

Use of a game simulator for mineral extraction to develop economic and management skills in mining students

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Abstract

The article describes the possibilities of introducing a game simulator for mineral extraction to develop economic and management skills in mining students. The authors justify the need for innovative approaches to education in the context of modern challenges facing the mining industry, in particular digitalisation, environmental requirements and the volatility of global markets. The article analyses current research in simulation training and gamification of education, demonstrating the effectiveness of gaming technologies for developing professional competencies. A conceptual model of a simulator is presented, combining educational tests, interactive geoanalytics and a step-by-step financial model. The simulator includes modules for thematic testing with a gamified reward system, an interactive map of deposits for analysing investment attractiveness, configuration of production parameters (equipment, personnel, intensity), scenario analysis of macroeconomic risks, financial planning and monitoring of results. The functionality of each simulator module is described in detail, including management decision-making mechanisms, data visualisation and a feedback system. The platform demonstrates how it helps develop business analysis, financial management, strategic planning and risk management skills in a safe virtual environment.

Keywords

simulation training, gamification of education, mining education, economic and management competencies, game simulator, mineral extraction, digital educational resources

1. Introduction

The current stage of development of higher education in Ukraine characterises a transition from traditional lecture and seminar-based teaching to innovative technologies that ensure the formation of professional competencies through practical activities. This issue is particularly acute in training specialists for the mining industry, which is strategically important for the Ukrainian economy.

Curricula are slowly adapting to changes in the industry, including digitalisation, new environmental requirements and the volatility of global raw material markets. Effective management of mining projects requires interdisciplinary knowledge, ranging from geology and ecology to finance and law. The traditional education system separates technical, economic and management disciplines, which hinders the formation of a holistic understanding of production processes. Students study geology, equipment, finance and ecology as separate subjects without understanding how they are interrelated in fundamental business processes. In addition, most curricula focus on theoretical study without the opportunity to apply knowledge in conditions close to real life. Students have no experience making investment decisions, analysing risks and managing resources.

Training using simulation technologies contributes to developing key competencies, including economic and managerial ones, through students' active participation in decision-making, scenario

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analysis, and impact assessment. This approach aligns with modern principles of competence-based learning, where knowledge is formed through experience.

2. Literature review

Contemporary research in the field of simulation training and gamification of education demonstrates a steady trend towards the integration of gaming technologies into the process of developing professional competencies among students of various specialities [1]. Researchers pay particular attention to the potential of these technologies for developing the economic and management skills of future specialists.

A significant contribution to understanding the potential of gamification in engineering education has been made by scientists [2] who have studied the implementation of game mechanics and dynamics in non-game applications for educational purposes. Their research has shown that gamification in engineering education can provide high returns both at the pre-university level and in professional practice.

Research [3] demonstrated the positive impact of gamified strategies on engineering students' motivation and academic performance. Researchers are particularly interested in using serious games in the mining industry for safety training and professional competence development. For example, Gürer et al. [4] describes a serious virtual reality game called MINING-VIRTUAL for training occupational health and safety in underground mines. Their research showed that virtual reality allows you to explore training scenarios that are impossible or potentially risky to recreate in the real world. Liang et al. [5] also describes a serious virtual reality game for teaching safety related to hazards associated with rock masses in underground mines.

In [6], a systematic review of the literature on serious game methodologies for the mining industry was conducted, and in [7], a systematic review of empirical studies of business simulation games in higher education was conducted, which demonstrated their effectiveness in actively engaging students in learning and increasing their motivation. A meta-analysis [8] showed that games and simulations positively impact learning outcomes in higher education. Three categories of learning outcomes achieved through integrating gaming technologies into the educational process were identified: cognitive, behavioural and affective.

Platz [9] has shown that digital game-based learning attracts attention in economic education because it allows abstract content to be modelled through simulation.

Despite the positive results, researchers also identify certain limitations and challenges, in particular Alhammad and Moreno [10] states that gamification should be seen as a supporting tool rather than a replacement for traditional teaching methods; research [11] found that the use of gamification can lead to improved productivity by reducing downtime and improving operational methods, as well as reducing costs by reducing the need for equipment, fuel and labour during traditional training exercises.

An analysis of the current literature [2, 3, 1, 12] shows that training using simulation technologies and gamification are promising areas for developing students' professional competencies, including economic and management competencies, where game simulators allow for the safe practice of complex decision-making in conditions of uncertainty.

The **study aims** to describe the possibilities of using a game simulator for mineral extraction to develop economic and management competencies in students of mining specialities.

3. Methodology

In preparing this article, a set of interrelated scientific methods was used to ensure an interdisciplinary approach to the research. In particular, analysis and synthesis methods were used to study individual components of the educational process in mining education and their integration into a single simulator system; the modelling method was used to build a conceptual model of a simulator aimed at developing economic and managerial competencies; the design method was used to develop the architecture and functional support of the training simulator; the gamification method was used to introduce game

mechanics to increase student motivation; the simulation modelling method was used to reproduce real business processes in the mining industry.

4. Results

As a result, a software simulator was proposed [13] that combines gamified tests, geoanalytics, and a step-by-step financial model for training and practical analysis of the profitability of mining projects. The simulator allows students to make management decisions regarding purchasing deposits, modernising equipment, staffing, setting production intensity, and assessing macroeconomic risks. Visual modules (maps, graphs, tabular reports) provide instant feedback, developing skills in business analysis, financial management, and strategic planning.

After completing the simulation in this simulator, students should be able to explain the basic concepts of the investment cycle in the mining industry (exploration → capital investment → extraction), name the main types of minerals in Ukraine and the factors that affect their market value, calculate fundamental financial indicators for a given deposit, and use scenario analysis to assess the impact of external factors (exchange rates, raw material prices, environmental regulations) on profitability.

The simulator is designed so that each student goes through the simulation independently in a browser. It should be noted that before the simulation, the teacher should give short micro-lectures (10 minutes) before each stage to help students understand the essence of the game. After each session, it is also worth conducting a discussion of the results (“debriefing”) to improve understanding of the essence of the game and exchange experiences between students. Earning additional income through separate modules is important, as it will make the game more realistic. The simulation should be conducted in two 90-minute sessions, but the time and number of sessions can be extended after testing.

Let us consider the conceptual model of the simulator (see figure 1).

