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PEDAGOGICAL POTENTIAL OF INNOVATIVE TECHNOLOGIES IN THE DEVELOPMENT OF SUBJECT-METHODOLOGICAL COMPETENCE OF FUTURE TECHNOLOGY TEACHERS

Abstract

The article addresses the topical issue of developing the subject-methodological competence of future technology teachers within the context of the modernization of higher pedagogical education. The study substantiates the expediency of employing innovative educational technologies as an effective means of integrating the theoretical and practical components of professional teacher training. The essence of the subject-methodological competence of future technology teachers is clarified in accordance with the Professional Standard for Teachers of General Secondary Education Institutions, and its significance for ensuring the quality of the educational process is emphasized. Particular attention is paid to the pedagogical potential of information and communication technologies (ICT), digital technologies, project-based and interactive teaching methods, STEM and STEAM approaches, distance and blended learning formats, problem-based learning, the case study method, as well as technologies for modelling and visualizing educational content.

The purpose of the study is to provide a theoretical substantiation of the pedagogical potential of innovative educational technologies in the development of the subject-methodological competence of future technology teachers and to

identify effective approaches, forms, and methods for their implementation in the educational process of higher pedagogical education institutions.

Research methodology is based on theoretical methods, including analysis, synthesis, and generalization of scientific literature, educational policy and regulatory documents, as well as comparative analysis of pedagogical approaches to the professional training of future technology teachers.

Scientific novelty lies in the comprehensive analysis and identification of the methodological potential of innovative educational technologies as an integrated didactic toolkit for developing the subject-methodological competence of future technology teachers.

The findings indicate that innovative educational technologies create favourable conditions for developing the professional autonomy of future technology teachers, as well as their critical, technical, and creative thinking. Furthermore, they promote the ability to make pedagogically sound decisions and enhance readiness to implement contemporary methods of technology education in general secondary education institutions.

Keywords: subject-methodological competence, future technology teachers, innovative educational technologies, professional teacher training, higher pedagogical education.

Problem statement. In the context of contemporary educational development, particular attention is paid to the preparation of highly qualified teachers who are capable of effectively organizing the educational process, integrating modern technologies into teaching, and adapting educational content to the individual needs of learners. One of the key components of the professional training of future technology teachers is the development of subject-methodological competence, which encompasses not only comprehensive theoretical knowledge of the

technological education domain but also the ability to apply effective teaching methods and innovative pedagogical approaches in professional practice.

According to the Professional Standard for Teachers of General Secondary Education Institutions [2], subject-methodological competence is defined as a complex, multidimensional construct integrating professional knowledge, skills, and abilities, communicative competence, as well as an appropriate level of professional responsibility and teacher autonomy. In the context of technology teacher education, subject-methodological competence implies thorough mastery of the content of the technological education field, knowledge of contemporary teaching methods and instructional technologies, and the ability to adapt them pedagogically to meet the diverse educational needs of learners in order to ensure the effectiveness and quality of the educational process.

This competence constitutes the theoretical and methodological foundation for achieving educational objectives, organizing and assessing students' learning outcomes, and creating conditions conducive to their academic development. In accordance with the Professional Standard, the structure of subject-methodological competence of future technology teachers includes the ability to design educational content in alignment with the mandatory learning outcomes established by national educational standards; to develop learners' key competencies and cross-curricular skills; to organize integrated learning by applying knowledge of the types and mechanisms of integration within the technological education domain and implementing interdisciplinary approaches in technology education; and to select and implement contemporary teaching, learning, and assessment methods aimed at fostering students' knowledge, skills, values, and personal development [2].

Despite the regulatory definition of subject-methodological competence and its pivotal role in teachers' professional practice, a number of contradictions remain between contemporary requirements for teacher education and the actual

organization of the educational process in higher pedagogical education institutions. In particular, the insufficient integration of innovative educational technologies into the process of developing the subject-methodological competence of future technology teachers continues to hinder the effective implementation of the competency-based approach in teacher education.

Another significant contradiction lies between the necessity of preparing future teachers to design, model, and implement contemporary technology education and the continued predominance of traditional instructional forms and teaching methods, which often fail to provide an adequate level of practical training or foster students' professional autonomy. Against the backdrop of the digital transformation of education, the expansion of distance and blended learning, and the increasing implementation of information and communication technologies (ICT), as well as STEM-oriented educational approaches, there is a growing need for the purposeful integration of innovative educational technologies into teacher education. Such technologies represent an effective means of developing the subject-methodological competence of future technology teachers and are consistent with the current demands of technology education as well as the requirements of the Professional Standard for Teachers of General Secondary Education Institutions.

Analysis of recent research and publications. The development of the subject-methodological competence of future teachers, including future technology teachers, has become an important focus of scholarly research conducted by Ukrainian educators, who examine this issue within the broader context of teacher professional training and the implementation of the competency-based approach in education. In our previous studies, we analyzed theoretical approaches to defining the content and structure of the subject-methodological competence of technology teachers, thereby establishing a

theoretical foundation for further investigation into the potential of innovative educational technologies as a means of developing this competence [4].

O. Kobernyk, S. Yashchuk, and M. Oleksiuk emphasize the significance of methodological and project-technological competencies in the professional preparation of future technology teachers. V. Steshenko and D. Kilderov identify a system of specialized professional competencies required for technology teachers, whereas V. Savchenko, L. Kutsak, Yu. Tsyna, O. Kitova, and S. Chernyshov consider professional and pedagogical competence as an integrative characteristic of students' readiness for effective professional practice. Subject-methodological competence has been investigated directly by V. Vorozhbit-Horbatiuk, A. Boiarska-Khomenko, and S. Dotsenko, while its structural components and dynamic nature have been substantiated in the studies of A. Voloshchuk, O. Piskunova, and N. Yatsynina. Furthermore, the research conducted by I. Tkachivska [3], H. Lokarieva, and V. Nikonenko [1] demonstrates the positive impact of innovative educational technologies—particularly information and communication technologies, project-based learning, and digital technologies—on the development of students' professional knowledge, skills, and competencies, which constitute essential components of subject-methodological competence.

Despite the substantial body of research devoted to this issue, the scientific and methodological literature still lacks a systematic approach to the purposeful use of contemporary innovative educational technologies as a means of developing the subject-methodological competence of future technology teachers. Most existing studies focus either on the theoretical foundations of professional competence or on the application of individual educational technologies without considering their integrated implementation within the system of professional teacher education. Consequently, there remains a clear theoretical and practical need for further research aimed at designing integrated pedagogical models, developing methodological guidelines, and establishing criteria for the effective

implementation of innovative educational technologies in the professional preparation of future technology teachers.

Purpose of the article. The purpose of this study is to provide a theoretical substantiation of the pedagogical potential of innovative educational technologies in the development of the subject-methodological competence of future technology teachers and to identify effective approaches, forms, and methods for their implementation in the educational process of higher pedagogical education institutions in order to enhance the quality of professional teacher education, foster students' creative and critical thinking, and develop their readiness to effectively implement contemporary approaches to technology education in general secondary education institutions.

Presentation o f the main material o f the study. Within the framework of this study, the subject-methodological competence of a future technology teacher is regarded as an integral component of professional teacher education, manifested in the ability to design, organize, and implement the educational process in accordance with the requirements of contemporary educational standards. It is based on the integration of comprehensive knowledge of the technological education domain, proficiency in modern teaching methods and instructional technologies, and practical experience in applying pedagogical strategies in authentic educational settings [5].

Contemporary innovative educational technologies play a pivotal role in developing the subject-methodological competence of future technology teachers. These include information and communication technologies (ICT), digital technologies, project-based and interactive learning technologies, STEM and STEAM approaches, distance and blended learning, problem-based learning, the case study method, modelling and visualization technologies for educational content, as well as the use of online educational platforms and digital resources. Together, these technologies facilitate the integration of theoretical instruction

with practical training, promote professional autonomy and creativity, and enhance future teachers' capacity to design and implement contemporary technology education. The following sections examine their pedagogical potential and specific features of application within the professional preparation of future technology teachers.

Distance learning and digital educational platforms provide prospective teachers with continuous access to instructional and methodological resources regardless of time and location, thereby expanding opportunities for individualized learning and the development of personalized educational trajectories. Lecture materials, practical assignments, methodological guidelines, video tutorials, examples of educational projects, and teaching resources hosted on digital learning platforms such as Google Classroom, Moodle, and Microsoft Teams create a comprehensive digital learning environment that supports the systematic acquisition of professional knowledge and skills. The integration of these platforms into the educational process ensures a close connection between theoretical preparation and practical training. Students are able to engage with interactive learning materials, complete practical and creative assignments at their own pace, analyze their performance, and refine their work based on formative feedback provided by instructors.

Furthermore, the distance learning environment promotes students' independent cognitive activity by developing their ability to plan their own learning, monitor academic progress, and evaluate learning outcomes. These competencies are of particular professional significance for future technology teachers, whose future responsibilities extend beyond mastering contemporary instructional technologies to include organizing project-based technological activities, facilitating both individual and collaborative student learning, and monitoring learners' academic achievement. In addition, the systematic use of distance learning technologies contributes to the development of students' digital

competence, preparing them to effectively employ digital resources, online tools, and educational platforms in their future professional practice within general secondary education institutions.

Interactive teaching methods are designed not only to facilitate the acquisition of theoretical knowledge but also to promote learners' active engagement in the educational process through experiential learning. These methods encompass the use of virtual laboratories, simulation software, digital assessment systems, and online consultations.

The integration of virtual laboratories into the study of technology-related disciplines, such as General Physics, Electrical Engineering, Engineering Mechanics, Machine Science, and Fundamentals of Manufacturing, enables students to simulate authentic industrial, technical, and technological processes without risks to health and without the need for sophisticated or costly equipment. Consequently, future technology teachers are provided with opportunities to repeatedly perform experimental procedures, modify process parameters, and evaluate the outcomes of their decisions. Such learning experiences contribute to a deeper understanding of cause-and-effect relationships and foster the development of engineering thinking.

Simulation software represents an effective instructional tool for developing students' analytical and critical thinking, as it involves solving problem-based tasks that closely reflect the professional activities of technology teachers. Simulating classroom instruction, students' project-based activities, manufacturing processes, and technical systems encourages prospective teachers to predict outcomes, evaluate alternative solutions, and independently identify the most appropriate strategies for achieving educational objectives.

The use of digital assessment systems ensures systematic monitoring of students' academic achievement while fostering self-assessment and reflective learning skills. Computer-based testing incorporating immediate feedback enables

learners to identify knowledge gaps, analyze common errors, and adjust their learning strategies accordingly. For future technology teachers, such experience is particularly valuable, as it equips them with the ability to design and apply digital assessment tools for evaluating students' learning outcomes in their future professional practice.

Online consultations facilitate effective communication between instructors and students, promote individualized learning, and provide continuous pedagogical support throughout the educational process. During these consultations, future technology teachers are able to discuss complex theoretical issues, receive guidance on practical and project-based assignments, and refine their individual learning trajectories.

Project-based learning provides opportunities for students to engage actively in purposeful, independent, and creative educational activities. Throughout the implementation of educational projects, students not only acquire theoretical knowledge but also gain practical experience in applying it within authentic or professionally simulated educational contexts.

Within the system of professional preparation of future technology teachers, project-based methods facilitate the integration of technical, technological, artistic-design, psychological, and pedagogical disciplines, thereby contributing to the development of a holistic professional worldview. The implementation of educational projects enables students to model both typical and complex situations encountered in the professional practice of technology teachers, including lesson planning and organization, extracurricular activities, the development of instructional and methodological materials, the selection of appropriate teaching methods and instructional resources, and the assessment of students' learning outcomes.

A distinctive feature of project-based learning is its alignment with the activity-based and competency-based approaches, which position students as

active participants in the educational process. Within project activities, prospective teachers learn to formulate project goals and objectives, plan implementation stages, select appropriate resources, search for, analyze, and synthesize information, as well as present and justify the results of their work. This approach promotes the development of independence, responsibility, critical and creative thinking, reflective skills, and the ability to evaluate one's own professional performance.

Multimedia technologies and digital educational resources create favourable conditions for the visual, accessible, and well-structured presentation of educational content, which is particularly important in the study of technical and technological disciplines, engineering design, and art and design education. Their integration into the educational process enhances students' cognitive engagement, facilitates the comprehension of complex technological concepts and processes, and contributes to the development of digital literacy alongside subject-specific and methodological competencies.

The use of digital educational resources enables the integration of various types of information, including textual, graphical, audio, and video materials, as well as dynamic models, animations, and interactive simulations. This facilitates a deeper understanding of complex technological processes, the operating principles of machines and mechanisms, the stages of product design and manufacturing, and contributes to the development of future technology teachers' spatial, technical, and design thinking. In this context, multimedia technologies function not only as a means of visualizing educational content but also as a powerful tool for knowledge construction and students' creative self-expression.

Mastering contemporary tools for presenting and demonstrating educational content, such as multimedia presentations, video lectures, interactive posters, digital instructional materials, three-dimensional (3D) models, and electronic textbooks, enables future teachers to develop the methodological skills required

for the pedagogically appropriate selection and application of digital technologies in the educational process. Furthermore, the development of students' own multimedia products provides valuable experience in project-based technological activities and pedagogical creativity, both of which constitute essential components of the subject-methodological competence of future technology teachers.

Problem-based learning is aimed at enhancing higher education students' cognitive activity, developing critical and technical thinking, and fostering their ability to independently analyze and solve educational and professional problems. Its implementation facilitates the transition from the reproductive acquisition of knowledge to its meaningful application in novel, dynamic, and professionally relevant contexts.

Within the professional preparation of future technology teachers, problem-based learning is implemented through the creation of problem situations that simulate authentic or professionally relevant teaching contexts. Such situations may arise during the analysis of technological processes, product design and modelling, the selection of materials and manufacturing technologies, the development of engineering solutions, the organization of educational projects, or the planning of technology lessons. Confronting students with pedagogical and technological problems encourages them to explore alternative solutions, formulate hypotheses, justify their decisions, and select the most appropriate technological and instructional strategies.

Problem-based learning is particularly significant for the development of the methodological competence of future technology teachers. Through the analysis of pedagogical problem situations, students acquire the ability to select appropriate teaching methods and instructional strategies, predict learning outcomes, engage in reflective practice, and adjust their pedagogical decisions accordingly. Consequently, future teachers become better prepared to implement problem-

oriented tasks in technology education, organize project-based learning, and facilitate students' research and creative activities.

