Towards Development of Innovative Software Platform for Serious Educational Games with Creative Visualization in Selected Eco-context

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Abstract. The application of new digital technologies for a sustainable society has a long-term effect on the environment and the quality of life of present and future generations. Achieving sustainable natural resource management through modern digital technologies starts with awareness raising and education. It is imperative to develop innovative digital solutions with high added value and educational initiatives that equip the younger generation to become responsible environmental stewards. In the frame of ProNature project in 2024, the development of an innovative software platform for serious educational games with creative visualization to build competence on natural ecosystems, responsible management of natural resources and environmental protection, started. With the built software platform and based on created educational game scenarios, demonstration serious educational games with creative visualization will be created in a selected eco-context. This paper targets the design and development of the ProNature platform, highlighting its modular architecture and the role of the game scenario module in facilitating the creation of adaptable and reusable educational games. The paper also discusses several learning scenarios of a serious educational game and their formalization, considering their key role in the development process.

Keywords: Serious Educational Games, Game-based Learning, Environmental Education, Platform for Serious Games Development, Learning (Game) Scenarios, Creative Visualization, Green and Digital Technologies.

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1 Introduction

The rapid development of digital and green transition is an essential feature of modern society. The application of new digital technologies in favour of a green society has a long-term effect on environmental protection and the quality of life of present and future generations. It creates a balance between social, economic and environmental factors and provides new technological tools for the management of natural resources and biodiversity, for sustainable development, responsible production and consumption of resources and action on climate and life on earth (Caeiro-Rodríguez et al., 2022; Tan & Nurul-Asna, 2023; Ahmadov et al., 2024; Tene et al., 2025).

Sustainable natural resource management through modern digital technologies naturally starts with awareness raising and education. It is essential to develop innovative digital solutions and educational initiatives that prepare the younger generation to eventually become responsible actors related to environmental sustainability in all aspects of life and society. Educating the younger generation to adopt a responsible attitude towards natural resources and their management requires the development of scientific and technical knowledge about the functioning of ecosystems and their impact on life. It requires critical and analytical thinking, innovative attitudes to design environmentally sustainable solutions, and the ability to collaborate in multidisciplinary teams to achieve specific goals. Although digital tools exist that contribute to natural resource management, much more can be done to enrich environmental education through new digital technologies (Flood et al., 2018; Boncu et al., 2022; Tsalapatas et al., 2023).

The main goal of the current ProNature project is to conduct research and develop new technological solutions for an innovative software platform for serious educational games with creative visualization with TRL 7 to build competence for natural ecosystems, responsible natural resource management and environmental protection (Luchev et al., 2024). With the software platform and based on the game educational scenarios created, the specific objective of developing demonstrations of serious educational games with creative visualization in selected eco-context and social impact will be achieved. Through its relevance and innovation potential the proposed technological solutions will significantly advance new digital technologies in the creative industry for the benefit of an eco-friendly society. The project will contribute to the formation of innovative thinking in solving the problems of the future towards sustainable management practices in industry and social life. Section 2 of this paper presents opportunities for serious educational games to provide innovative learning. Sections 3 discusses several learning scenarios for serious educational games with creative visualization in natural eco-context, developed as research results of the ProNature project. Section 4 presents motivation and choice of content in the scenarios in terms of environmental education, as well as formalization and specification of the scenarios. Section 5 describes the architecture and core functionality of the software platform for serious educational games with creative visualization in selected eco-context.

2 Serious Educational Games as Innovative Education Tools

Contemporary serious educational games are similar to interactive system or simulator type games, developed using game technology and design principles, which are usually designed for learning purposes and rely on the added pedagogical value of fun and competition. Understanding the role of computer games, technologies, media, tools, experiences and target objects can significantly improve the visibility of the creative industries sector and the potential for innovation in the context of an eco-friendly society (Graser & Böhm, 2022; Ahmadov et al., 2024).