Let us consider each module in detail. One of the key parts of the simulator is the educational module, presented in the form of thematic tests (figure 2). The user is asked to answer questions grouped into categories: geology, business, taxes, equipment, safety, economics, legal aspects, and ecology (see figure 3).

This approach allows students to test their knowledge in relevant areas and promotes interdisciplinary understanding of the investment process.

A reward system has been introduced to motivate students to learn: for correct answers, users receive virtual funds that can later be used in the simulation to invest in projects. In this way, the platform combines learning with game elements, providing students with theoretical knowledge and practical skills for making investment decisions in limited resources.

Figure 2 shows an example of one of the test questions from the “Ecology” category. The student is asked an applied question about the percentage of profit allocated to environmental protection measures. After selecting the correct answer, the system automatically informs the player of their success and rewards them with virtual profit – in this case, \$1,000.

This gamified approach makes the educational process interactive and practice-oriented. Learning through action encourages students to memorise information and understand how this knowledge is applied in real-life natural resource management. At the same time, the amount earned for correct answers influences the participant’s further strategic decisions in the investment simulation, increasing their interest and involvement in the process.

Another key component of the simulator is an interactive map of deposits (figure 4), which allows users to analyse the investment attractiveness of regions, considering factors such as resource quality, availability, political risks and regional characteristics.

The filters at the top allow you to customise the display by country, region, resource type and minimum rating. This helps develop analytical thinking skills when selecting the most promising locations for investment. The map shows deposits with visual indicators of risk and resource type, and the top deposits by rating are displayed on the right – for example, “Gas Field East”, “Lithium Future”, and “Golden Field”.

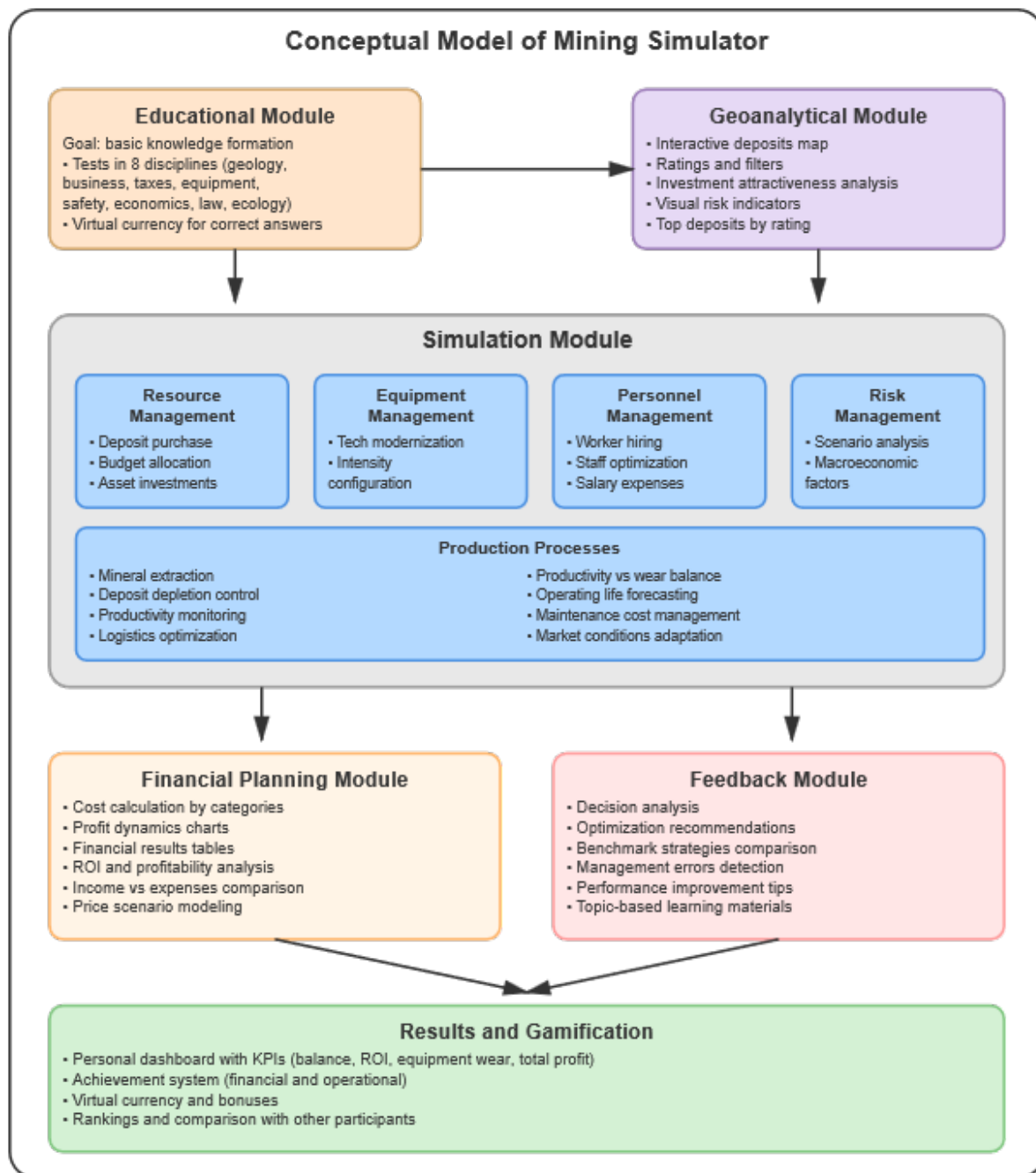


Figure 1: Conceptual model of the simulator.

This approach helps students simulate real-life processes of geoeconomic data analysis and decision-making in natural resource use and extraction.

At the stage of purchasing a deposit, the user receives detailed information about the object (see figure 5), including its coordinates, resource type (in this case, graphite), and projected indicators: volume (90,000 tonnes), volatility (25%), and expected collection rate (14%). These characteristics help to assess the potential profitability and riskiness of the investment.

The user can independently form a starting set of resources necessary for extraction: select the number of excavators, trucks, separators, and personnel. Each type of investment has its own cost, which affects the total amount of the initial capital investment. In the example in figure 5, the total cost is \$145,000 with an available balance of \$500,000.