STEM and STEAM approaches are implemented through the interdisciplinary integration of technical, technological, scientific, and information-oriented educational components. Future technology teachers learn to integrate knowledge from physics, electrical engineering, mechanics, engineering and computer graphics, computer science, and the fundamentals of programming to solve complex practical tasks related to product design and manufacturing, technological process analysis, and the organization of students' learning activities. Such an interdisciplinary approach develops the ability to perceive technological objects and processes as complex systems governed by scientific principles and engineering solutions. It ensures the integrity of professional teacher education while promoting systems thinking, engineering thinking, creativity, and innovation, all of which correspond to the contemporary requirements of technology teachers' professional practice within the framework of the New Ukrainian School reform.

By incorporating the Arts component into STEM education, the STEAM approach further expands the opportunities for the professional preparation of future technology teachers through the development of creativity, aesthetic awareness, and design competence. The integration of decorative and applied arts, design and product modelling, computer graphics, and design education enables students to develop the ability to create functionally appropriate, technologically sound, and aesthetically appealing products. Moreover, the implementation of STEM and STEAM approaches possesses substantial methodological potential, as it equips future technology teachers with the competencies required to design contemporary technology lessons, integrated curricula, elective courses, and extracurricular activities based on interdisciplinary connections and practice-oriented learning tasks.

The case study method is focused on the analysis of authentic or simulated professional and pedagogical situations and facilitates the development of students' ability to apply theoretical knowledge in practical contexts. Its implementation brings the educational process closer to the real conditions of general secondary education institutions, stimulates students' cognitive engagement, and creates favourable conditions for the development of the professional thinking of future technology teachers.

Within the professional preparation of future technology teachers, the case study method is implemented through the analysis of educational and professional situations related to the design and delivery of technology lessons, the organization of students' project-based technological activities, the selection of educational content, teaching methods and instructional resources, as well as the solution of pedagogical, methodological, and technological problems. The analysis of cases based on the content of technology-, engineering-, and information-oriented educational components promotes the integration of knowledge acquired in the theory and methodology of technology education, computer science, machine science, electrical engineering, engineering graphics, computer-aided design, and the fundamentals of product design and modelling.

The case study method possesses considerable methodological potential in the professional preparation of future technology teachers, as it enables students to develop the competence required to design their own educational cases for implementation in general secondary education. Prospective teachers acquire practical experience in developing educational scenarios that reflect authentic technological processes, engineering and design tasks, issues related to workplace organization and occupational safety, as well as interdisciplinary connections within technology education.

Educational content modelling and visualization technologies provide effective visual representation of complex technical and technological processes,

engineering solutions, and manufacturing operations that are often difficult to comprehend through traditional explanatory and illustrative teaching approaches. Their implementation enhances the quality of students' learning, promotes the development of spatial and technical thinking, and fosters competencies essential for engineering design and project-based activities.

In the professional education of future technology teachers, modelling and visualization technologies are implemented through the use of computer-aided design (CAD), engineering graphics, three-dimensional (3D) modelling, digital prototypes, animations, and virtual models integrated into technology- and engineering-related educational components. These digital tools enable students to reproduce product design processes step by step, analyze structural characteristics of technical objects, investigate the operating principles of mechanisms and systems, and simulate technological processes while taking into account functional, aesthetic, and safety requirements.

An important advantage of modelling and visualization technologies lies in their substantial methodological potential for the professional preparation of future technology teachers. The use of these technologies enables prospective teachers to create digital product models, technical drawings, diagrams, technological process charts, and visual instructional materials that can subsequently be employed as didactic resources in general secondary education institutions. Consequently, these technologies enhance students' methodological readiness to organize project-based learning activities, promote learners' cognitive engagement, increase learning motivation, and support the development of creativity and problem-solving abilities.

Conclusions. The development of the subject-methodological competence of future technology teachers is a complex, multidimensional, and purpose-driven process that requires the systematic integration of traditional pedagogical approaches with contemporary innovative educational technologies. The

effectiveness of this process largely depends on scientifically grounded instructional design, the gradual progression of learning tasks, the organization of independent, project-based, and research-oriented learning activities, as well as the use of digital tools for modelling pedagogical situations and ensuring objective assessment of learning outcomes.

The integration of information and communication technologies (ICT), digital technologies, interactive and project-based learning methods, STEM and STEAM approaches, distance and blended learning formats, problem-based learning, the case study method, and technologies for modelling and visualizing educational content significantly expands the opportunities for developing the subject-methodological competence of future technology teachers. These innovative educational technologies create favourable conditions for enhancing students' cognitive engagement, fostering their critical, technical, and creative thinking, and developing their ability to make pedagogically sound decisions in diverse educational contexts.

Therefore, the integration of innovative educational technologies into the professional preparation of future technology teachers represents a key factor in improving the quality of teacher education. It ensures the development of subject-methodological competence in accordance with contemporary scientific and methodological standards and contributes to the preparation of competitive, highly qualified teachers capable of effectively implementing modern educational strategies, instructional methodologies, and innovative pedagogical practices in the context of the rapidly evolving educational environment.

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FINANCIAL STABILITY OF INSURANCE COMPANIES IN UKRAINE: CURRENT CHALLENGES AND PROSPECTS FOR SUSTAINABLE DEVELOPMENT

Abstract

The insurance sector is one of the key components of the financial system, ensuring the protection of individuals and businesses against financial risks while promoting macroeconomic stability and sustainable economic development. Under current conditions, Ukrainian insurance companies operate in an environment characterized by heightened uncertainty resulting from military aggression, macroeconomic instability, inflationary processes, structural transformation of the financial services market, and the implementation of new regulatory requirements. These factors significantly affect insurers' financial resilience, making the assessment of their financial stability particularly relevant.

The study demonstrates that the financial stability of insurance companies is determined by a combination of internal and external factors. Internal determinants include the effectiveness of financial management, the adequacy of insurance reserves, underwriting quality, investment and reinsurance policies, portfolio diversification, and corporate governance. External influences are associated with military risks, macroeconomic instability, inflation, regulatory changes, fluctuations in financial markets, and declining consumer purchasing power. Particular attention is devoted to analyzing the impact of wartime conditions on the functioning of insurance companies, including changes in regulatory requirements, the

emergence of insurance products covering war-related risks, and the adaptation of insurers to new operational conditions.

The results indicate that, despite a substantial reduction in the number of insurance companies operating in Ukraine, the insurance market has become more transparent and financially resilient due to strengthened prudential supervision and the gradual implementation of European regulatory standards. At the same time, insurers continue to face significant challenges related to capitalization, solvency, liquidity, risk management, and maintaining consumer confidence.

The scientific value of the study lies in the comprehensive assessment of contemporary factors influencing the financial stability of Ukrainian insurance companies under wartime and economic transformation. The practical significance of the research consists in the proposed recommendations that may be used by insurance companies, regulatory authorities, and other market participants to strengthen financial resilience, improve the competitiveness of the insurance sector, and support its sustainable long-term development.

Keywords: financial stability, insurance company, insurance market, financial security, solvency, insurance services, risk management, sustainable development, wartime economy.

Introduction. The insurance sector is an integral component of the financial system, playing a crucial role in ensuring economic resilience, mitigating financial risks, and supporting sustainable economic development. Stable insurance companies not only provide reliable protection for individuals and businesses against unforeseen events but also contribute to investment activity, capital accumulation, and the overall stability of the financial market. Consequently, maintaining the financial stability of insurance companies has become one of the key priorities of financial sector development in both developed and emerging economies.

In Ukraine, the importance of insurers' financial stability has significantly increased under the influence of large-scale economic, political, and social transformations. The full-scale military aggression against Ukraine has intensified existing systemic problems within the insurance market while simultaneously creating new challenges associated with declining economic activity, growing uncertainty, inflationary pressures, destruction of insured assets, increased insurance claims, and changes in consumer demand for insurance services. These factors have substantially affected insurers' solvency, liquidity, profitability, and long-term financial sustainability.

Problem statement. Financial stability represents one of the fundamental characteristics determining the long-term viability of an insurance company. It reflects an insurer's capacity to maintain solvency, fulfill insurance obligations, withstand adverse internal and external influences, and preserve its competitive position within the insurance market. Consequently, effective financial stability management has become an essential component of strategic decision-making aimed at ensuring sustainable development under conditions of economic uncertainty.

Theoretical and methodological issues related to the financial stability of insurance institutions have been extensively examined by both Ukrainian and international scholars. Significant contributions to this field have been made by K. Horiacheva, M. Yermoshenko, and R. Ferguson. Various aspects of financial stability in insurance markets and insurance organizations have also been explored by R. Pikus, N. Vnukova, P. Nikiforov, Yu. Pankov, O. Hamankova, and numerous other researchers. Their studies have established an important theoretical foundation for assessing insurers' financial resilience and developing mechanisms to enhance their stability under changing market conditions.

The purpose of this study is to assess the current state of the financial stability of insurance companies in Ukraine, identify the principal internal and external

challenges affecting their sustainable operation, and determine the priority directions for strengthening their financial resilience under contemporary economic conditions. The research is based on the application of logical generalization, comparative analysis, financial and economic analysis, synthesis, systematization, and deductive methods, which made it possible to comprehensively evaluate the current trends in the development of Ukraine's insurance market.

Research problem. The Ukrainian insurance industry currently operates in an environment characterized by significant uncertainty and heightened exposure to both external shocks and internal vulnerabilities. The ongoing military conflict, prolonged socio-economic and political instability, inflationary pressures, declining household incomes, contraction of business activity, and uncertain macroeconomic prospects have substantially complicated insurers' operating conditions. These challenges have affected virtually all sectors of the national economy, including the insurance market.

Given their economic and social role, insurance companies are expected to provide financial protection against a broad spectrum of risks faced by households and businesses while mitigating the economic consequences of unforeseen events. However, the effectiveness with which insurers perform these functions largely depends on their own financial resilience. The financial security of policyholders is closely linked to the financial stability of insurance companies, as only solvent, sustainable, and financially reliable insurers are capable of meeting their contractual commitments and ensuring continuous insurance protection.

Result. Maintaining financial stability within the insurance sector is a prerequisite for establishing an effective system of financial protection for economic agents at both the macroeconomic and microeconomic levels, including households, businesses, and the state. Moreover, the achievement of social equity and the prevention of excessive economic disparities largely depend on the

efficient operation of the insurance market, whose institutions perform an essential risk-sharing and financial protection function.

The financial stability of the insurance sector is influenced by a wide range of objective and subjective factors originating from both the internal and external business environment. Internal risks primarily arise from ineffective financial and managerial decisions adopted by insurance companies. Weak financial governance, inefficient allocation of resources, and deficiencies in strategic planning reduce insurers' financial resilience, weaken their solvency, and ultimately undermine the reliability and security of insurance operations.

Financial stability of an insurance company may therefore be defined as its ability to sustain stable financial and economic development, maintain uninterrupted payment and settlement operations, withstand the adverse effects of external economic disturbances, and prevent conflicts among stakeholders regarding the allocation and utilization of corporate financial resources. [1]

According to the sources of their origin, threats to the financial stability of the insurance market can generally be classified into internal and external categories. External threats stem from interactions with business partners, competitors, criminal activities, foreign market participants, mass media, governmental institutions, and international economic developments. Internal threats, by contrast, are predominantly associated with weaknesses in insurers' financial management systems. These include inappropriate pricing strategies, poorly balanced insurance portfolios, and ineffective management of insurance reserves with respect to their composition and maturity structure. Errors in actuarial calculations or tariff setting may lead either to excessive insurance premiums, reducing market competitiveness, or to underpricing, which threatens insurers' solvency and long-term financial sustainability. [2]

An essential prerequisite for ensuring financial stability is the formation of a well-diversified and balanced insurance portfolio capable of absorbing substantial

insurance losses without jeopardizing the insurer's financial position. A persistent challenge within the Ukrainian insurance market is that many insurers continue to finance claim payments primarily through newly collected premiums rather than through adequately accumulated insurance reserves. Such practices weaken their financial resilience and increase vulnerability to unexpected loss events.

Strengthening the financial stability of insurance companies requires the implementation of several interrelated strategic measures, including:

- developing a comprehensive long-term strategy for insurance company development;
- continuously identifying, forecasting, and assessing potential financial and operational risks;
- maintaining an appropriate balance between underwriting, pricing, investment, and reinsurance policies;
- introducing effective organizational mechanisms, management methods, and financial instruments aimed at improving the financial stability framework;
- ensuring continuous monitoring and management of financial security indicators;
- maintaining a high level of professional competence among employees and ensuring compliance with internal policies and regulatory requirements designed to preserve financial stability. [4]

Numerous factors contribute to the emergence of threats affecting insurers' financial stability. Among the most significant are:

- the rapid expansion of globalization and internationalization of financial and insurance markets;
- increasing concentration of financial resources within international insurance and reinsurance markets;
- growing interdependence and mobility of insurance capital facilitated by advanced information technologies;

- stronger interaction between domestic and international economic policies, resulting in greater dependence on global financial developments;
- excessive reliance of national insurance markets, particularly the reinsurance sector, on foreign capital, which increases financial vulnerability;
- the accumulation of systemic instability within the global financial system and the inability of existing international financial institutions to effectively prevent emerging crises;
- an insufficient regulatory framework and limited international experience regarding financial stability management in insurance;
- inadequate practical experience in customer relationship management;
- relatively low standards of management and marketing across the domestic insurance market. [3; 5]

Addressing these challenges would substantially strengthen the resilience of Ukraine's insurance market by creating balanced conditions for all market participants and enhancing the overall financial stability of the insurance sector.

Since February 2022, the Ukrainian insurance market has been operating under unprecedented conditions caused by the full-scale military invasion. Existing financial risks have been significantly intensified, while entirely new threats have emerged, posing serious challenges to the stability of insurance companies and the insurance market as a whole (fig. 1). [2; 4; 6]

The full-scale war has fundamentally transformed the operating environment of Ukraine's insurance sector. The most significant challenges that have emerged include the following:

1. Restoration of regulatory requirements.

Following the outbreak of the full-scale invasion, the National Bank of Ukraine (NBU) temporarily relaxed several regulatory requirements to enable insurers to continue operating under extraordinary wartime conditions. As market conditions stabilized, however, supervisory authorities identified violations of key

prudential standards by certain insurers engaged in excessively risky business practices. Consequently, the NBU reinstated a number of regulatory requirements aimed at strengthening market discipline. These measures included the restoration of mandatory timely submission of reliable financial statements, allowing regulators to monitor insurers' financial condition and respond promptly to emerging risks. In addition, on-site inspections resumed, and supervisory sanctions for breaches of solvency and risk management requirements were reintroduced.