Given that popular computer games can raise awareness, attract interest and increase the popularity of embedded virtual reality content, more efforts should be made to use games in a broader perspective and benefit (Ofosu-Ampong, 2020; Kobari et al., 2022; P K et al., 2023). There is a lack of data and evaluations on the potential of games for creativity, effective learning and the acquisition of useful knowledge and skills about natural resources and environmental protection (Hamari et al., 2014; Qian & Clark, 2016; All et al., 2016; Chugh & Turnbull, 2023). Thanks to their sophisticated interactivity and multimedia interfaces, today's serious educational games convey complex concepts and facts in a widely accessible and engaging way (Knox, 2023; Dahalan et al., 2024; Karimov et al., 2024; Sun et al., 2024). The rapid development of virtual and mixed reality games provides additional opportunities for collaboration and teamwork, critical thinking, problem solving, flexibility and adaptability, global and social awareness, information and technology literacy, leadership, communication, initiative, social responsibility and ethics (Lee et al., 2024; Lampropoulos & Kinshuk, 2024; Zakrzewski et al., 2025; Nguyen-Viet & Nguyen-Viet, 2025).

Gamification and computer games are now an integral part of the information age. The unprecedented proliferation of digital games is becoming a key component of culture and society (Bertacchini & Borrione, 2012; Cerezo-Pizarro et al., 2023). It has a profound impact on social trends by legitimising the bridging of gaps in scientific knowledge on the impact of games on society on the one hand, and on the other hand, necessitating the provision of digital gaming solutions with high added value (Mohd et al., 2023).

Non-commercial serious educational games occupy a certain place in the gaming space (Solinska-Nowak et al., 2018; Pueyo-Ros et al., 2023). A good example of non-commercial serious educational games developed by the team of this project and created in Bulgaria, are the games "Thracians" and "Aquae Calidae" (Paneva-Marinova et al., 2022a; Paneva-Marinova et al., 2022b; Zlatkov et al., 2019; Pavlov et al., 2021). In these games, by immersing themselves in the virtual 3D reality of ancient archaeological complexes, learners can play intuitive mini-games and improve their historical knowledge and understanding of ancient inhabitants and Balkan civilizations. In the field of ecology, we would like to mention the European project Nature, which relies on digital gaming solutions to build the capacity of higher education students and their teachers to adopt responsible behaviour with regard to natural resource management. In addition, it is important to mention the European project B-Green-ED (Boosting the Green Future via University Micro-Credentials) (B-Green-ED, 2022) with participants

from the team of this project, which aims to stimulate the European green economy and climate neutrality through the development of innovative teaching practices. Improving awareness of green and digital transition related standards and their fields of activity by providing open educational resources supporting the acquisition of knowledge and skills on industry related environmental, governance and green standards is reported as a key outcome.

3 Learning Scenarios for Serious Educational Games with Creative Visualization in Natural Eco-context

Three educational game scenarios have been developed, each designed to support environmental education through engaging, interactive gameplay (Goynov et al., 2025). All scenarios are set within the context of Atanasovsko Lake, a protected ecosystem in Bulgaria, known for its exceptional biodiversity. The games are intended to raise awareness, foster ecological knowledge, and cultivate responsible attitudes toward the environment, particularly among young learners.

As part of an educational initiative to promote environmental awareness, three interactive game scenarios have been developed, with a fourth currently in the works. Each scenario immerses players in the rich natural world of Atanasovsko Lake, a unique protected area along Bulgaria's Black Sea coast that is renowned for its exceptional biodiversity. These scenarios blend educational goals with engaging game mechanics, transforming scientific and ecological knowledge into meaningful, story-driven experiences for learners. The games based on the developed scenarios are intended to raise awareness, foster ecological knowledge, and cultivate responsible attitudes toward the environment, particularly among young learners. Below is provided brief description of the developed scenarios.

Scenario 1: *Atanasovsko Lake and Its Inhabitants: The main educational focus of this scenario is to introduce the players to the lake's key wildlife species, particularly protected birds.*

In this scenario, players embark on an interactive journey through Atanasovsko Lake, exploring its diverse landscape across different seasons. The learning goal is to enhance the player's ecological awareness regarding the functioning of protected ecosystems. The game introduces them to the lake's most iconic bird species, including the Dalmatian pelican, pied avocet, shelduck, white-tailed eagle, and common tern. Each species is depicted through detailed 2D and 3D visuals, sound, and narrative elements. The gameplay follows a cyclical ecological calendar, highlighting key periods such as winter resting, spring migrations, nesting, feeding, and chick-rearing seasons. Players learn about the distinctive characteristics, habitats, nesting behaviors, dietary needs, and threats faced by each species. By interacting with these elements, players develop a systems-thinking approach to biodiversity, gaining a deeper understanding of the complex interdependence within the ecosystem.