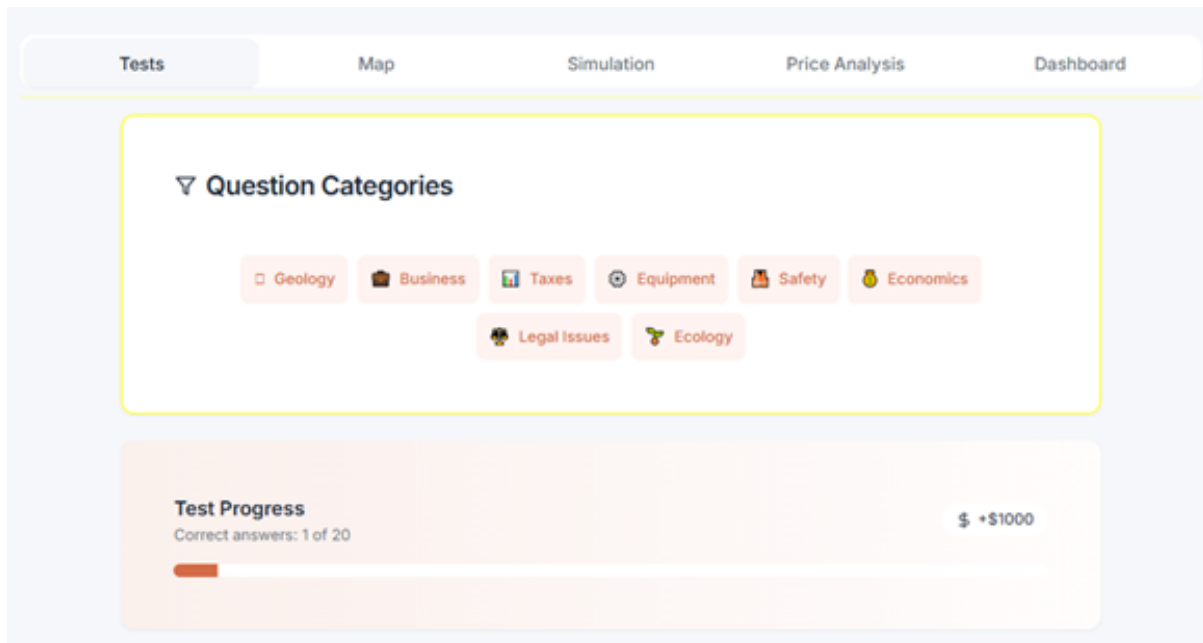


Figure 2: Educational component of the mineral extraction simulator.

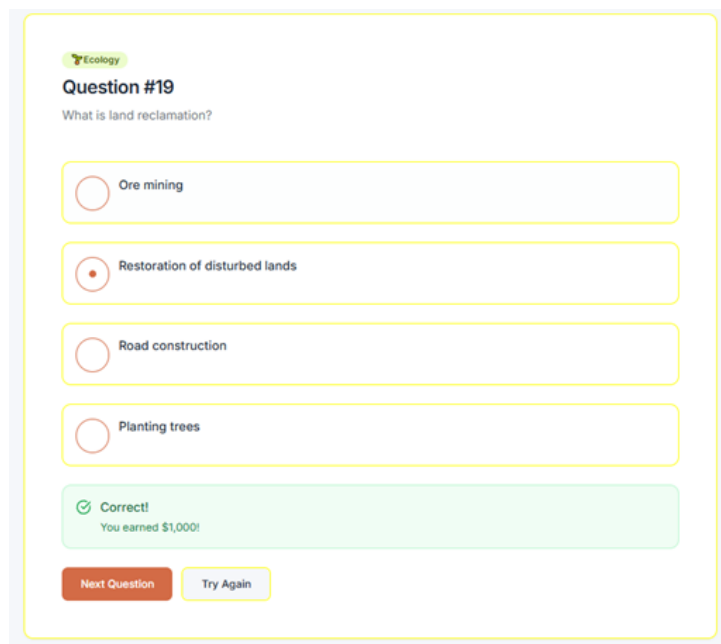


Figure 3: Test questions.

This feature allows students to simulate resource allocation scenarios, evaluate the effectiveness of different strategies, and learn to plan investments within a limited budget.

After a deposit is acquired, its mark on the interactive map changes colour to green (figure 6). This allows users to quickly identify which objects already belong to them and control the geographical location of their assets.

This visual indicator simplifies strategic planning, as users can see the distribution of resources on the map, assess the concentration of their investments, consider risks, and make decisions about further purchases. Colour differentiation makes the simulator easier to use and helps users better understand their progress in the game.

After purchasing a deposit, the user can upgrade equipment, directly affecting the extraction efficiency

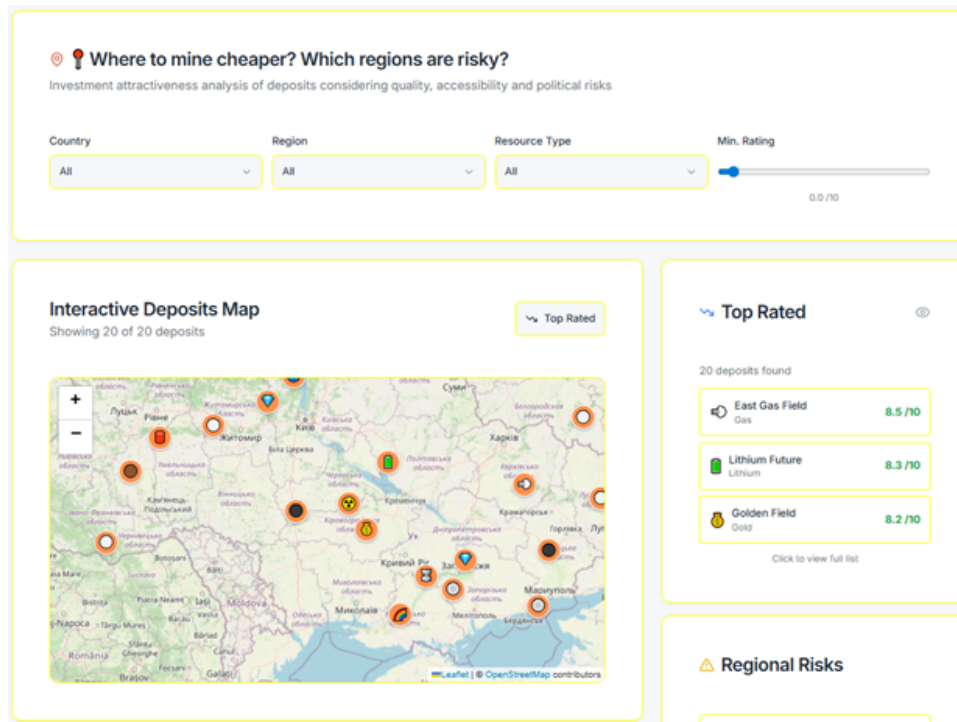


Figure 4: Interactive map of the mineral extraction simulator.