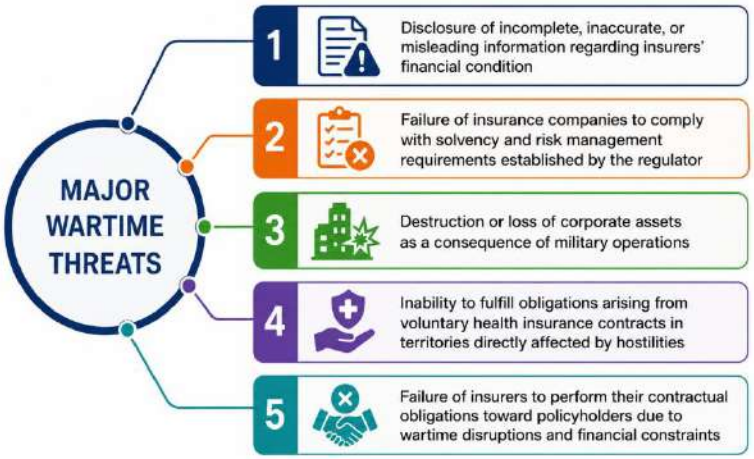


Figure 1. Major wartime threats to the financial stability of insurance companies in Ukraine

2. Insurance coverage against war-related risks.

Before 2022, insurance products covering military risks were virtually absent from the Ukrainian insurance market. The outbreak of the war created an urgent need for such coverage, leading insurers to introduce new insurance products beginning in late 2022. Property insurance policies now provide protection against losses resulting from explosions, shelling, landmines, fires, and destruction caused by military operations. Furthermore, insurers have expanded their portfolios by offering personal accident insurance related to wartime events. The leading providers of war-risk insurance products include INGO, TAS Insurance Group,

ARX, Arsenal Insurance, VUSO, MetLife, Universalna, and Kniazha Vienna Insurance Group.

3. Fulfilment of voluntary health insurance obligations.

Another significant challenge has been the provision of voluntary health insurance services in territories affected by active hostilities. Insurance companies have adapted by implementing remote service models, including online medical consultations for policyholders residing in areas with limited access to healthcare facilities. At the initial stage of the war, the National Bank of Ukraine recommended simplifying claims settlement procedures through the use of electronic documentation and remote claims processing. In regions unaffected by active military operations, insurers have largely maintained their standard operating procedures. [1; 2; 4]

Future research should primarily focus on two strategic directions. First, there is a need to develop a unified methodological framework for assessing and maintaining insurers' financial stability that adequately reflects current trends in the development of Ukraine's insurance market. Second, it is advisable to introduce a mandatory state-supported rating system that evaluates the financial strength of insurance companies according to the level of risks they assume through underwriting activities.

Accordingly, public policy in the insurance sector should prioritize the following objectives:

- ensuring an adequate level of consumer protection in the insurance market;
- strengthening insurers' solvency and long-term financial resilience;
- conducting continuous monitoring and analytical assessment of insurance market developments to preserve financial stability;
- establishing an integrated system for identifying and assessing insurance-related risks;

• increasing transparency and accountability among insurance companies as well as the governmental authorities responsible for their supervision and regulation. [1]

Reducing the risks associated with insufficient stability, transparency, and competitiveness of the insurance sector also requires strengthening the institutional and financial capacity of public authorities responsible for regulating financial services markets. In this regard, state insurance policy should be implemented in accordance with the principles of Ukraine's Concept of National Financial Security.

Priority measures include developing an effective risk identification system, continuously monitoring insurance market conditions to facilitate timely preventive actions, improving transparency of both insurers and supervisory institutions, enhancing insurers' solvency and financial sustainability, strengthening consumer protection mechanisms, and preventing insurance companies from being used as channels for unproductive capital outflows abroad.

Conclusions

The findings of this study indicate that the financial stability of insurance companies is a fundamental prerequisite for the sustainable development of Ukraine's insurance market and an essential component of the country's financial system. Under current conditions, insurers operate in an environment characterized by heightened uncertainty caused by military aggression, macroeconomic instability, inflationary pressures, regulatory transformation, and structural changes within the financial services market. These factors significantly influence insurers' solvency, liquidity, profitability, and overall financial resilience.

The analysis demonstrated that the financial stability of insurance companies depends on the combined influence of internal and external factors. Internal determinants include the quality of financial management, the adequacy of insurance reserves, the effectiveness of underwriting, investment and reinsurance policies,

portfolio diversification, and corporate governance. External factors are associated with changes in the macroeconomic environment, military risks, regulatory policy, fluctuations in financial markets, and the overall level of public confidence in insurance institutions.

Despite the reduction in the number of insurance companies operating in Ukraine in recent years, the insurance market has become more transparent and financially resilient due to strengthened prudential supervision, higher solvency requirements, and ongoing regulatory reforms implemented by the National Bank of Ukraine. Nevertheless, significant challenges remain, including insufficient capitalization of certain insurers, limited demand for insurance services, growing exposure to military risks, and the need to further align the Ukrainian insurance market with European regulatory standards.

Strengthening the financial stability of insurance companies requires the implementation of comprehensive measures aimed at improving risk management systems, increasing capitalization, maintaining adequate insurance reserves, diversifying insurance portfolios, expanding reinsurance protection, introducing modern digital technologies, and enhancing transparency in financial reporting and corporate governance. Equally important are the continued development of effective state regulation, improvement of consumer protection mechanisms, and the creation of conditions that promote sustainable competition within the insurance market.

Overall, ensuring the financial stability of insurance companies should be regarded as a strategic priority for the development of Ukraine's financial sector. The implementation of coordinated actions by regulators, insurers, and other market participants will contribute to strengthening public confidence in insurance institutions, increasing the resilience and competitiveness of the insurance market, and supporting the country's long-term sustainable economic development.

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DIDACTIC POTENTIAL OF DIGITAL PLATFORMS IN THE DEVELOPMENT OF COGNITIVE INTEREST OF PRIMARY SCHOOL PUPILS

Abstract

The article studies the didactic potential of digital platforms in the development of cognitive interest of primary school pupils. It is substantiated that the activation of cognitive interest is determined not by the very fact of using digital technologies, but by the nature of educational activities organized through digital platforms.

Psychological and pedagogical approaches to the interpretation of cognitive interest as an integrative characteristic of the educational activity of junior schoolchildren are analyzed. Its structural components are revealed and the pedagogical mechanisms through which digital platforms affect the development of students' cognitive activity are characterized, in particular, emotional involvement, visualization of educational material, organization of cognitive search, provision of prompt feedback, individualization of learning and support of educational interaction.

A systematization of digital platforms according to their didactic purpose, built on the basis of dominant pedagogical functions, is proposed. Groups of digital resources designed for the creation and visualization of educational content, the organization of interactive educational activities, formative assessment, communication and cooperation, as well as the development of creative and

research activities of younger students have been allocated. It is substantiated that the proposed approach provides a pedagogically balanced selection of digital platforms in accordance with the goals of individual stages of the lesson and contributes to their holistic integration into the educational process of primary school.

The practical possibilities of using digital platforms at different stages of the modern lesson are determined and it is proved that their effectiveness depends on the subordination to the logic of the organization of educational activities, and not the technical characteristics of individual digital resources. It is concluded that the didactic potential of digital platforms is realized under the condition of their methodically justified use, aimed at the development of cognitive interest, intensification of educational activities and the formation of key competencies of younger students.

Keywords: cognitive interest, junior schoolchildren, digital platforms, didactic potential, educational activities, digital educational environment, digital technologies.

Problem statement. The formation of a stable cognitive interest of primary school pupils is one of the key tasks of modern primary education, since it provides internal motivation for learning, contributes to the development of independence, initiative and readiness of students for active acquisition of knowledge. The preservation and development of younger pupils' natural curiosity largely depend on largely depends on the extent to which the educational environment encourages them to active cognitive activity, research search and independent solution of educational tasks.

At the same time, the digital transformation of education opens up new opportunities for organizing such an educational environment. Modern digital platforms and tools provide interactive interaction of students with educational

material, expand the possibilities of its visualization, create conditions for prompt feedback, individualization of learning and organization of joint activities. Thanks to this, they can act not only as technical means of supporting the educational process, but also as an effective pedagogical tool for the development of cognitive interest, educational activity and positive motivation of younger students.

Despite the active introduction of digital technologies in the practice of primary education, their use is often fragmented and is associated mainly with individual electronic services or digital resources. In scientific research, the main attention is paid to the description of the functionality of digital platforms or the analysis of certain aspects of the digitalization of the educational process. At the same time, the issues of pedagogical justification for the use of digital platforms as a means of activating the cognitive interest of younger students, as well as their systematization in accordance with the didactic functions they perform in the educational process, remain insufficiently disclosed.

The need to solve these issues necessitates a comprehensive analysis of the pedagogical potential of modern digital platforms and tools, determining their role in the formation of cognitive interest of primary school students and substantiating approaches to their pedagogically appropriate use in accordance with the goals and content of education.

Analysis of recent research and publications. The problem of the formation of cognitive interest, the development of educational motivation and cognitive activity of students occupies an important place in the national pedagogical science. The theoretical foundations of this problem are revealed in the works of N. Bibik, I. Kozlovska, N. Lysenko, L. Maryanenko, V. Bohuslavska, M. Zabrotsky and other scientists. In their research, they substantiate the role of cognitive interest as one of the leading factors of successful learning, emphasize the need to create an educational environment that stimulates independence, research activity and positive motivation of younger students.

A separate area of modern research is related to the digitalization of education and the use of digital technologies in the educational process. These issues are covered in the works of N. Aristova, O. Nozdrova, M. Onopriychuk, L. Poryadchenko, A. Popesko, M. Savchyn, A. Silveistra, V. Stanchyk, I. Trubenko, O. Uspenska, A. Melnyk and other researchers. The authors consider the possibilities of electronic educational resources, interactive platforms and digital services to increase the effectiveness of learning, individualize the educational process, develop digital competence and organize active interaction of students with educational material.

The analysis of scientific publications shows that the issue of the use of digital technologies in education has been studied quite extensively. At the same time, most of the works are devoted to individual digital services or general aspects of the digitalization of education. On the other hand, the possibilities of modern digital platforms as a means of activating the cognitive interest of primary school students remain insufficiently covered. Methodological approaches to the selection and use of digital tools, taking into account the age characteristics of younger students, also need to be further generalized.

The article is aimed at theoretical substantiation of pedagogical possibilities of using digital platforms and tools to activate the cognitive interest of primary school students.

Presentation of the main material of the study. It is advisable to evaluate the effectiveness of using digital platforms in primary school not only by their technical capabilities or variety of functions. Much more important is how much they are able to influence the internal mechanisms of students' educational activities, support their cognitive activity and create conditions for the conscious assimilation of knowledge. In this context, the central place is occupied by cognitive interest, which determines the nature of the interaction of younger students with the educational material and significantly affects the effectiveness of learning [1; 10; 9; 6].

In psychological and pedagogical research, cognitive interest is considered as a complex personal formation formed at the intersection of intellectual need, positive emotional attitude to learning, internal motivation and active activity of the student [1; 7]. It cannot be reduced only to interest in a particular topic or an unusual form of conducting a lesson. Unlike situational curiosity, which quickly arises and just as quickly fades away, cognitive interest has a more stable character. It encourages the student not only to perceive new information, but also to ask questions, look for explanations, test their own assumptions, establish cause-and-effect relationships and apply the acquired knowledge in new learning situations [1; 10; 8; 6].

For primary school age, this is of particular importance. It is during this period that the child's attitude to learning is formed, the foundations of educational independence are laid, and the first strategies for solving educational problems are developed [7; 9]. The natural curiosity of children creates favorable conditions for the development of cognitive interest, but by itself it does not guarantee its stability. If educational activity is based mainly on the reproduction of ready-made information, interest gradually weakens. Instead, learning, which involves searching, researching, choosing ways of acting and being able to see the result of one's own efforts, supports intrinsic motivation and turns cognition into a personally meaningful process [1; 7; 8].

Cognitive interest is not an isolated characteristic of the personality. It is closely related to educational motivation, cognitive activity, independence and reflection, gradually determining the student's readiness for continuous learning [1; 10; 6]. That is why in modern primary education, its development is considered not as a concomitant result of learning, but as one of the leading pedagogical goals [7; 8]. This approach also changes the requirements for the selection of teaching tools: they should not only ensure the transfer of knowledge, but also support the child's inner need to learn new things.

Cognitive interest is not a homogeneous psychological and pedagogical phenomenon. Its development is ensured by the interaction of several components, each of which performs its own function in the organization of educational activities [1; 10; 6]. That is why it is advisable to assess the effectiveness of pedagogical tools not only by the final results of learning, but also by what components of cognitive interest they affect. This approach allows you to move from the intuitive use of digital resources to their conscious selection in accordance with specific educational tasks.

The emotional component determines the child's attitude to the learning process [10; 9; 6]. A feeling of interest, positive experiences from the successful completion of a task, a desire to continue working or discover new things create a psychological basis for further cognitive activity [1; 8]. Younger students are especially sensitive to novelty, clarity and changes in activities, so the emotional perception of educational material directly affects the level of their involvement in the lesson [9]. This explains why the use of digital platforms with multimedia elements, interactive models or gamification elements often provides not only an increase in interest in a particular task, but also forms a positive attitude towards educational activities in general.

The cognitive component reflects the student's desire to understand the educational material, establish relationships between phenomena, find answers to problematic questions and independently acquire new knowledge [1; 10; 6]. Its development is associated with the performance of such activities that require analysis, comparison, generalization, suggestion and verification of one's own conclusions [10; 7]. Thus, digital tools perform a developmental function only when they encourage students not to mechanically choose the correct answer, but to intellectual search, research and comprehension of educational material.

No less important is the motivational and volitional component, which ensures the readiness of schoolchildren to make efforts to achieve the educational

goal [1; 7; 6]. It manifests itself in the desire to complete the work started, overcome difficulties, improve one's own result and maintain interest even while performing complex tasks [9; 8]. In this context, digital platforms can act as an effective means of supporting learning motivation through prompt feedback, the ability to gradually complicate tasks, track individual progress, and create a situation of success for each student.

The activity component integrates all the previous ones, since it is in practical activity that the real level of formation of cognitive interest is manifested [10; 7; 6]. If the student seeks to experiment, offers his own ways of solving problems, creates new products or uses the acquired knowledge in other learning situations, this indicates a transition from situational interest to a stable cognitive need [1; 8]. With this in mind, the greatest pedagogical value is those digital tools that provide not only the implementation of ready-made exercises, but also the creation of their own projects, models, interactive stories, or other results of creative activity.

This approach allows us to consider the structure of cognitive interest not only as a theoretical characteristic of the individual, but as a practical guideline for the choice of digital learning tools. Each component requires different pedagogical support mechanisms, and therefore different functionalities of digital platforms. It is this pattern that should determine the logic of their use in primary school and serves as the basis for further systematization of digital tools according to their didactic purpose.

