered material.

Sample question: *Determine the domain of the function*

$$y-\log_{0.5}\left(x-2\right).$$

2. Identifying Learning Losses. Types and Building Trajectories

After testing, analyze errors and identify typical patterns:

– Individual losses

– Group losses

– Adaptive needs

3. Interactive Explanation

Depending on the type of error, choose appropriate tools.

For example, use **GeoGebra** to explore graphs of $y=\log_a x$ for different bases a ($\alpha > 1$ and $0 < \alpha < 1$). Allow students to manipulate parameters and observe changes in the graph.

Guiding question:

What determines whether the graph of a logarithmic function is increasing or decreasing?

4. Practical Work (15 minutes)

Use problems from the textbook. Solve typical tasks, ask guiding questions, and engage students in discussion.

5. Differentiated Practice

– Visual learners (V): Work with graphs in interactive tools.

– Auditory learners (A): Explain graphing algorithms in pairs.

– Kinesthetic learners (K): Draw graphs on paper and demonstrate changes physically.

– Read/write learners (R): Take notes on function properties and write mini-guides.

Adaptive Tasks (Google Forms or LearningApps):

– Level A (high learning losses): Determine domain, substitute values.

– Level B (moderate losses): Graph $y=\log_3\left(x+2\right)$, simplify expressions like $\log_2\left(8x^3\right)+\left(4x^2\right)$,

– Level C (low losses): Solve equations like $\log_2\left(x^2-3x\right)=1$.

6. Ongoing Monitoring and Support

Continuously observe students’ progress, provide individual or group assistance, and document achievements in real time. Maintain active communication throughout the lesson.

7. Reflection and Self-assessment (5 minutes)

Use **AhaSlides** to create a word cloud around the prompt:

– *"What did I learn today?"*

– *"Three new skills I gained today."*

This helps assess overall class progress and identify which content was best understood and which needs more attention.

Homework

Ask students to:

– Build 3–4 logarithmic function graphs with different bases using **GeoGebra**.

– Solve 5 problems applying logarithmic properties.

Or provide personalized homework based on the learning loss level:

– Low losses: A few complex graph-related tasks.

– Moderate losses: Problems on properties and logarithmic equations.

– High losses: Watch an explanatory video and solve 5 basic examples.

Note: Since the lesson plan was developed with the support of AI tools, we recommend aligning the selected tasks with the national curriculum and lesson objectives. While AI can streamline lesson preparation, it is important to critically review its outputs. When prompting AI, include specifics like the textbook, curriculum, and desired task types. A well-structured and clear prompt greatly improves the quality of the AI's output.

Since the practical testing was conducted using a specific educational institution as an example, our study limits the possibility of generalizing conclusions to a broader contingent of students. Our research is limited by:

1. Technical infrastructure of educational institutions and teachers' level of digital literacy, as these factors may vary significantly across different schools.

2. External factors, such as power outages, air raid alerts, stress, and the overall situation in the region where the school is located. These factors have a substantial impact on students' learning activities and may distort research results.

3. Artificial Intelligence: Although AI can significantly reduce lesson preparation time, the content it generates must be carefully reviewed for validity, alignment with national educational standards, curriculum requirements, and the age appropriateness of learners.

Future research on the topic "Methodological Approaches to Overcoming Learning Losses in the Topic 'Logarithmic Function' Through Interactive Learning Tools" should include experimental studies to determine the impact of interactive technologies on addressing specific types of learning losses—particularly gaps in understanding the properties of logarithms, constructing and analyzing graphs, and solving applied problems. It would also be appropriate to expand the sample (to include different types of educational institutions) and explore the impact of interactive learning tools on the development of critical thinking and the ability to apply acquired knowledge.

6. Conclusions

1. Based on a literature review and practical experience, it was found that the issue of learning losses in the topic "Logarithmic Function" is becoming more acute. These losses are associated with difficulties in understanding the properties of logarithms and their applications; interpreting the graph of the logarithmic function and its practical use; low student motivation, which leads to knowledge gaps; and a low level of digital competence.

2. We propose the use of:

– Visualization tools (GeoGebra, Desmos, and others) for constructing and exploring graphs of logarithmic functions;

– Assessment platforms (Quizizz, Moodle, etc.) for testing the understanding of key concepts and properties;

– Adaptive and differentiated tasks to support personalized learning paths for students.

3. We encourage mathematics teachers to develop a system that integrates traditional instruction with interactive technologies, taking into account students' individual learning needs.

A possible algorithm may include: diagnostics, explanation of material (with the use of interactive technologies), practical tasks (adaptive and differentiated), reflection, and self-assessment. The model we have developed enables educators to address the individual learning needs of students and build personalized learning trajectories.

Conflict of Interest

The authors declare no conflict of interest, including financial, personal, authorship, or any other influence that could affect the research or its outcomes, presented in this article.

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Data Availability

This manuscript has no associated datasets.

Use of Artificial Intelligence

The authors used artificial intelligence tools within appropriate ethical boundaries in Section 5. The lesson plan was AI-generated and then edited to meet the specific goals of the study.

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