Diamond Royal ✕

Coordinates: 50.7800 , 29.4500

Diamonds **Hard**

Volume	Volat.	Fee
8,500 tons	65 %	30 %

Initial Investments

Excavator \$ 50,000 /unit - 1 +	Truck \$ 30,000 /unit - 1 +
Separator \$ 40,000 /unit - 1 +	Personnel \$ 5,000 /unit - 5 +

\$ Total Cost: \$ 145,000

Current Balance: \$ 356,000

Buy Deposit

Figure 5: Field settings.

(figure 7). In this case, we consider the “Excavators” category, where three options are available: basic, improved, and premium.

Interactive Deposits Map

Showing 20 of 20 deposits

Top Rated

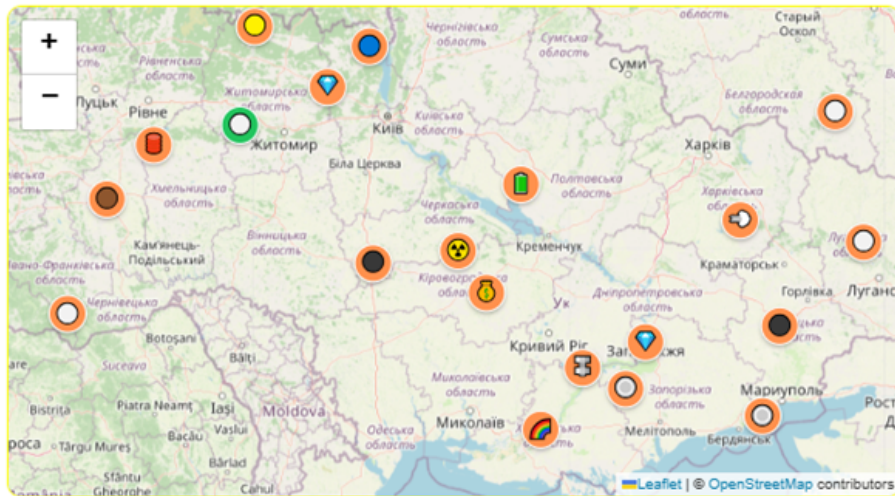


Figure 6: Change of icon for purchased deposit.

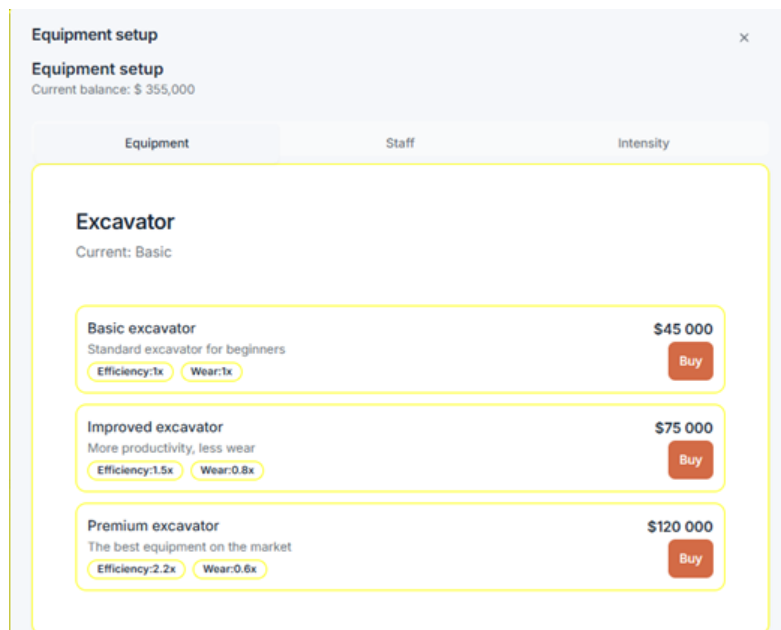


Figure 7: Equipment settings.

Each model has its characteristics in terms of efficiency and wear. For example, a premium excavator costs \$120,000 but offers the highest productivity (2.2x) and lowest wear (0.6x), which can significantly reduce operating costs in the long term. At the same time, the basic model is cheaper but less efficient and wears out faster.

This module allows students to independently weigh costs and benefits, make informed capital investment decisions, and thus develop strategic resource management skills in the mineral industry.

Another important step in optimising a deposit is adjusting the number of personnel for extraction (figure 8). The user can select the desired number of employees at a fixed rate of \$5,000 per employee per month. Depending on the strategy, you can hire between 5 and 30 people, adapting the scale of operations to your budget.

Equipment setup

Equipment setup
Current balance: \$ 355,000

Equipment **Staff** Intensity

Staff
Adjust the number of personnel for mining

Staff (\$ 5000 /month)

5 people (\$ 5,000 /month) 5 people (\$ 5,000 /month)

Cancel Save changes

Figure 8: Personnel settings.

This decision affects both productivity and costs. For example, more personnel allow for faster extraction but increase monthly costs. Thus, the player faces a typical management task – balancing resource capabilities and economic feasibility.

The module explains the role of human capital in the extractive industry and helps students develop cost management skills.

The simulator allows you to adjust the intensity of equipment operation to model production processes in greater depth (figure 9).

Equipment Personnel **Intensity**

Mining intensity
Select the equipment operating mode

Low intensity
Economical operating mode
Productivity: 0.7x Wear: 0.5x

Medium intensity
Standard operating mode
Productivity: 1x Wear: 1x

High intensity
Maximum performance
Productivity: 1.4x Wear: 1.8x

Figure 9: Intensity settings.