In modern primary school, digital platforms are increasingly used not only as an additional source of educational information, but as a full-fledged tool for organizing the educational process [2; 3]. Their pedagogical value is determined not by the number of available functions or technological novelty, but by the ability to change the nature of educational interaction between teacher, student and educational content. That is why the assessment of the effectiveness of digital resources

requires, first of all, the analysis of the pedagogical opportunities that they open up for the development of cognitive activity of primary school pupils [7].

The traditional model of teaching is mainly focused on the transfer of ready-made knowledge from teacher to student. With this approach, the student mostly acts as a performer of the proposed tasks, and his cognitive activity is often limited to the reproduction of already known information [1; 7]. Digital platforms make it possible to change this logic. They create conditions under which the student becomes a direct participant in the educational process: independently researches the material, performs interactive tasks, tests his own hypotheses, analyzes the results of activities and corrects further actions. In this case, the digital resource is not a substitute for the teacher, but a means of organizing active cognitive activity.

A feature of digital platforms is the ability to combine different ways of presenting educational information. Text materials can be supplemented with animations, video fragments, interactive diagrams, virtual models or educational simulations. The combination of several channels of perception contributes to a better understanding of the educational material, facilitates the establishment of relationships between concepts and makes the learning process more accessible to children of primary school age. At the same time, it is not the multimedia itself that is crucial, but its pedagogically expedient use in accordance with the set educational goal [7; 9; 2].

No less important is the ability to ensure constant interaction of the student with the educational material. Unlike printed didactic tools, digital platforms involve active actions: choosing answer options, moving objects, performing interactive exercises, modeling situations, creating your own digital products. This format of training supports concentration, stimulates research behavior and promotes the transition from passive perception of information to its active processing [1; 10; 6].

At the same time, the effectiveness of digital platforms is not automatically determined by the very fact of their use. One and the same resource can either support the cognitive activity of students, or turn into only a modern form of presenting traditional reproductive tasks. It depends on how well the teacher integrates digital tools into the structure of the lesson, selects the content of educational tasks and organizes the interaction of students with the digital environment [7]. Therefore, the decisive factor is not the technology itself, but the method of its pedagogical use.

That is why it is advisable to consider digital platforms not as a universal means of increasing motivation, but as a tool for the implementation of specific pedagogical functions. Their impact on cognitive interest depends on what mechanisms of educational activity they activate, what types of interaction they support and what opportunities they provide students for independent cognition [1; 10; 7; 6; 4]. This approach creates the basis for the analysis of individual pedagogical mechanisms through which digital resources affect the development of cognitive interest of younger students.

It is advisable to assess the pedagogical potential of digital platforms not through the list of their functionality, but because of the changes that they provide in the educational activities of younger students. The same digital tools can demonstrate different effectiveness depending on what pedagogical mechanisms they activate, how organized the interaction of students with educational material is organized and how this interaction corresponds to the age characteristics of children. In this regard, the analysis of not the digital technologies themselves, but the methods of their pedagogical application is of key importance [7; 9].

One of these mechanisms is emotional involvement. Younger students are much more actively involved in educational activities if the educational material evokes positive emotions, supports curiosity and creates a situation of discovery [1; 9; 6]. Digital platforms have ample opportunities to implement this mechanism

due to the combination of visual images, animation, soundtrack, interactive elements and game techniques. However, by themselves, these means do not guarantee the development of cognitive interest. If they are used only for external "enlivenment" of the lesson, their impact quickly disappears [8]. Emotional involvement becomes pedagogically valuable when it stimulates further intellectual activity, and does not replace it [6].

An equally important mechanism is the creation of a situation of cognitive search. Unlike the traditional presentation of ready-made information, digital platforms make it possible to organize learning situations in which the student independently analyzes facts, establishes patterns, makes assumptions and checks them in the process of completing tasks [10; 7]. It is this activity that ensures the transition from passive assimilation of knowledge to its active construction [1; 6; 5]. Accordingly, a digital resource performs not an informational, but a cognitive-organizational function.

Operational feedback plays a special role in maintaining cognitive interest. Younger students need quick confirmation of the correctness of their own actions, as this helps them to correct mistakes in a timely manner, realize their own progress and maintain confidence in their own capabilities [9]. Unlike traditional forms of control, digital platforms provide an almost instantaneous response to the student's performance. At the same time, the pedagogical value of such feedback lies not only in reporting the correct or incorrect answer, but also in creating conditions for analyzing the mistakes made and choosing ways to overcome them [7].

An important factor in the development of cognitive interest is also the individualization of learning. Younger students differ in the pace of work, level of training, learning experience and cognitive needs [7; 9]. Digital platforms allow you to vary the complexity of tasks, choose different ways of presenting educational material, return to previous stages of learning, or, conversely, offer additional tasks for students with a higher level of training. Under such conditions, ed-

ucational activity becomes more personally significant, and interest is maintained not due to external stimulation, but through the opportunity to work at your own pace and feel success from the achieved result [1; 7; 9; 2].

Another mechanism is the organization of educational interaction. Modern digital environments have long ceased to be a space for individual work. They provide the opportunity to implement joint projects, discuss results, mutual evaluation, and collective problem solving. This format contributes to the development of not only cognitive interest, but also communication skills, critical thinking, the ability to argue one's own position and take into account the opinion of other participants in the educational process. For younger students, this is of particular importance, because educational activities at this age gradually acquire a social character [7; 9].

Therefore, the effectiveness of digital platforms is determined not by individual technical characteristics, but by a set of pedagogical mechanisms that they provide. It is through emotional involvement, organization of cognitive search, timely feedback, individualization and educational interaction that digital tools create conditions for the development of sustainable cognitive interest [1; 10; 6; 4]. At the same time, different digital platforms implement these mechanisms to an unequal extent, which necessitates their systematization not by technical features, but by didactic purpose and dominant pedagogical functions.

An analysis of modern scientific publications shows that digital platforms are most often classified according to technical characteristics, functionality or scope of use. In scientific and methodological works, you can find a division into services for creating educational content, distance learning platforms, formative assessment tools, communication tools or collaborative environments. This approach is appropriate for describing digital resources, but it only partially reflects their pedagogical potential, since it focuses mainly on the technical features of digital products.

For a primary school teacher, another question is more important: what didactic function does this or that digital tool perform in the learning process. The same resource can be used to explain new material, organize research activities, formative assessment, reflection or joint work of students. At the same time, different digital platforms often implement the same pedagogical function, despite differences in the interface, toolkit, or ways of interacting with the user. That is why their comparison only in terms of functionality does not give the teacher sufficient guidelines for a pedagogically grounded choice.

In our opinion, the selection of digital platforms should be carried out primarily in accordance with the didactic goal of a particular stage of the lesson. This approach avoids a situation where digital technologies are used only as a means of diversifying the educational process. Instead, each digital tool becomes an element of a holistic methodological system, in which its use is determined not by popularity or technical characteristics, but by pedagogical expediency.

With this in mind, the study proposes a systematization of digital platforms according to their dominant didactic purpose. The basis of the classification was not the software capabilities of individual services, but the pedagogical functions that they mainly implement in the process of teaching younger students. This approach makes it possible to consider digital tools as a component of teaching methods, and not only as a technical means of supporting the educational process.

The proposed systematization is based on three interrelated principles.

The first principle is didactic expediency. Each group of platforms is determined according to which learning task it helps to implement most effectively. The focus is not on the list of functions of the digital service, but on its place in the organization of the educational process.

The second principle is the dominance of the pedagogical function. Most modern platforms combine several tools, so they can be used in different learning situations. However, for systematization, it is important to determine the function

that is leading and most fully characterizes the pedagogical purpose of a particular resource.

The third principle is methodological universality. The proposed classification is not tied to individual software products. It will remain relevant even with the emergence of new digital platforms, since it is based on pedagogical functions that remain unchanged regardless of the development of digital technologies. This, in our opinion, makes such systematization more suitable for use in the professional activity of a teacher.

It should be noted that modern digital platforms are characterized by multifunctionality and can be used to solve various educational problems. This complicates their unambiguous distribution by technical characteristics or scope, since the same digital resource can be effective in explaining new material, organizing independent work, carrying out formative assessments or performing creative tasks. Under such conditions, it is more expedient to arrange them in accordance with the didactic role they play in the structure of the educational process [7].

The proposed systematization is based on the proposition that the choice of a digital tool should be determined not by its popularity or number of functions, but primarily by the educational goal of a particular stage of the lesson. This approach allows us to consider digital platforms as a component of the methodological system of education, in which each resource is used to implement a certain set of pedagogical tasks. The systematization is based on the dominant didactic function, which most fully characterizes the capabilities of a particular digital resource in the organization of educational activities of younger students.

According to the proposed approach, it is advisable to combine digital platforms into five main groups: tools for creating and visualizing educational content, tools for organizing interactive learning activities, formative assessment platforms, communication and collaboration environments, digital resources for creative and research activities of students. The proposed classification is not intended to be

exhaustive, but reflects the most common areas of pedagogical use of digital platforms in the practice of primary education.

Table 1

Systematization of digital platforms by didactic purpose

Category of digital platforms	Main didactic function	Examples of platforms	Pedagogical opportunities
Tools for creating and visualizing educational content	Explanation of new educational material, its visualization and structuring	Canva, Genially, Google Slides, Prezi	Creation of presentations, interactive diagrams, infographics, digital stories, visual models
Tools for organizing interactive learning activities	Knowledge consolidation, formation of practical skills, activation of educational activities	LearningApps, Wordwall, Educaplay	Performing interactive exercises, didactic games, classifications, matching exercises
Formative assessment platforms	Monitoring learning progress, self-assessment and feedback	Kahoot!, Quizizz, Classtime, Plickers	Online testing, quick evaluation of results, analysis of common errors, monitoring of educational progress
Communication and collaboration environments	Organization of interaction of participants in the educational process and joint activities	Google Classroom, Microsoft Teams, Padlet, Miro	Joint completion of tasks, exchange of study materials, group discussion, mutual assessment
Digital resources for creative and research activities	Development of creativity, research skills and project activities	Scratch, Book Creator, Tinkercad	Creation of digital projects, programs, models, interactive books, presentation of research results

The proposed approach demonstrates that one digital resource can be used to implement several pedagogical tasks, but when selecting it, it is advisable to take into account the leading didactic purpose. For example, formative assessment services can be used not only to control educational achievements, but also to actualize supporting knowledge, identify learning difficulties, or organize reflection. Similarly, it is advisable to use the means of creating digital content not only as a tool for demonstrating educational material, but also as an environment for the development of creativity and the formation of information and digital competence of students.

The practical value of the proposed systematization lies in the fact that it orients the teacher to a conscious choice of digital platforms in accordance with the purpose and content of a particular stage of the lesson. This approach contributes to the pedagogically expedient integration of digital technologies into the educational process, ensures their coordination with modern didactic principles and creates prerequisites for activating the cognitive interest of younger students.

The proposed systematization of digital platforms acquires practical significance only if it is integrated into the methodology of organizing the educational process. The selection of digital resources should be carried out not according to the principle of their popularity or accessibility, but in accordance with the didactic purpose of a particular stage of the lesson. This approach ensures the pedagogically expedient use of digital technologies, contributes to the activation of students' cognitive activity and increases the effectiveness of learning [1; 7].

At the stage of motivation, it is advisable to use digital tools that can arouse cognitive interest, actualize the life experience of students and create a problem situation [1; 9; 6]. Interactive presentations, short educational videos, digital stories, virtual demonstrations or interactive surveys help to draw the attention of younger students to the educational topic and form a positive emotional attitude to further work. At the same time, the digital resource performs not an informational, but a motivational function, stimulating the inner readiness of students for cognitive activity [6].

When studying new material, it is advisable to use digital platforms as a means of visualization and research of educational content. The use of interactive models, diagrams, maps, simulations or animated objects makes it possible not only to present information in an accessible form, but also to organize active interaction of students with educational material. This contributes to the formation of a holistic view of the phenomena under study, the development of logical thinking and the establishment of cause-and-effect relationships [10; 7; 9].

At the stage of consolidation of knowledge, digital tools that provide for the active implementation of practical actions are most effective. Interactive exercises, educational games, exercises for classification, matching, modeling of educational situations provide multiple application of the acquired knowledge in various conditions. Thanks to this, students not only reproduce the educational material, but also gain experience in its practical use, which has a positive effect on the development of cognitive activity and the stability of interest in learning [1; 10; 6].

An important place in the structure of a modern lesson is occupied by formative assessment. The use of digital platforms at this stage provides prompt feedback, timely identification of learning difficulties, the possibility of self-assessment and adjustment of further educational activities. For the teacher, this creates conditions for making informed pedagogical decisions, and for students – the opportunity to realize their own progress and determine directions for further improvement [7; 9].

No less important is the use of digital platforms when organizing reflection. Interactive whiteboards, shared digital spaces, online questionnaires or electronic observation logs contribute to the comprehension of the results of the work done, the development of reflective skills and the formation of a responsible attitude to learning [7]. Analysis of their own achievements and difficulties helps younger students to realize personal progress, which has a positive effect on maintaining internal educational motivation [1; 6].

At the same time, digital platforms should not be considered as a universal means of improving the effectiveness of learning. Their effectiveness is determined primarily by the pedagogical skill of the teacher, who chooses digital tools in accordance with the purpose of the lesson, the age characteristics of students, the content of the educational material and the expected learning outcomes [7; 9]. Only under the condition of methodically justified use, digital resources become an effective means of developing cognitive interest, support the active educational

activity of younger students and contribute to the formation of key competencies [1; 7; 6].

The proposed approach allows us to consider the use of digital platforms as an integral pedagogical system, within which the components of cognitive interest, pedagogical mechanisms of their development, the didactic purpose of digital resources and the structure of a modern lesson are interconnected. Such logic provides a conscious choice of digital tools in accordance with the educational goal, increases the efficiency of the organization of the educational process and creates conditions for the formation of a stable cognitive interest of primary school students.

Conclusions. The development of cognitive interest of younger students is determined not so much by the use of modern digital platforms as by the nature of the educational activities they provide. Even the most functional digital tools do not contribute to the formation of a sustainable interest in learning if their application is limited to the demonstration of information or the mechanical performance of interactive exercises. Instead, educational activities that involve searching for different ways of solving learning tasks, cooperation, reflection and meaningful feedback create the conditions for, cooperation, reflection and receiving meaningful feedback, creates prerequisites for the transition from situational interest to stable cognitive motivation.

In this context, it is advisable to consider digital platforms not as separate technical means of learning, but as a component of an integral didactic system. Their pedagogical potential is realized only under the condition of purposeful selection in accordance with the didactic purpose of the lesson, the age characteristics of younger students and the logic of assimilation of educational material. It is the pedagogically grounded use of the possibilities of multimedia, interactivity, gamification, formative assessment, communication and creative activity that en-

sures the activation of students' cognitive activity and supports a positive attitude to learning.