Scenario 2: *Life in the Lake – An Ecosystem Shared by Birds and Humans: This scenario is focused on the sustainable human use of the lake's natural resources, specifically salt harvesting, and on the biology and ecology of various bird species during their breeding season.*

This scenario highlights how Atanasovsko Lake is not only a crucial habitat for birds but also a space where humans have sustainably harvested salt for centuries. Players will explore how the lake's shallow, saline waters—engineered into salt pans—support both biodiversity and a local economy based on traditional practices. The main goal is for players to understand the delicate balance between human activity and natural ecosystems through visual storytelling, knowledge exploration, and interactive simulations. Engaging mini-games and narratives will help learners uncover the steps involved in salt production and discover how the lake's unique management strategies help preserve breeding grounds for birds. In the second sub-level, the focus shifts to bird reproduction, where players will learn to identify nests, eggs, and the various strategies species use to raise their young. They will follow the life cycles of individual birds and reflect on the environmental conditions necessary for successful nesting and survival.

Scenario 3: *Enemies and Allies of the Lake and Its Birds: Depicting threats to the ecosystem—predators, human interference, and pollution.*

This scenario introduces a layer of challenge and urgency, confronting players with real-world threats to the ecosystem. Through dynamic scenes and simulations, players encounter dangers such as habitat destruction, climate change, invasive predators (including jackals, foxes, and feral dogs), pollution, and careless human activity. The focus on visualizing ecological problems and actively engaging with potential solutions contributes to a deeper understanding of habitat conservation and the importance of environmental protection. Players are tasked with assessing risks and making decisions to preserve nesting areas, manage human infrastructure, and educate local communities. These responsibilities require critical thinking and strategic planning, emphasizing the role of human stewardship in ecological protection.

Scenario 4: *The Migration of Birds: The context of this scenario is focused on improving the understanding of the functioning of protected ecosystems, sustainable use, conservation, and management of natural resources, prevention and control of environmental pollution, and protection and response to critical threats to biodiversity and natural ecosystems.*

In this scenario, players follow the migratory paths of various bird species that pass through or rely on Atanasovsko Lake as a stopover during their long-distance seasonal journeys. The game immerses learners in the spectacular phenomenon of bird migration—an ancient, instinctual cycle driven by the need for survival, reproduction, and resource optimization. As the game progresses, players discover that Atanasovsko Lake, due to its strategic location along the Via Pontica, plays a crucial role in the survival of countless migratory birds. It serves as an essential resting and feeding ground during their journeys between Northern Europe and Africa. This natural "airport" for

birds becomes a key setting where players monitor, assist, and analyze migratory movements.

Together, these three scenarios create a cohesive learning experience—beginning with observation and exploration, progressing through human-nature interaction, and culminating in active conservation and problem-solving. They enable learners to experience firsthand how ecosystems function, why they are important, and how we can all contribute to their preservation.

4 Motivation and Content Selection of Learning Scenarios for Serious Educational Games with Creative Visualization in Natural Eco-context

The primary motivation behind the development of these scenarios stems from the growing need to make environmental education more dynamic, accessible, and meaningful. Rather than relying on traditional, passive learning approaches, these educational games use storytelling, role-play, and interactivity to immerse learners in real ecological situations. By placing players in the roles of protectors, researchers, and observers of the ecosystem, the games aim to stimulate curiosity, empathy, and responsibility. This approach makes the abstract concepts of biodiversity, conservation, and ecosystem balance tangible and emotionally resonant.

The principles of relevance, authenticity, and cross-curricular integration guided the content selection (Goynov et al., 2025). Real-world ecological data from Atanasovsko Lake, including species profiles, ecosystem dynamics, seasonal changes, and human impacts, were incorporated to ensure scientific credibility and contextual accuracy. The lake itself serves as a microcosm of larger environmental issues, making it an ideal setting for immersive, place-based learning.