The user can choose one of three modes: low, medium or high intensity. Each mode affects the extraction performance and the level of equipment wear. Low intensity provides an economical mode of operation with minimal wear (0.5x) and reduced performance (0.7x). Medium intensity is the standard balance between efficiency (1x) and maintenance costs (1x). High intensity maximises extraction (1.4x) but significantly accelerates equipment wear (1.8x).

This tool teaches users to consider the long-term consequences of operational decisions, emphasising

the importance of balancing profit, speed and equipment maintenance costs.

To bring the simulation closer to real business conditions, the platform provides scenario analysis of the impact of external economic factors on profitability (figure 10).

⚠ Economic risk model

Scenario analysis of the impact of external factors on the profitability of operations

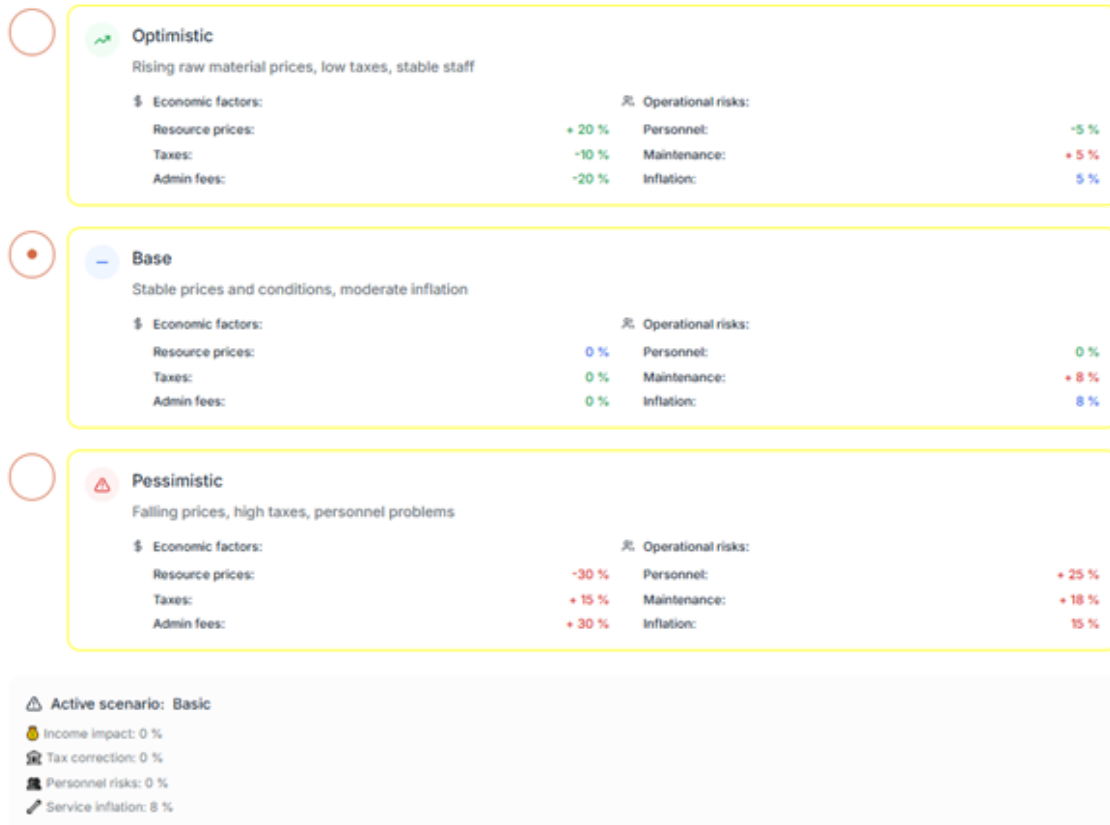


Figure 10: Intensity settings.

The user can choose one of three scenarios. The first is optimistic, assuming a favourable market situation with rising resource prices (+20%), lower taxes (-10%) and administrative costs (-20%), stable staffing levels and moderate maintenance costs. The next is the baseline scenario, which is characterised by stable conditions, no changes in key economic indicators, but with moderate inflation (8%) and maintenance costs (8%). Moreover, finally, the pessimistic scenario shows a challenging market situation with falling raw material prices (-30%), high taxes (+15%) and staffing problems (+25%), which significantly affect costs and profitability. This module teaches students to consider macroeconomic risks when investing, analyse scenarios and develop adaptive business strategies.

The financial planning module provides a detailed review of expenses by category (figure 11). The user can see the structure of monthly expenses broken down by key factors (equipment, salaries, fuel, licences and logistics). Each category has a corresponding label, colour indication and specified amount.

This approach makes it easy to analyse the financial model and identify potential sources of savings. For example, in the case shown, the largest share is accounted for by equipment costs (\$15,000) and salaries (\$12,000), which may influence strategic decisions regarding equipment upgrades or staff optimisation.

This feature helps students develop financial management skills, such as tracking expenses, finding a balance between investment and savings, and assessing the impact of each category on overall business profitability.

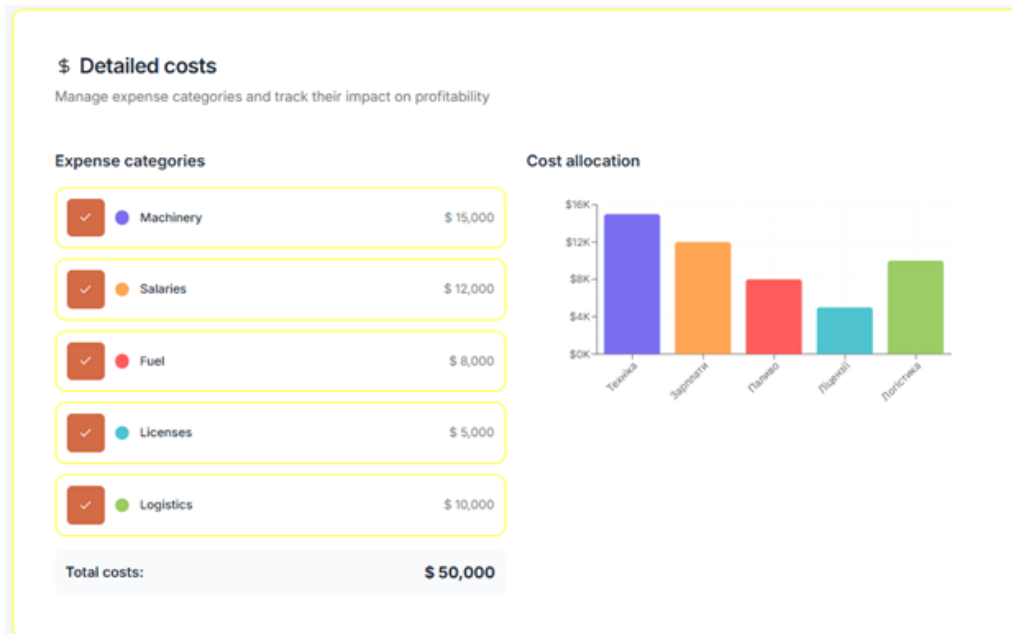


Figure 11: Visualisation of expenses.