The proposed systematization of digital platforms is based on their didactic purpose and reflects the most common directions of pedagogical use of digital resources in the practice of primary education. This approach allows you to move from the choice of digital services according to their technical characteristics to the conscious design of the educational process, within which each digital tool performs a certain pedagogical function. This creates conditions for the integrated use of digital platforms at different stages of the lesson and ensures their organic integration into the educational activities of younger students.

Thus, the effectiveness of the use of digital platforms in primary school is determined by their integration into a holistic didactic learning system, in which each digital tool is used in accordance with its pedagogical function and ensures the achievement of certain learning outcomes. It is this approach that allows you to maximize the potential of digital technologies for the development of cognitive interest of younger students and creates a methodological basis for their pedagogically appropriate use in the context of digital transformation of education. We see the prospects for further research in the experimental verification of the effectiveness of the proposed systematization of digital platforms, the determination of pedagogical conditions for its implementation in various educational areas of primary school and the development of methodological recommendations for the integrated use of digital resources in the educational process.

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СИСТЕМА ПРОГНОЗУВАННЯ ПОПИТУ НА ТАКСІ В РІЗНИХ РАЙОНАХ МІСТА

SYSTEM FOR PREDICTING TAXI DEMAND IN DIFFERENT CITY DISTRICS

Анотація

Метою роботи є скорочення середнього часу очікування клієнтів таксі шляхом створення програмної системи прогнозування попиту в різних районах міста на основі аналізу просторово-часових даних і застосування методів машинного навчання, що забезпечує завчасний перерозподіл автомобілів у зони з прогнозованим підвищенням попиту.

Серверна частина реалізована мовою Python із використанням Django

REST Framework. Для зберігання даних використано PostgreSQL, яке дозволяє працювати з просторовими об’єктами та координатами районів міста. Інтелектуальний модуль прогнозування створено на базі бібліотек TensorFlow, Keras і scikit-learn із використанням архітектури LSTM. Клієнтська частина системи побудована з використанням React.js, Chart.js і Leaflet.js, що забезпечує інтерактивну візуалізацію прогнозів у вигляді графіків і карт міста.

У результаті розроблено програмну систему, яка дозволяє прогнозувати попит на таксі, скорочувати середній час очікування клієнтів і підвищувати ефективність роботи автопарку.

Ключові слова: прогнозування попиту, таксі, машинне навчання, Python, Django, PostgreSQL, LSTM, React, Docker.

Abstract The purpose of this work is to reduce the average waiting time for taxi clients by developing a software system for demand forecasting in different city areas based on the analysis of spatio-temporal data and the application of machine learning methods, enabling the proactive redistribution of vehicles to zones with predicted demand growth.

The server side is implemented in Python using the Django REST Framework. For data storage, PostgreSQL is used, which allows working with spatial objects and city district coordinates. The intelligent forecasting module is built using the TensorFlow, Keras, and scikit-learn libraries, employing the LSTM architecture. The client side of the system is developed with React.js, Chart.js, and Leaflet.js, providing interactive visualization of forecasts in the form of charts and city maps.

As a result, a software system has been developed that enables taxi demand forecasting, reduces the average client waiting time, and improves fleet operation efficiency.

Keywords: demand forecasting, taxi, machine learning, Python, Django, PostgreSQL, LSTM, React, Docker.

Постановка проблеми. У сучасних умовах стрімкого розвитку міської мобільності та зростання попиту на послуги перевезення пасажирів ключовим завданням транспортних сервісів є забезпечення швидкої та ефективної взаємодії між попитом і пропозицією. Служби таксі займають важливе місце в інфраструктурі міста, однак їх ефективність значною мірою залежить від здатності передбачати зміни попиту у просторі та часі.

Нерівномірний розподіл викликів таксі по районах міста призводить до проблеми надмірного навантаження в одних зонах і простою транспортних засобів в інших. Це знижує рентабельність роботи перевізників і погіршує якість обслуговування клієнтів через збільшення часу очікування. Існуючі системи диспетчеризації здебільшого орієнтовані на реактивний режим, тобто реагують на вже сформований попит, не передбачаючи його зміни наперед.

Актуальність розробки системи прогнозування попиту на таксі зумовлена необхідністю підвищення ефективності розподілу транспортних ресурсів, скорочення часу подачі автомобілів та оптимізації роботи служби таксі. Використання алгоритмів машинного навчання і просторово-часового аналізу дає змогу виявляти закономірності попиту за різними параметрами (час доби, день тижня, погодні умови, події в місті) і формувати прогнози, які допомагають приймати обґрунтовані управлінські рішення.

Аналіз останніх досліджень і публікацій. Сучасні транспортні системи та служби таксі функціонують у конкурентному середовищі, де ефективність управління автопарком і задоволеність клієнтів безпосередньо залежать від здатності сервісу прогнозувати попит і гнучко реагувати на

його зміни [1]. Тому протягом останніх років у різних країнах активно розвиваються аналітичні платформи, які застосовують алгоритми машинного навчання, прогнозування часових рядів і просторового аналізу для оцінювання майбутнього навантаження на служби таксі [2].

Перші покоління інформаційних систем для керування таксі були зосереджені на автоматизації диспетчерських процесів. Такі системи, як Taximeter, Mobile Dispatch System або TaxiMaster, забезпечували приймання замовлень, розрахунок вартості поїздки, реєстрацію водіїв і базове відстеження автомобілів за допомогою GPS. Проте ці рішення не містили аналітичних інструментів прогнозування попиту, а працювали лише в реактивному режимі, тобто після надходження запиту від клієнта [3].

Із розвитком великих даних (Big Data) та аналітики реального часу з’явилися системи нового покоління, орієнтовані на передбачувальне управління транспортними ресурсами [4]. Першими масштабними прикладами стали глобальні платформи Uber, Lyft і Bolt, які впровадили алгоритми машинного навчання для прогнозування попиту в різних районах міста [5]. Їхні аналітичні модулі збирають мільйони записів про поїздки, визначаючи закономірності за часом, погодою, святами, трафіком і поведінкою користувачів [6].

Система Uber Demand Prediction Model, зокрема, базується на гібридному підході: дані агрегуються у просторові сітки, для кожної з яких побудовано модель прогнозування на основі нейронних мереж LSTM (Long Short-Term Memory).

Ці мережі ефективно моделюють часові залежності, оскільки враховують попередні стани попиту [7]. Додатково використовуються фактори погодних умов, локальних подій і транспортної інфраструктури. Перевагою підходу Uber є масштабованість і можливість оновлення прогнозів у режимі близькому до реального часу, однак алгоритми компанії

є закритими, а їхня адаптація до локальних умов потребує великих обсягів навчальних даних [8].

Платформа Lyft реалізує схожу концепцію, але робить більший акцент на геопросторовій кластеризації. Місто поділяється на шестикутні зони (Hexagonal Grids), для кожної з яких обчислюються метрики активності користувачів. На основі історії поїздок і стану трафіку формується прогноз попиту, який передається до диспетчерського модуля для перерозподілу автомобілів [9]. У системі також передбачено механізм динамічного ціноутворення, коли підвищення попиту у певному районі автоматично збільшує тариф, стимулюючи водіїв переміщатися до цієї зони [10].

Сервіс Bolt (Taxify) використовує модель прогнозування, засновану на градієнтному бустингу (Gradient Boosted Decision Trees), що дозволяє обробляти гетерогенні дані: історію замовлень, GPS-треки, погодні дані, статуси водіїв і клієнтів. Цей підхід забезпечує високу швидкість навчання та інтерпретованість результатів, однак має нижчу здатність до врахування довготривалих часових залежностей порівняно з рекурентними мережами [11].

Окрім комерційних рішень, останніми роками з’явилася низка наукових і відкритих дослідницьких проєктів, присвячених прогнозуванню транспортного попиту. Наприклад, у роботах, присвячених моделі DeepTTE (Deep Travel Time Estimation), досліджується поєднання рекурентних і згорткових нейронних мереж (CNN+LSTM) для моделювання просторово-часових процесів у транспортних даних.

Такі підходи дозволяють не лише прогнозувати час поїздки, а й оцінювати майбутній рівень попиту. Інший відомий напрям – це моделі типу ST-ResNet (Spatio-Temporal Residual Network), які поєднують залишкові блоки ResNet з часовими рядами, забезпечуючи високу точність прогнозів у густонаселених районах мегаполісів.

У межах відкритих даних активно використовується набір NYC Taxi Dataset, який містить мільйони записів поїздок у Нью-Йорку. На його основі реалізовано численні експерименти з використанням методів ARIMA, Prophet, XGBoost і LSTM, що дозволило оцінити переваги та обмеження кожного з підходів. Наприклад, лінійні моделі ARIMA добре працюють для стабільних районів із передбачуваним попитом, тоді як нейронні мережі значно перевершують їх у випадках із високою варіативністю даних [12].

В Україні подібні рішення тільки починають з'являтися. Деякі служби, зокрема Uklon і Bolt Україна, впроваджують базові алгоритми прогнозування пікових навантажень, проте на рівні локальних міст подібні системи здебільшого відсутні [13]. Це створює передумови для розробки універсальної платформи прогнозування попиту, орієнтованої на середні та великі міста, яка може адаптуватися до регіональних особливостей і локальної структури міської мережі [14]. Аналіз існуючих рішень показує, що більшість сучасних систем характеризується складністю архітектури та високими вимогами до обсягів даних, але водночас демонструє високу точність прогнозування. Комерційні платформи використовують закриті моделі, орієнтовані на великі міста з розвиненою інфраструктурою, тоді як у відкритих дослідженнях наголошується на важливості адаптації моделей до локальних умов і обмежених даних [15]. Отже, актуальним завданням є створення програмної системи, здатної поєднувати просторово-часове моделювання, доступність реалізації, інтерпретованість результатів і можливість використання в умовах середніх міст [16].

Мета статті. Метою роботи є скорочення середнього часу очікування клієнтів таксі шляхом створення програмної системи прогнозування попиту в різних районах міста на основі аналізу просторово-часових даних і застосування методів машинного навчання, що забезпечує завчасний перерозподіл автомобілів у зони з прогнозованим підвищенням

попиту.

Виклад основного матеріалу дослідження. З огляду на результати аналізу предметної області та характеристику існуючих рішень, головною задачею системи є побудова прогнозу попиту на послуги таксі у просторі та часі з урахуванням історичних даних, погодних умов, транспортної активності та особливостей міських районів.

Для цього обрано комбінований підхід, який поєднує статистичні моделі часових рядів і алгоритми машинного навчання, що забезпечує як інтерпретованість, так і високу точність результатів.

На першому етапі застосовується попередня обробка даних: очищення від шумів, агрегація за часовими інтервалами (15, 30 або 60 хвилин) та просторове групування за районами міста. Для таких задач доцільно використовувати кластеризацію за географічними координатами (K-Means або DBSCAN), що дозволяє визначити зони з подібним рівнем транспортної активності.

Далі реалізується блок короткострокового прогнозування на основі моделей часових рядів: ARIMA – для стабільних районів із регулярними патернами попиту; Prophet (Meta) – для трендів із сезонністю, вихідними днями та святами; XGBoost – для врахування взаємозв’язків між попитом, погодою, годинами доби, днями тижня тощо.

Для районів із високою варіативністю та нерегулярною динамікою застосовується нейронна модель типу LSTM (Long Short-Term Memory), яка навчається на послідовностях часових відрізків і зберігає залежності між попередніми та поточними станами попиту.

У разі достатнього обсягу даних можлива інтеграція згорткових шарів (CNN), що дозволяє враховувати просторові кореляції між сусідніми районами.

Комбінування результатів кількох моделей (ensemble) дає змогу

підвищити стійкість прогнозу та адаптувати систему до різних типів міських середовищ.

ARIMA є одним із найпоширеніших статистичних підходів до короткострокового прогнозування, особливо у задачах, де структура даних змінюється в часі.

Модель добре підходить для економічних, транспортних та демографічних показників, де спостерігаються регулярні патерни поведінки. ARIMA містить три компоненти:

– AR (autoregressive) – враховує вплив попередніх значень ряду;

– I (integrated) – відповідає за усунення тренду через різницювання;

– MA (moving average) – моделює випадкові збурення та залишки.

Формально ARIMA(p, d, q) описується як:

$$y_t = c + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t,$$

де y_t – значення часового ряду у момент часу t;

c – константа (середнє або зсув моделі);

p – порядок авторегресійної частини (AR);

q – порядок частини ковзного середнього (MA);

ϕ_i – коефіцієнт авторегресії при i-му попередньому значенні ряду;

y_{t-i} – значення часового ряду на i кроків раніше;

θ_j – коефіцієнт ковзного середнього при j-й похибці;

ε_t – поточна випадкова похибка (шум);

ε_{t-j} – похибка прогнозу j кроків тому.

У системі модель ARIMA застосовується для стабільних районів міста, де попит має виражену періодичність (наприклад, ділові центри чи вокзальні

зони). Її перевагою є інтерпретованість та невисока обчислювальна складність.

Модель Prophet – це сучасна реалізація декомпозиційного підходу до прогнозування часових рядів, яка поєднує тренд, сезонність і вплив спеціальних подій:

$$y(t) = g(t) + s(t) + h(t) + \varepsilon_t,$$

де $g(t)$ – нелінійний тренд;

$s(t)$ – сезонні компоненти;

$h(t)$ – ефект свят або подій;

ε_t – похибка.

Перевага Prophet полягає у здатності швидко адаптуватися до коротких рядів даних і автоматично визначати точки зміни тренду. У контексті прогнозування попиту на таксі модель корисна для врахування сезонних коливань (робочі/вихідні дні, свята, години пік) без складної параметризації.

XGBoost – це ансамблевий метод градієнтного бустингу на базі дерев рішень, який створює послідовність слабких моделей, кожна з яких покращує результати попередньої.

Основна ідея полягає у мінімізації втрат через додавання коригувальних дерев:

$$\hat{y}_i = \sum_{k=1}^{K} f_k(x_i), \;\; f_k \in F,$$

де f_k – дерево рішень;

K – кількість дерев;

F – простір усіх можливих дерев.

XGBoost ефективно враховує нелінійні залежності між факторами – наприклад, вплив погодних умов, годин доби чи транспортних обмежень на попит.

У системі цей метод використовується як другий рівень ансамблю після базового прогнозу ARIMA/Prophet, що дозволяє підвищити точність та адаптувати модель до складних взаємозв'язків.

Модель LSTM – це різновид рекурентної нейронної мережі (RNN), здатний запам'ятовувати довготривалі часові залежності. Вона складається з комірок пам'яті та керуючих вентилів (input, forget, output gates), які контролюють, яку інформацію зберігати або відкидати.