The educational focus is not only on recognising endangered species but also on understanding the complex relationships between organisms and their habitats, the impact of human activity, and the importance of sustainable resource use. Topics such as salt harvesting, migratory bird behaviour, and habitat threats are explored through richly illustrated, interactive tasks that encourage exploration and decision-making.

4.1 Formalisation and Specification of the Scenarios

Each game scenario is carefully structured and formalised to meet clear pedagogical objectives aligned with the national educational standards. The scenarios are designed with both game mechanics and educational methodology in mind, ensuring a balance between learning outcomes and engaging gameplay.

Each scenario encompasses a set of key formal elements, including:

- Defined Learning Objectives: Every level or activity is tied to specific cognitive and affective goals, such as increasing knowledge of protected species, understanding food webs, or identifying ecological threats.

- Scenario Structure: Each scenario is broken down into thematic levels (e.g., habitat exploration, food sources, reproduction, threats), each with a logical progression and increasing complexity.
- Interactive Environments: Players interact with 2D and/or 3D representations of Atanasovsko Lake and its wildlife. These visual environments are enhanced with audio narration, text, animations, and sounds that help bring the ecosystem to life.
- Active Learning Mechanics: Engage with the material through quizzes, puzzles, matching tasks, simulations, and open-ended exploration. For example, place bird nests in appropriate locations, select the right food for each bird species, or identify environmental threats.
- Feedback and Assessment: Player performance is tracked through indicators such as "Knowledge Level" and "Points," which provide continuous feedback and motivate learners to explore and learn more.
- Content Modularity and Scalability: Each scenario is modular, allowing for the integration of future content (e.g., new bird species, conservation challenges) or adaptation to different age groups and educational settings.
- Cross-disciplinary Potential: The scenarios combine elements of biology, geography, environmental science, digital literacy, and ethics, making them suitable for interdisciplinary curricula.

Ultimately, the game scenarios are not only tools for information transfer but also interactive learning environments that support the development of systems thinking, critical analysis, and ecological empathy—skills that are vital in educating future generations of environmentally responsible citizens.

5 Requirements and Specification of a Software Platform for Serious Educational Games with Creative Visualization in Selected Eco-context

The work on the design and construction of the software platform for serious educational games ProNature started with the specification of the software requirements to create a clearly defined foundation for the subsequent implementation of the system and its modules. The specification serves as a basis for the creation of the test scenarios that will be used to verify and validate the system's performance in the relevant stage of its development.

The software requirements shall be divided into major groups for further detailing in the functional specification. Some software requirements are presented in the following Table 1.

Table 1: Software requirements for the ProNature software platform.

Use cases	Description
Associate Active Points	Associating active points with game
Game Object Visualization	Visualizing game objects in the game creation process
Actions	Defining possible actions (and required resources) to each task
Define Active Points	Defining active points in the environment type object
Define Mission/Level	Adding/editing a level or mission to the game scenario
Add Game Object	Adding a Game object
Tasks	Defining tasks that will be used to reach the solution to the problem
Game rules	Defining game rules
Game scenario selection	Selection of a game scenario based on the already created scenarios
Environment object selection	Selection of an environment type object - a panorama of a real geographical area, a 3D representation or an interactive map of an area.
GameObject deletion	Deleting a GameObject
Inventory	Defining an inventory - auxiliary tools, through which the player will be able to perform the assigned tasks
Success criteria	Defining the criteria for successful completion of a mission/game
Evaluation mechanism and bonuses	Defining a mechanism for evaluation, bonuses, achievements, trophies, rewarding players
Player experience	Defining the player's experience, depending on the missions/tasks completed
Task sequence	Defining a task tree (sequence), according to the possible actions/results
View GameObject	Game object view

View GameObject	Game object view in the game creation process
Problem	Defining a problem to be solved
Edit GameObject	Editing a game object
Results	Defining possible outcomes (and resources acquired - knowledge, skills, etc.) to each action
Resources	Defining resources (and ways of acquiring) available to the player (money, energy, knowledge, etc.).
GameObject Selection	Selection of game objects in the game creation process
Create Game	Create, manage, view, delete, copy a game
Manage GameObject	Brings together all game object management activities
Manage Scenarios	Add, edit, view, delete, copy scenarios

In addition, the Specification defines both functional requirements for the system, including all use cases that need to be implemented, and non-functional requirements, which largely focus on the quality of the software product created. Such non-functional requirements are:

- *Performance*

The platform must meet current best practices for performance. Average screen load time should not exceed 1 second. After implementation, the system should be subjected to load and stress tests to confirm its stability.