The final part of the simulation focuses on monitoring long-term results (figure 12). The upper block shows the degree of depletion of the deposit (in this example, 95.9% of reserves remain). The user also sees a forecast, which indicates that at the current level of resource extraction, reserves will last for 140 months. This indicator encourages strategic planning, which involves answering questions about accelerating extraction or maintaining a steady pace.

Below is a profit dynamics chart showing monthly income and accumulated balance. This allows the user to analyse the impact of previous decisions (equipment, personnel, intensity, risk scenarios) on the financial result. The graph provides feedback, which is important for learning the basics of business analysis.

The final stage of the simulation is presented in a summary table of monthly operating results (figure 13). It shows key performance indicators: production volume, revenue, expenses, net profit, and current balance.

This format makes it easy to analyse performance trends, identify the relationship between production volume and profit, and assess the stability of financial results. For example, in the second month, the maximum revenue was \$529,340, and the profit was \$465,111, which significantly affected the growth of the total balance.

This block teaches students to work with financial statements, analyse profitability indicators, and make informed decisions based on data. It is important to develop project management skills for highly complex projects.

The simulator also has a “Price Analysis” tab, which allows the user to simulate changes in profit depending on key production and market parameters (figure 14). In this module, the type of mineral (in the example – coal), the base price (\$120/tonne) and the level of demand (1,000 units) are selected.

Below are the production parameters that can be changed using sliders (production volume, fixed costs (e.g., \$50,000), and variable costs per unit (e.g., \$30)). Based on the values entered, the system calculates efficiency (in this case, 89%), helping to understand how profitable the production process will be under current conditions.

This block performs an important educational function, as it helps students understand the financial model of an enterprise and the impact of changes in raw material costs, expenses, and production volume on the final result. Students learn not only to assess the market, but also to adapt to it in conditions of instability.

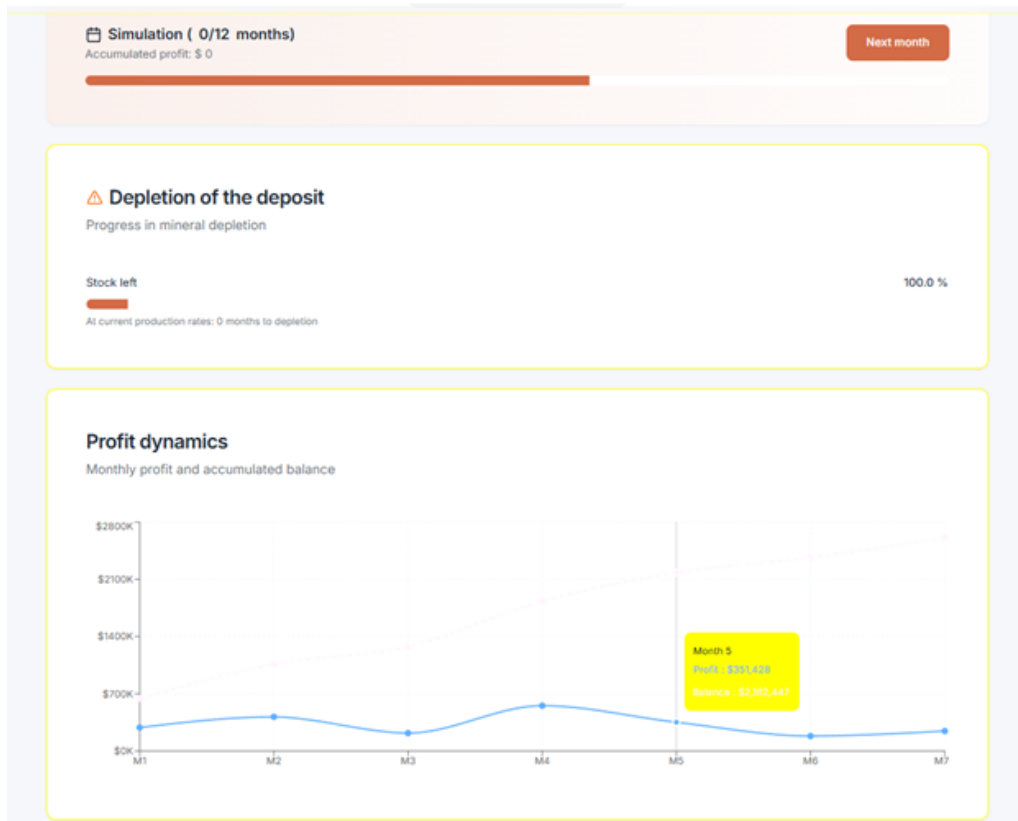


Figure 12: Step-by-step simulation.

Mining results
Monthly profitability indicators of the operation

Month	Extracted (t)	Income (\$)	Costs (\$)	Profit (\$)	Balance (\$)
1	2,290	292,603	62,327	+ 230 275	585 275
2	1,466	247,902	63,996	+ 183 906	769,181
3	2,598	520,303	64,975	+ 455 328	1,224,509
4	2,036	344,889	68,114	+ 276 774	1,501,283
5	2,129	476,804	67,944	+ 408 860	1,910,143
6	1,528	294,593	64,554	+ 230 038	2,140,181
7	2,369	317 321	66,156	+ 251 165	2,391,346
8	1,734	334,952	68,147	+ 266 804	2,658,150
9	1,618	232,393	66,863	+ 165 529	2,823,679
10	1,675	343,551	66,510	+ 277 040	3,100,719
11	2,579	447,817	67,415	+ 380 401	3,481,120

Figure 13: Results in table form.