Рівняння роботи однієї комірки описуються так:

$$f_t = \sigma\big(W_f \cdot [h_{t-1}, x_t] + b_f\big), \quad i_t = \sigma(W_i \cdot [h_{t-1}, x_t] + b_i),$$
$$C_t = f_t * C_{t-1} + i_t * \tanh(W_C \cdot [h_{t-1}, x_t] + b_C),$$
$$h_t = o_t * \tanh(C_t),$$

де f_t – коефіцієнт, який визначає, яку частину попереднього стану пам'яті зберегти;

i_t – визначає, яку нову інформацію додати до стану пам'яті;

o_t – контролює, яка частина поточного стану пам'яті буде передана далі;

C_t – поточний стан пам'яті (у момент часу *t*;

h_t – вихідний вектор, тобто активність LSTM на поточному кроці;

x_t – вхідний вектор у момент часу t (наприклад, набір ознак для прогнозу попиту);

W_f, W_i, W_C – матриці ваг, що відповідають за зв'язки між входами й попередніми станами для кожного вентиля (підмодуль у комірці

LSTM, який вирішує, яку інформацію пропустити далі, а яку «забути»);

b_f, b_i, b_C – вектори зміщення, які додаються для корекції обчислень;

σ (·) – сигмоїдна функція активації, що переводить значення у діапазон [0; 1];

tanh (·) – гіперболічний тангенс, який обмежує значення між [–1; 1];

$*$ – покомпонентне множення векторів (елемент на елемент).

LSTM застосовується у системі як основний модуль прогнозування, який оперує послідовностями попередніх значень попиту, що охоплюють часові залежності між періодами та дозволяє моделі адаптуватися до нерегулярних змін попиту.

Інформаційна модель системи прогнозування попиту на таксі, представлена на рис. 1, описує логіку обробки даних і взаємодію основних компонентів системи – від збору інформації до представлення результатів користувачеві.

На початковому етапі дані про поїздки, які включають історію замовлень, місця посадки й висадки, час доби, вартість і тривалість, надходять до модуля попередньої обробки даних. Разом із цими даними до системи також інтегруються додаткові джерела інформації:

– дані про погоду (H) – температура, опади, вітер, які суттєво впливають на поведінку користувачів таксі;

– дані про транспорт (I) – завантаженість доріг, наявність ремонтів або обмежень руху;

– зовнішні фактори (J) – локальні події, свята, концерти, спортивні матчі, що можуть різко змінювати попит у певних районах.

Модуль попередньої обробки виконує очищення даних від шуму, заповнення пропусків, нормалізацію та агрегування за часовими інтервалами й географічними зонами. Після цього дані передаються до блоку аналітики,

де відбувається їх первинний аналіз – виявлення закономірностей, сезонності, пікових годин та просторового розподілу попиту.

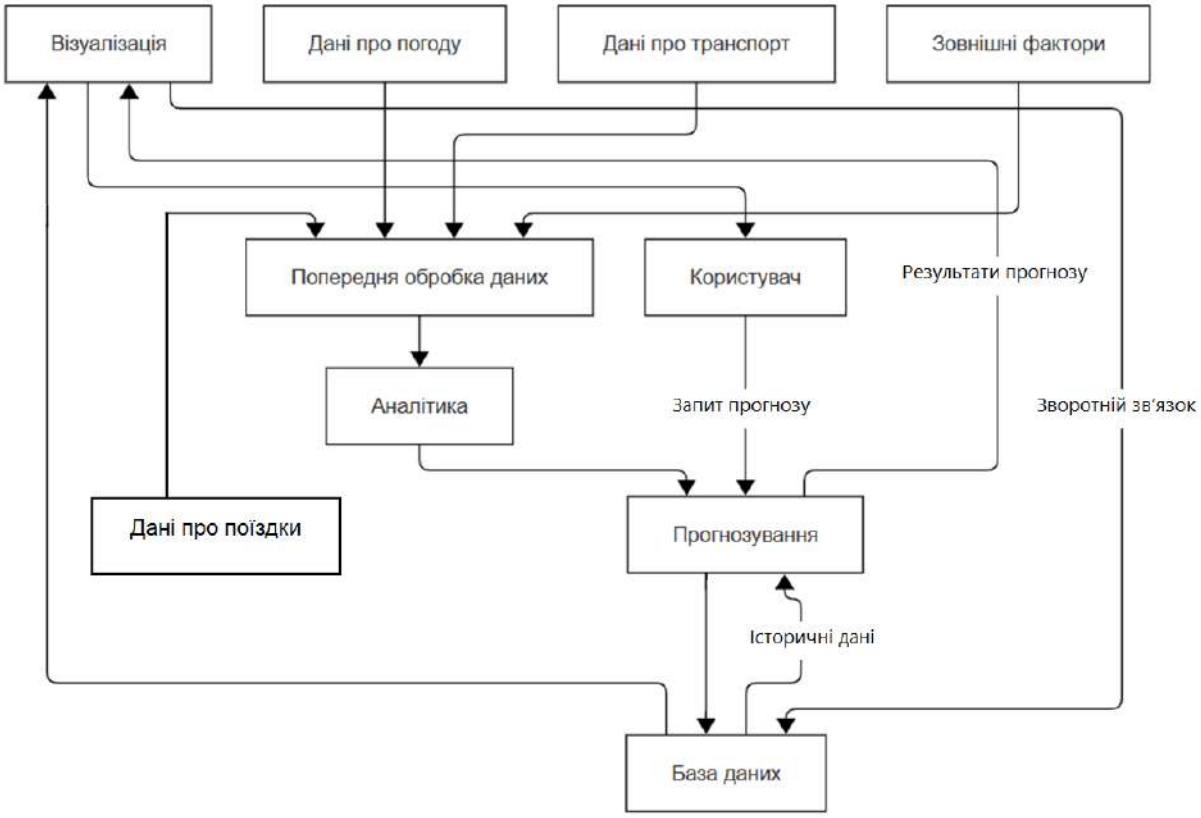


Рисунок 1 – Інформаційна модель системи

На основі отриманих ознак формується вхід для модуля прогнозування, який реалізує алгоритми машинного навчання, наприклад LSTM, XGBoost або ST-ResNet. Цей модуль будує короткострокові або середньострокові прогнози попиту для кожного району міста, враховуючи історичні закономірності, зовнішні фактори та поточну ситуацію.

Результати моделі зберігаються у базі даних, де також зберігаються історичні записи поїздок, оброблені ознаки та попередні прогнози. Це дозволяє здійснювати повторне навчання моделі та перевірку точності прогнозів.

Далі інформація надходить до модуля візуалізації, який перетворює прогнозовані показники в зручну для сприйняття форму – інтерактивні карти міста з кольоровим відображенням зон високого або низького попиту, графіки зміни навантаження протягом доби, а також панелі моніторингу для операторів служби таксі.

Кінцевим елементом системи є користувач – це диспетчер, менеджер автопарку або аналітик, який отримує прогноз у вигляді візуального звіту чи інтерактивного дашборду. Користувач може надсилати запит на прогноз, переглядати історичні дані з бази даних, а також залишати зворотний зв'язок, що зберігається в базі даних для подальшого вдосконалення моделі.

Основні функції та актори розроблюваної системи наведені на діаграмі варіантів використання, які наведено на рис. 2

Адміністратор системи відповідає за керування користувачами, налаштування параметрів прогнозування, оновлення даних та моніторинг стану програмних компонентів. Аналітик даних здійснює збір, очищення та підготовку даних, навчає модель прогнозування та оцінює її точність на основі порівняння фактичних і прогнозованих показників. Диспетчер служби таксі використовує результати прогнозування для оперативного управління автопарком – переглядає прогноз попиту, візуалізує його на карті міста та приймає рішення про перерозподіл автомобілів. Менеджер автопарку аналізує довгострокові тенденції попиту, формує аналітичні звіти для керівництва та приймає стратегічні рішення щодо планування ресурсів.

Діаграма концептуальних класів системи прогнозування попиту на таксі, побудована на основі клієнт-серверної архітектури, відображає основні структурні елементи системи та взаємодію між ними (рис. 3).

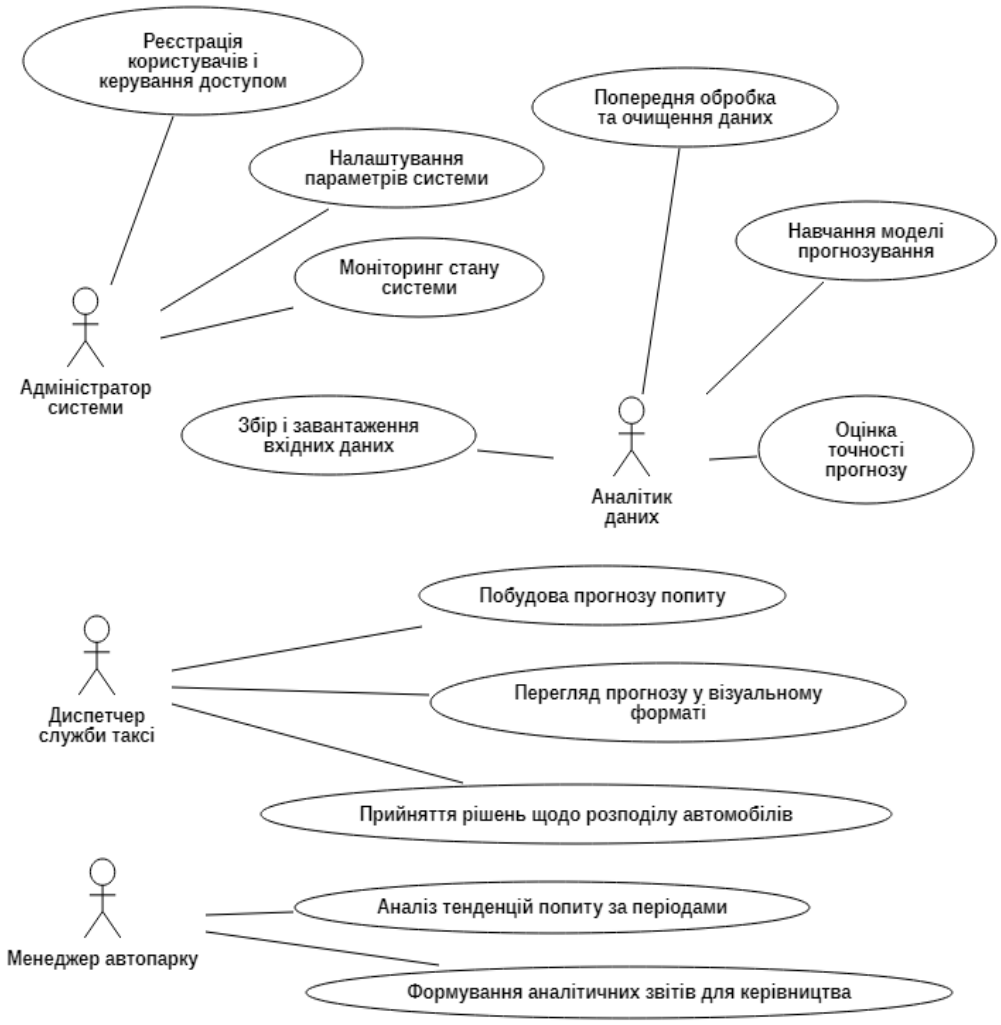


Рисунок 2 – Діаграма варіантів використання системи

Комунікація між клієнтською та серверною частинами реалізується через API-шару (інтерфейс прикладного програмування), який відповідає за приймання запитів, перевірку доступу, передавання результатів і захист обміну даними. Клієнтський інтерфейс забезпечує взаємодію кінцевого користувача з системою: відображає карти міста, графіки, таблиці прогнозів і дозволяє надсилати запити на оновлення чи створення звітів.

Для оцінки ефективності було змодельовано два режими роботи служби: базовий (без прогнозування) та інтелектуальний (із прогнозуванням попиту).

У базовому режимі автомобілі розподілялися рівномірно або реагували

на замовлення лише після їх надходження, що є типовим підходом для більшості традиційних служб таксі.



Рисунок 3 – Діаграма концептуальних класів

У другому режимі використовувалася розроблена система прогнозування, яка на основі історичних просторово-часових даних, погодних умов та зовнішніх факторів (свята, події тощо) формувала прогноз попиту на найближчі 30–60 хвилин. На основі цього прогнозу система пропонувала перерозподіл вільних автомобілів у райони з очікуваним підвищенням кількості замовлень.

Для проведення експерименту було згенеровано вибірку з понад 10 000 записів поїздок, що охоплювали дані за декілька тижнів у межах умовного міста з поділом на 12 районів. Після моделювання обох сценаріїв проведено

порівняння середнього часу очікування клієнтів.

У базовому режимі середній час очікування склав 6,4 хвилини. Це значення відображає ситуацію, коли автомобілі реагують на виклики постфактум, а їхня кількість у певних районах може бути недостатньою. Після впровадження прогнозування середній час очікування скоротився до 4,9 хвилини, що становить зменшення на 23,4 %.

Детальні результати показали, що найбільше скорочення часу спостерігалося в години пікового навантаження (ранок 7:00–9:00, вечір 17:00–20:00), коли система завчасно розміщувала автомобілі поблизу районів із прогнозованим підвищенням попиту. У таких періодах середній час очікування зменшився з 7,1 хвилини до 5,3 хвилини (на 25 %). У міжпікові години покращення було менш вираженим, але стабільним – з 4,3 до 3,5 хвилини (на 18,6 %).

Отримані результати підтвердили, що впровадження прогнозної моделі дозволяє завчасно реагувати на зміни попиту, що забезпечує більш раціональний розподіл транспортних ресурсів і скорочення часу, який клієнт витрачає на очікування автомобіля. Система продемонструвала стабільність результатів навіть при збільшенні обсягу даних та кількості активних районів міста.

Загалом, результати експериментального тестування показали, що розроблена система прогнозування попиту на таксі дозволяє скоротити середній час очікування клієнтів на 20–25 %, що є суттєвим показником ефективності. Це свідчить про практичну доцільність впровадження системи у реальні служби таксі, особливо у великих містах із високою динамікою попиту, та підтверджує досягнення основної мети роботи.

Висновки. У представленій роботі проведена розробка інтелектуальної системи прогнозування попиту на таксі в різних районах міста, що базується на аналізі просторово-часових даних і застосуванні методів

машинного навчання. Використання системи сприяло скороченню середнього часу очікування клієнтів на 20–25 % у порівнянні з базовим сценарієм без прогнозування.