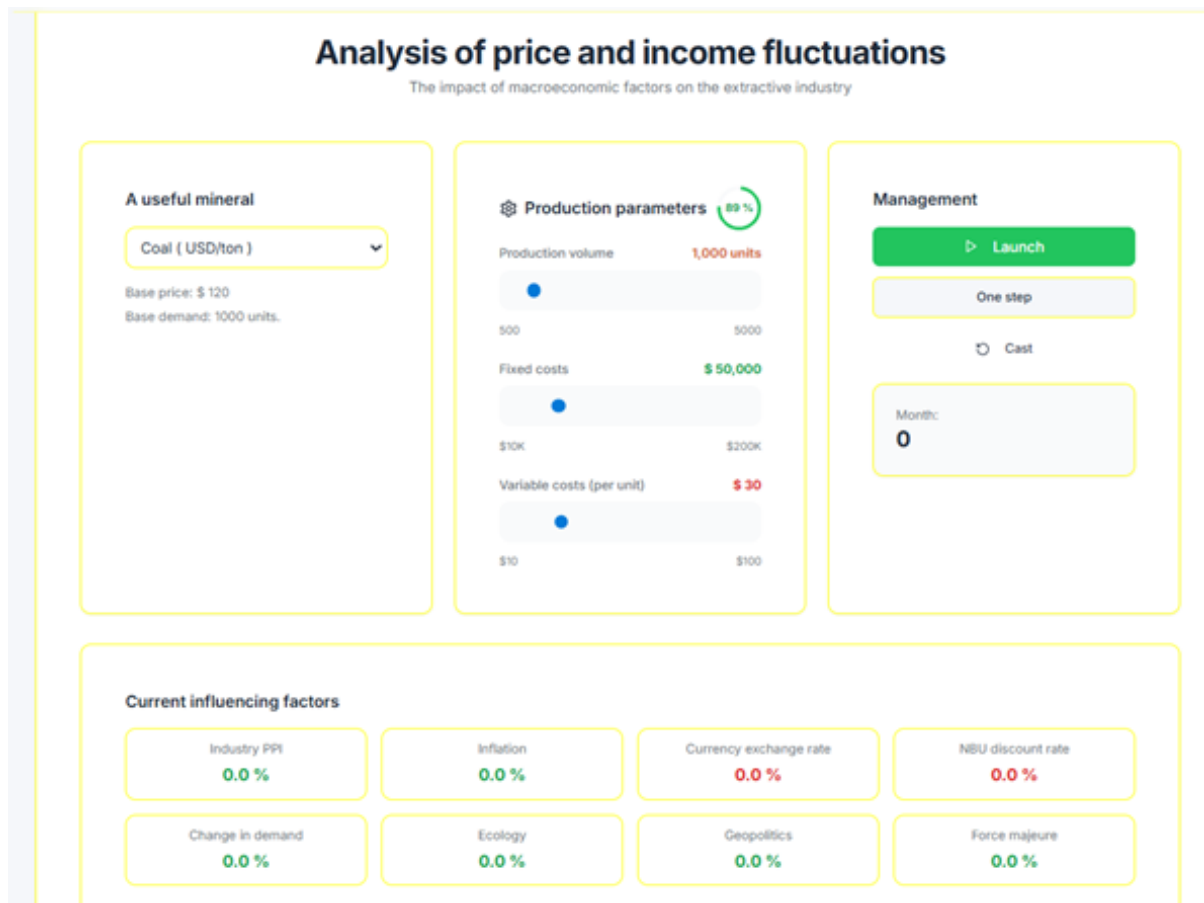


Figure 14: Analysis of price and income fluctuations.

At the final stage of the simulation, participants gain access to analytical graphs that allow them to assess the impact of external and internal factors on performance (figure 15).

The first graph shows the dynamics of coal prices, one of the primary resources in the model. Both short-term fluctuations and the general trend are visible. This allows you to assess market volatility and adapt your production and sales strategy.

The second graph compares revenues, expenses, and profits by month. This visualisation allows you to quickly identify periods of growth or decline in profitability and understand which expenses most impact the result.

These graphs teach students to work with business analytics, see cause-and-effect relationships between economic indicators, and adapt their decisions to changes in the external environment.

The final block of the simulator is the user's personal account, which provides summary information about the project's financial status, the technical condition of the equipment, and the player's level of achievement (figure 16).

The upper block displays key indicators such as current balance (\$2,092,702), ROI (return on investment) – an impressive 1298.4%, equipment depreciation – 50%, and total profit – \$1,882,702. Below is the achievement system, which is divided into financial (e.g., “First Million”, “Investor of the Year”) and operational (e.g., “First Production”, “Employer”, “Logistician”). This gamified element stimulates user progress and helps evaluate their strategic and management skills.

The dashboard is not only a summary block but also a motivational tool that shows the success of decisions made through achievements and financial metrics.