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THE ROLE OF DIET AND LIFESTYLE IN THE DEVELOPMENT OF DENTAL CARIES: A CLINICAL ANALYSIS OF RISK FACTORS AND PREVENTIVE POTENTIAL

Abstract

Dental caries is still a frequent finding in dental practice, even though preventive care is widely available. This article focuses on the role of diet and daily habits in increasing or reducing the risk of caries. The analysis is based on the author's clinical observations and data from evidence-based studies from 2014–2020. It is shown that the key factor is not the total amount of sugar in the diet, but rather how many times a day the teeth come into contact with an acidic environment. Patients who snack more than four times a day have 30–50% more active lesions than those who stick to three main meals. The habit of eating before bed increases the risk of caries by 40–60%, since saliva performs almost no protective function at night. Reduced salivation, associated in particular with the use of certain medications, is found in 15–25% of patients; in this group, active caries occurs in 60–80% of cases. Changing dietary and hygiene habits can prevent up to 70% of new lesions, and the first noticeable results appear within 1–3 months.

Keywords: dental caries, diet, lifestyle, sugar exposure, salivation, stress, oral hygiene, prevention.

Introduction. Dental caries is one of the most common chronic diseases in humans. According to a study on the global burden of disease, untreated caries of permanent teeth affects approximately 2.5 billion people worldwide [1, 3]. Despite

significant progress in understanding the pathogenesis and the emergence of effective preventive measures, the incidence rate is not decreasing in most countries.

In his practice, Stoianov regularly encounters patients with extensive caries who genuinely do not understand why. The person does not eat a lot of sweets, brushes their teeth, and yet still comes in with new lesions. Upon detailed questioning, the picture becomes clear: coffee with sugar in the morning, something sweet before lunch, more coffee after work, and fruit or cookies in the evening. The person does not consider any of these instances to be “a meal,” but each triggers an acid cycle in the mouth. The difference between “what they eat” and “how often they consume it” determines the rate of enamel destruction in most patients with active caries.

Traditionally, the development of caries is explained by the interaction of pathogenic biofilm, a carbohydrate substrate, and a susceptible host [2]. Clinical observations indicate that the decisive factor is not so much the presence of sugar as the pattern and frequency of its intake throughout the day [4, 5]. The activity of the process is also influenced by the quality and regularity of oral hygiene, reduced salivation, levels of chronic stress, and medication use [7, 8].

The purpose of this article is to analyze which dietary and behavioral factors most influence the development of caries and to determine which lifestyle changes yield tangible preventive results.

Literature review. **Prevalence of Dental Caries and Current Understanding of the Disease.** Global epidemiological data indicate that untreated caries of permanent teeth affects between 2.3 and 2.5 billion people [1, 3]. An analysis of trends from 1990 to 2017 showed that the prevalence of the disease has hardly decreased despite increased access to dental care [10]. Frencken et al. emphasize that in groups with lower socioeconomic status, caries progresses more rapidly and is more often left untreated [7].

Pitts et al. describe caries as the result of an imbalance between the destruction and repair of hard dental tissues under the influence of biological, behavioral, and social factors [2]. Machiulskiene et al. proposed a classification that distinguishes between active and inactive lesions and places the activity of the process at the center of clinical assessment [9]. This approach is important for prevention: the goal is not only to treat existing lesions but also to prevent new ones from developing.

Sugar and Caries: Frequency Matters, Not Quantity. A systematic review by Moynihan and Kelly confirmed that if the proportion of free sugars in the diet does not exceed 10% of daily caloric intake, the risk of caries is significantly reduced [4]. In its 2015 guidelines, the World Health Organization recommends reducing this proportion to 5% for maximum effect [6].

At the same time, Moynihan draws attention to an important nuance: it is not only the amount of sugars but the frequency of their intake that determines the caries risk [5]. Each intake of carbohydrates triggers acid production by the biofilm and lowers the pH in the mouth below 5.5, at which point enamel destruction begins [2]. Saliva requires 30 to 60 minutes to neutralize the acid and initiate repair [2, 4]. With two to three meals a day, this time is sufficient. With six to eight meals and snacks, the enamel barely leaves the demineralization zone.

Lifestyle, Stress, and Saliva Composition. Chapple et al. demonstrated that caries is linked to a person’s overall health: stress levels, sleep quality, and dietary habits alter the composition and quantity of saliva, which directly influences the risk of caries [8]. Chronic stress reduces saliva production, disrupts sleep patterns, and leads to irregular eating habits, increasing the risk even without changes in diet.

Saliva protects teeth in several ways: it physically washes away food debris and bacteria, neutralizes acids through the bicarbonate buffer system, and restores enamel through calcium and phosphate ions [2, 8]. When there is insufficient

saliva, all these functions weaken simultaneously: acid remains in contact with the enamel longer, plaque accumulates faster and is removed more slowly, and the enamel does not have time to regenerate between acid attacks.

Hujoel et al., in a systematic review of randomized studies, confirmed that regular oral hygiene reduces the incidence of caries, and interdental cleaning has an independent protective effect, especially in the spaces between teeth where a toothbrush cannot reach [11].

Materials and methods. This study is based on the author's clinical experience gained during dental consultations. Each patient with active caries was interviewed about their dietary habits: how many times a day they eat or drink something sweet, whether they have a habit of eating in the evening or at night, and how often they consume beverages throughout the day.

Oral hygiene was assessed based on the results of the examination, not on the patient's word. The color of the plaque indicated exactly where the person was not cleaning their teeth. The condition of the gums during probing indicated the duration and quality of cleaning in specific areas. The edges of restorations and the cervical areas indicated places where plaque accumulates constantly. A comprehensive medical history was taken to determine whether the patient was taking medications that reduce salivation, what their stress level was, and whether they had sleep problems.

For comparative analysis, patients were grouped based on the frequency of sugar intake (up to three times and more than three times per day), the regularity of oral hygiene, the presence of reduced salivation, and whether they followed preventive recommendations. Results were verified during follow-up examinations at 1–3 and 3–6 months. The numerical indicators presented correspond to data from systematic reviews and epidemiological studies [1, 3, 7, 10, 11].

Research results. **Prevalence of Dental Caries.** According to Stoianov's observations, dental caries is found in 70–80% of patients who come in for an

appointment. Multiple lesions are present in 30–40% of them. In children, both rates are higher: caries is present in 80–90%, and multiple lesions in 40–60%. Among adults, caries is found in 60–70%, and multiple lesions in 20–30% of patients.

Diet and the Frequency of Caries. Based on Stoianov's experience, a typical day for patients with active caries looks like this: coffee or tea with sugar in the morning, something sweet between tasks before lunch, coffee again after work, and fruit or cookies in the evening. People do not consider any of these episodes to be "meals." But each one lowers the acidity in the mouth, and if the next intake occurs too soon, enamel remineralization does not take place. Another common feature: the absence of distinct meal times. People snack throughout the day, and this is worse for the teeth than three full meals with breaks in between.

On average, patients had 2–4 sugar exposures per day. However, 40–50% exceeded four exposures per day. In this group, there were 30–50% more active carious lesions than in patients with three meals. At the same time, the total amount of sugar consumed did not differ significantly between the groups. Stoianov notes: the same piece of chocolate, eaten all at once, has almost no effect on the teeth; the same piece, consumed in small portions over several hours, results in a series of acid attacks.

Sweet, carbonated, or acidic beverages were consumed regularly by 40–50% of patients. The number of lesions in this group was 30–50% higher. Drinking slowly in "sips throughout the day" proved particularly harmful: a single glass of beverage that a person sips on for an hour or two results in numerous acid exposures. Carbonated drinks have their own acidity, so even without sugar, they can soften the enamel surface. Citrus juices and other acidic drinks usually damage the enamel in another way: they contribute to erosion. The surface of the tooth becomes less glossy, looks duller, and sensitivity may appear over time.

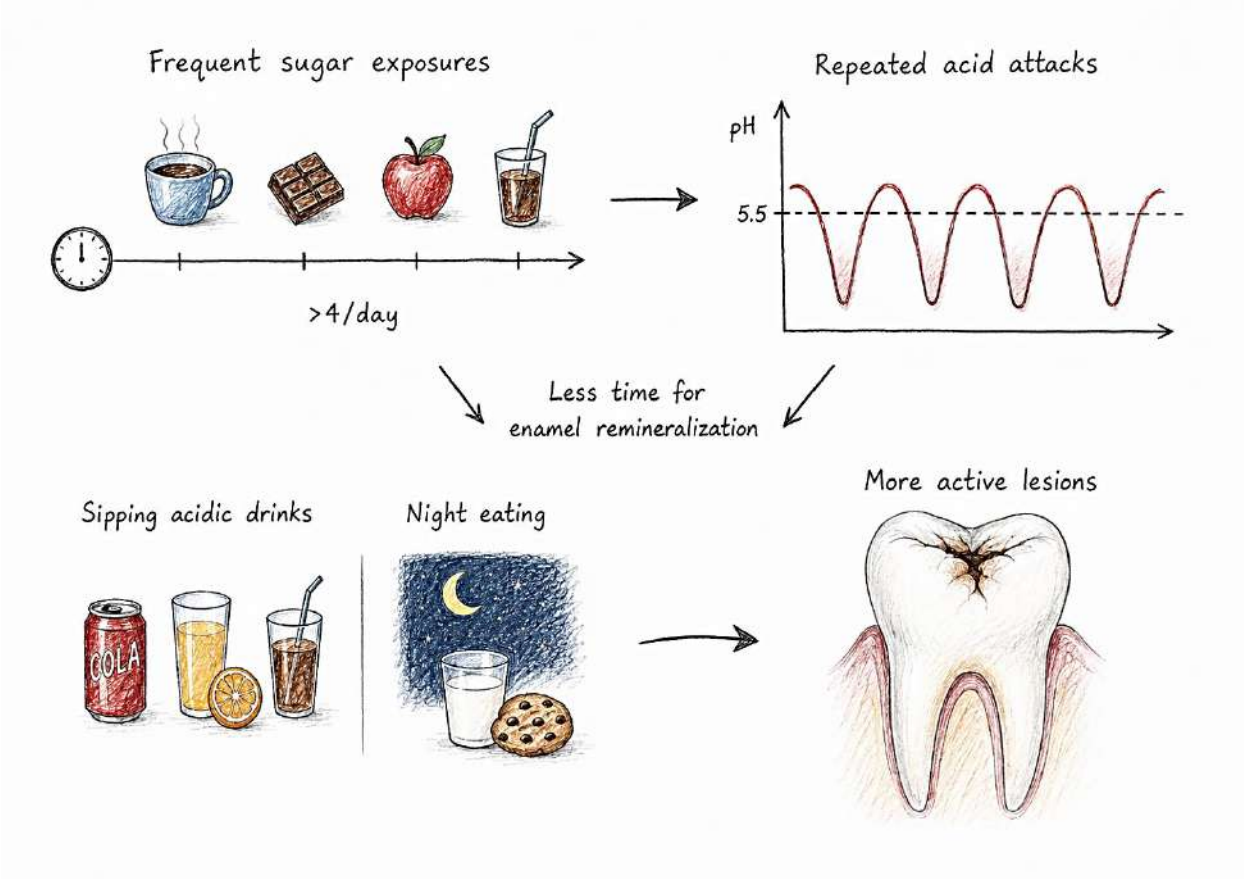


Figure 1. How Frequent Sugar and Acid Exposure Increases the Risk of Active Caries

The habit of eating before bed or at night was found in 20–30% of patients. The rate of caries in this group was 40–60% higher. The reason: at night, saliva production is low and does little to neutralize acids. The acidic environment following an evening snack can persist throughout the night, and during this time, enamel does not regenerate.

Hygiene: the gap between what the patient says and what is seen during the examination. 40–50% of patients brush their teeth twice a day, about 30–40% once a day, and another 15–20% brush irregularly. The less frequently teeth are brushed, the more damage occurs: with once-daily or irregular hygiene, there is on average 30–60% more damage than with twice-daily brushing.

In his practice, Stoianov notes a significant discrepancy between what the patient describes and what is observed during the examination. Most people are

convinced that they brush their teeth well. However, after staining the plaque on the cervical areas, in the interdental spaces, and along the edges of fillings, plaque is usually present. Moreover, these areas recur from examination to examination because the hand moves along the same habitual trajectory. The condition of the gums upon probing and darkening along the edges of fillings indicate how long this has been going on.

Only 30–40% of patients regularly used interdental brushes or dental floss. In this group, caries and gum inflammation were 20–40% less common. Most people avoid interdental cleaning due to discomfort or believe that a toothbrush is sufficient. However, a toothbrush physically cannot reach the spaces between the teeth, and it is precisely there that most plaque accumulates, leading to new lesions.

According to Stoianov's observations, a patient who "doesn't eat anything special" and "brushes their teeth well" but has active tooth decay typically has frequent, hidden exposure to acids (sugary tea between meals, fruit, small snacks) and uncleaned areas in two or three typical spots. It is precisely this combination, without any other causes, that explains the clinical picture.

Reduced salivation, stress, and lifestyle factors. Signs of reduced salivation were observed in 15–25% of patients. Among them, active caries was observed in 60–80% of cases, whereas among patients without this issue, it was observed in 20–30%. Clinically, such patients are more likely to have multiple caries, rapid progression of initial lesions, and lesions in the cervical regions. Reduced salivation was most commonly observed in patients taking antidepressants, antihypertensives, or antihistamines, as well as in the elderly and those who breathe through their mouths.

Patients with chronic stress and disrupted daily routines (30–40% of the total) had 30–50% more carious lesions. Stoianov notes that stress usually shows

up first in everyday habits. A patient may still brush their teeth, but do it quickly, skip the evening routine, drink more coffee, or snack on sweets between meals.

Table 1. The Gap Between Reported Oral Hygiene and Clinical Evidence of Plaque Retention

Hygiene factor	Observed pattern in patients	Clinical finding
Brushing frequency	40-50% brushed twice a day; 30-40% once a day; 15-20% irregularly.	Once-daily or irregular hygiene was associated with 30-60% more damage than twice-daily brushing.
Patient self-assessment	Most patients believed they brushed their teeth well.	Plaque staining often showed remaining plaque in cervical areas, interdental spaces, and along filling margins.
Repeated missed areas	The same areas remained uncleaned from visit to visit.	The brushing movement followed the same habitual trajectory, leaving persistent plaque accumulation.
Gum and restoration margins	Gum condition during probing and darkening near fillings were evaluated.	These signs helped indicate how long plaque retention had been present.
Interdental cleaning	Only 30-40% regularly used floss or interdental brushes.	In this group, caries and gum inflammation were 20-40% less common.
Main hidden risk	Patients often reported a normal diet and good brushing.	Active caries was usually linked to frequent hidden acid exposure and two or three chronically uncleaned areas.

Irregular sleep and chaotic eating make the situation worse: saliva protects the enamel less effectively, while frequent snacks repeatedly lower the pH in the mouth. If the patient also has bruxism, the edges of fillings are exposed to additional pressure and wear.