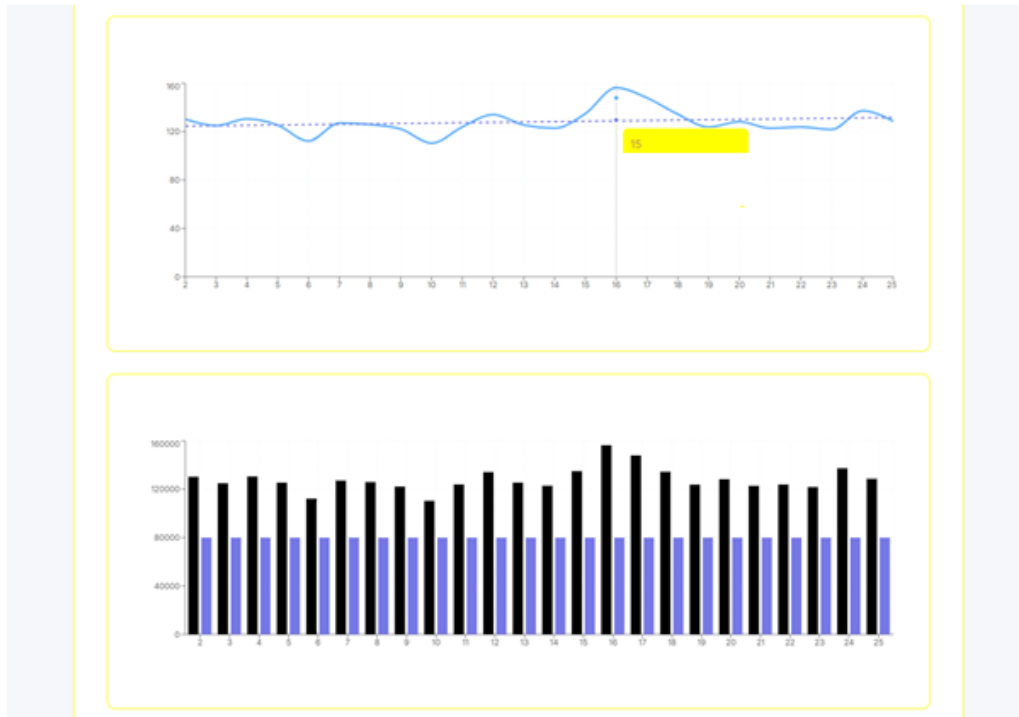


Figure 15: Analysis of price and income fluctuations.

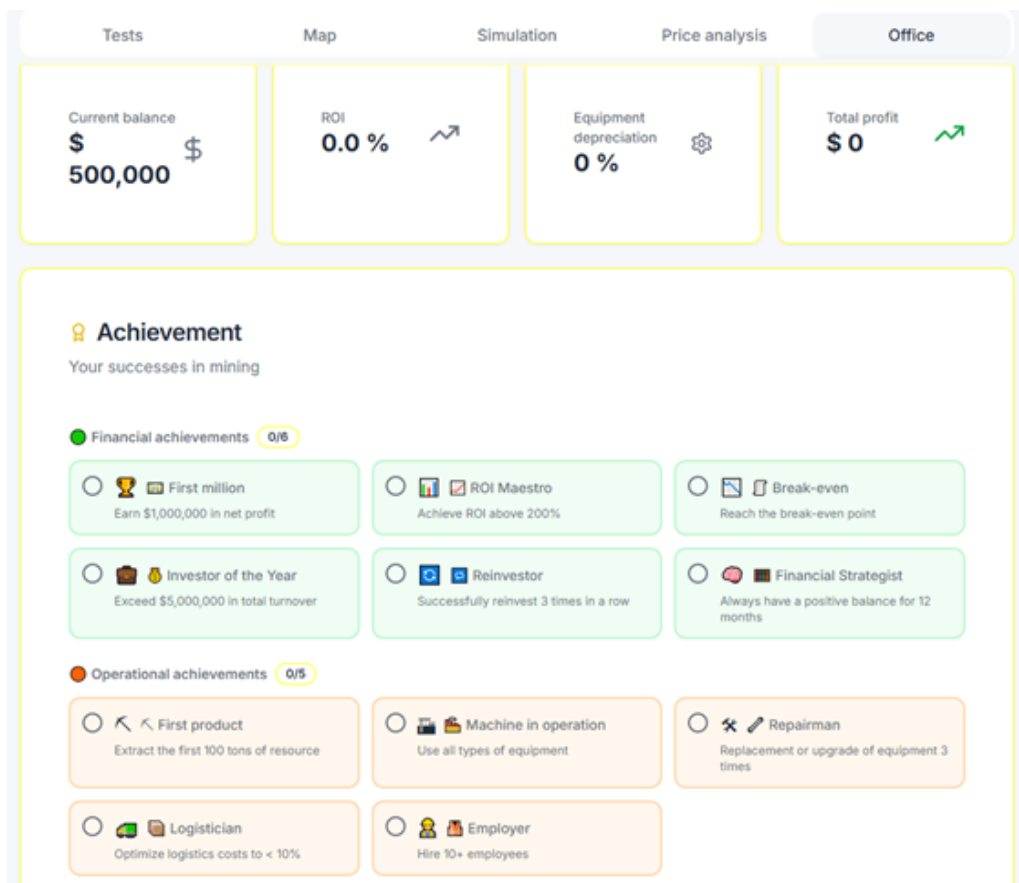


Figure 16: Gamified achievements.

5. Conclusions

The developed game simulator of mineral extraction demonstrates a new approach to forming economic and managerial competencies in mining students through integrating theoretical knowledge with practical experience in managerial decision-making. Such integration provides students with a comprehensive understanding of production processes in the mining industry, which is critical for modern specialists.

The simulator provides practice-oriented training, allowing students to gain experience in assessing the investment attractiveness of deposits, planning and allocating resources, managing personnel and equipment, conducting scenario risk analysis, and making decisions in conditions of market uncertainty. Working with the simulator helps develop economic and management competencies, including financial management skills through cost and profitability analysis, strategic thinking through long-term production planning, analytical skills through data visualisation and key performance indicators, etc.

Students also develop an understanding of the cause-and-effect relationships between management decisions and economic outcomes. An important aspect is the increase in motivation to learn through gamification elements. The achievement system, virtual currency, and rankings create additional incentives for in-depth study of the material and experimentation with different management strategies.

At the same time, the simulator provides a safe environment for experimentation. Students can test different management approaches without real financial risks, analysing the consequences of their decisions through instant feedback.

The developed simulator's practical significance lies in its ability to be integrated into mining training programmes as a tool for practical classes, independent student work, and assessment of professional competence. The proposed approach meets the modern requirements of the competence-based approach in education and can become an effective tool for training competitive specialists for Ukraine's mining industry.

Prospects for further research include conducting experimental testing of the simulator with measurement of the effectiveness of competence formation, expanding the functionality for modelling international markets and global economic crises, adapting the simulator for other extractive industries, and integrating elements of artificial intelligence to personalise students' learning trajectories.

Author contributions

Conceptualization, Denys V. Furikhata and Yana Hladyshchuk; literature review – Yana Hladyshchuk, Dmytro S. Antoniuk, Iurii M. Iefremov; methodology, Tetiana A. Vakaliuk and Dmytro S. Antoniuk; modelling – Tetiana A. Vakaliuk and Denys V. Furikhata; software, Denys V. Furikhata and Iurii M. Iefremov; writing – original draft, Denys V. Furikhata; writing – review and editing, Tetiana A. Vakaliuk. All authors have read and agreed to the published version of the manuscript.

Declaration on Generative AI

The authors used Claude Opus 4 to translate the article from Ukrainian into English.

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