The Difference Between Children and Adults. For children, the main problem is that neither their diet nor their hygiene is within their control. They do not control what they eat or whether they brush their teeth, and therefore, tooth decay in children largely reflects family habits. In families where parents frequently snack themselves and do not monitor the child’s hygiene, the risk is

higher. Children's enamel is less mineralized, so tooth decay progresses faster than in adults.

Adults are more aware, but the leading risks are acquired chronic habits: a work routine with constant snacking, coffee with sugar as a daily ritual, and dry mouth due to medication. Adults have more fillings, and there is a high-risk zone around each one. A new filling in an unchanged cariogenic environment will need to be replaced in two to three years for the same reasons.

What changes after behavioral correction. According to Stoianov's observations, the fastest results come from two simple changes: completely avoiding food after evening toothbrushing and regular hygiene every night. Within just 1–2 months, new lesions stop appearing. If the patient also reduces the number of snacks during the day, the initial demineralization spots stabilize within 3–6 weeks. Additional results come from switching from "sips of sweet drinks throughout the day" to occasional consumption and starting to use interdental brushes.

Patients who followed the recommendations had new lesions in 10–20% of cases, while those who made no changes had them in 40–60% of cases. The risk of new lesions among those who ignored the recommendations was two to three times higher. According to Stoianov's estimates, 50 to 70% of new cases of caries can be prevented simply by changing diet and hygiene habits without any treatment.

Stoianov's Structured Approach to Behavioral Caries Risk. Building on these observations, Stoianov systematized his clinical approach into a structured preventive model with three elements. First, a behavioral caries risk assessment scores each patient by the frequency of sugar and acid exposures per day, the timing of intake (night-time and post-brushing eating), salivation status, and the verified - not reported - level of plaque control. Second, an algorithm for detecting hidden risk factors directs attention to causes patients rarely report themselves:

"healthy" hidden-sugar foods (yogurts, muesli, bars, juices), medication-induced reduced salivation, and the gap between reported and clinically observed hygiene.

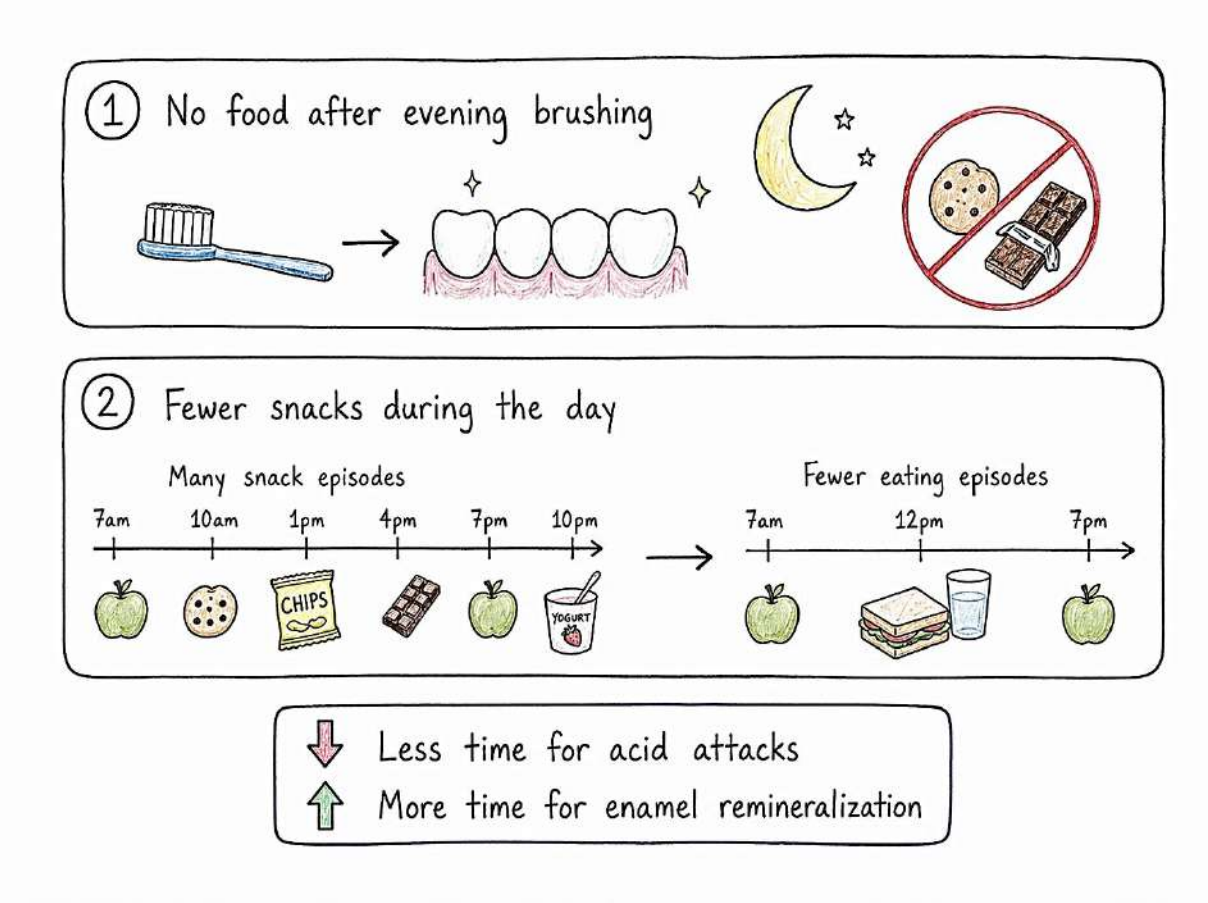


Figure 2. Behavioral Changes That Reduce Acid Exposure After Brushing and Between Meals

Third, a targeted behavioral correction plan replaces generic advice with two priority changes - eliminating night-time and post-brushing intake and reducing exposure frequency - followed by monitoring of new lesions. This three-part structure links risk identification directly to measurable behavioral outcomes.

Clinical observations. A patient with five to seven active lesions consulted Stoianov. When asked about his diet, he replied that he practically never eats sweets. However, during the conversation it turned out that he had tea or coffee with sugar four to six times a day, fruit or cookies in between, and a sweet drink in the evening. He did not clean between his teeth in the evening. After the patient understood the mechanism and changed his routine (three meals a day, nothing in

between, regular evening hygiene), no new lesions appeared over the next 6–12 months, and the initial spots stabilized.

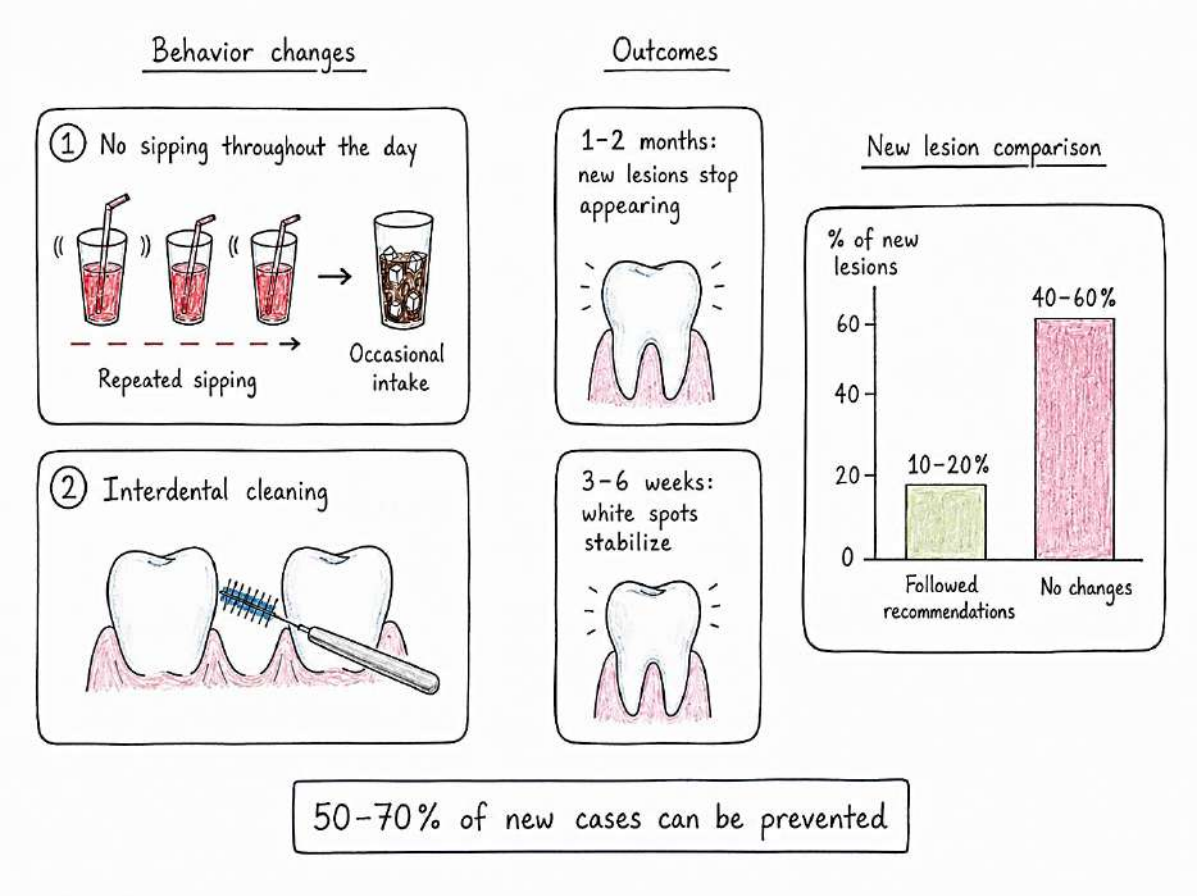


Figure 3. Clinical Outcomes After Behavioral Correction: Stabilization and Fewer New Lesions

Another patient brushed his teeth twice a day and wondered why there were four to six new lesions. The medical history revealed: a sweet drink that he sipped in small sips throughout the entire workday. This resulted in a continuous acid load that no amount of tooth brushing could compensate for. This case from Stoianov's observations clearly demonstrates: good hygiene does not protect if the frequency of acid exposure is too high. After changing just this habit, new lesions stopped appearing.

A patient complaining of dry mouth and four to six lesions, particularly in the cervical regions. The explanation appeared only after Stoianov reviewed the patient's medication history. She was regularly taking a drug for high blood

pressure that could reduce salivation. Until then, the case looked unclear: the patient did not consume much sugar and maintained good hygiene. After adding hydration recommendations and more intensive fluoride prevention, new carious lesions appeared less often.

A child with five to seven lesions. The parents did not understand the cause: they claimed there wasn't much sugar. However, the family had a habit of constant snacking and drinking sugary beverages, and toothbrushing was not monitored. After the parents changed their own habits and began monitoring the child's hygiene, no new lesions appeared over the next 6–12 months.

Stoianov also observed a patient who, despite being given recommendations when he had two or three initial lesions, made no changes and stopped coming for checkups. Within 3–6 months, the number of lesions increased to four or five, and deep cavities appeared. This case demonstrates a simple pattern: early-stage caries does not stabilize on its own without changes in the environment.

Discussion of results. **Why Dietary Habits Are More Important Than Sugar Intake.** Data from clinical observations align with the findings of the evidence-based literature: when daily sugar intake is the same, the incidence of dental caries depends on dietary habits [4, 5]. This comes as a surprise to patients, which is why Stoianov explains it in his practice without using technical terms: a tooth doesn't decay from a single piece of candy. It decays because the same situation repeats itself too often throughout the day - acid is present, but there's no time for recovery. Explaining things through a person's actual daily routine, rather than through theory, increases the chance that they will make a change.

"Healthy" foods require a separate explanation: yogurts, muesli, bars, and fruit juices have a reputation for being safe, but they contain fermentable carbohydrates and have a sticky consistency that lingers on the teeth. Frencken et al. emphasize that a preventive consultation should be part of every appointment, not an optional add-on [7].

Medications and Saliva: The Hidden Cause. The significantly higher incidence of caries among patients with reduced salivation confirms that saliva is one of the main protective factors in the oral cavity. In Stoianov's experience, it is precisely medication-induced reduced salivation that is often the hidden cause of multiple caries in a patient whose diet and hygiene appear entirely normal. Chapple et al. note that general health status and medication use are an integral part of caries risk assessment [8].

Why recommendations aren't followed and how to change that. Less than half of patients follow dietary recommendations. The main reason: people don't feel an immediate improvement and revert to their old habits. The general advice to "eat less sugar" doesn't change anything because it doesn't specify what exactly needs to be done. In his practice, Stoianov observes that when explanations are linked to consequences visible to the patient (from a stain on a tooth to darkening along the edge of a filling), and when specific changes are described rather than general principles, motivation increases significantly. It is also important to explain that results won't be seen overnight, but within a few weeks, new lesions will stop appearing.

Author's contribution. The author independently developed a structured behavioral approach to caries prevention based on personal clinical practice, comprising a behavioral caries risk assessment system, an algorithm for identifying hidden (under-reported) risk factors, and a targeted behavioral correction plan integrated into a single preventive model.

Conclusions. Clinical analysis shows that the main risk factor for dental caries is not the total amount of sugar consumed, but rather how many times a day the teeth come into contact with an acidic environment. Patients with more than four such exposures per day had 30–50% more active lesions, even if they consumed no more sugar than others. The same chocolate, eaten all at once, results in a single acidic episode; the same chocolate, spread out over several hours,

results in a series of episodes. Nighttime snacking, sipping sweet drinks slowly, and skipping evening toothbrushing are the three habits most predictably associated with the progression of caries.

In patients with dry mouth, active caries appeared much more often. Stoianov recorded it in 60–80% of such cases, while among patients without salivary problems the rate was about 20–30%. If the patient had new lesions despite normal hygiene and no obvious dietary excesses, the next step was to check what could be reducing saliva. This included regular medication, mouth breathing, chronic stress, and general health factors. Only after that was the prevention plan adjusted.

Even if the diet is fairly balanced, plaque remains a separate problem. It still has to be removed regularly. Typical areas where plaque accumulates - the cervical regions, interdental spaces, and edges of fillings - maintain an acidic environment regardless of what a person eats. The patient's subjective assessment of their hygiene almost always differs from what the plaque staining reveals during an examination. Interdental cleaning reduces the incidence of lesions by 20–40%, but it is the least followed recommendation.

Behavioral change yields measurable results. Patients who followed the recommendations had two to three times fewer new lesions than those who made no changes. The first noticeable changes appeared within 1–3 months. According to Stoianov's estimates, 50 to 70% of new caries cases can be prevented without treatment, simply by changing diet and hygiene habits. But this is only possible when discussions about diet and behavior are part of every appointment, rather than happening if there's time left.

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