The platform must meet the minimum requirements of the independent Google PageSpeed Insights (https://pagespeed.web.dev/)

- *Scalability*

The platform must be designed and implemented in such a way as to ensure that high performance is maintained regardless of the increase in the number of users, game scenarios, games, assets in the game object repository, usability of the system.

Any new system slowdown must be able to be compensated by a corresponding proportional increase in hardware resources.

- *Security*

The architecture of the platform must take into account all best practices to ensure the highest level of security, as well as the requirements of the European Union related to data protection, user profiles, sensitive information, etc.

After the implementation of the system, it is necessary to test it for vulnerabilities and, if there are any problems, to fix them in a timely manner.

The system must meet the requirements of the independent website verification platform Mozilla Observatory (https://observatory.mozilla.org/)

- *Maintenance*

The system must provide administrators with as easy and convenient access as possible to the modules related to its maintenance and all necessary activities related to its proper functioning. All activities not requiring human intervention must be automated.

- *Usability*

The system must be designed in accordance with the latest best practices in the field of UI/UX, intuitively, in a way that allows the user to navigate the system without the need for prior consultation of manuals or other documents.

- *Multilingualism*

The first version of the platform will be implemented in one language only - Bulgarian. However, internally, the platform should be designed in a way that allows new language interfaces to be easily added.

- *Monitoring*

The platform and all its modules must support the ability to audit the activities of all users, as well as a log of system events and errors.

It is necessary to provide the ability to monitor the built hardware infrastructure in order to identify anomalies (hardware defects, external attacks, exceptional system workload, unforeseen events/conditions)

- *Availability*

The system must be designed and implemented in a way that guarantees an availability of at least 99.9% (i.e. unavailability of no more than 1 minute per day, no more than 30 minutes per month)

Based on the created specification of software requirements, the creation of the functionalities has been started.

The architecture of the software platform for serious educational games with creative visualization in selected eco-context (Fig. 1) tries to isolate the components in order to divide and simplify the process of a serious educational game creation by strictly separating the tasks of (Goynov et al., 2025):

- Creating and selecting the game artefacts - texts, audio and visual assets (2D or 3D), animations, configurable embeddable mini-games;
- Creating the scenario by defining a flow of sequences;
- Defining game rules;
- Creating the complete game using the desired environment (2D or 3D), scenarios, artefacts and rules using interactive software tools.

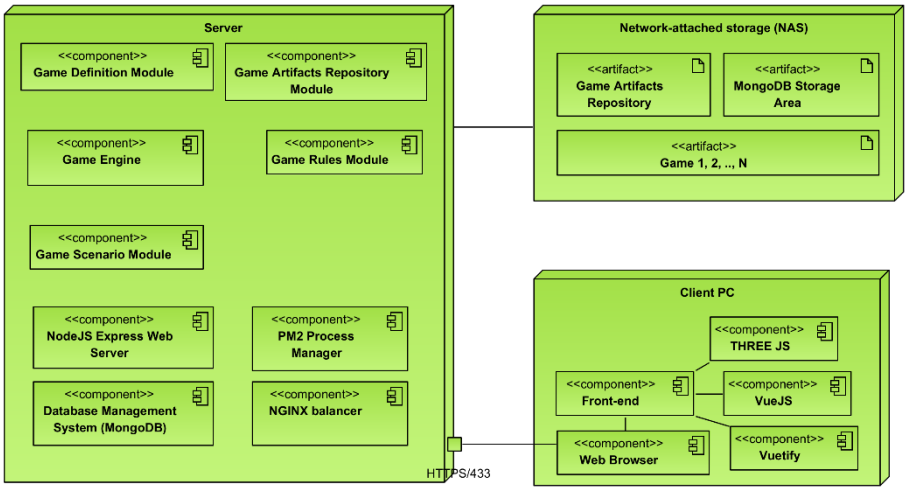

Fig. 1. General software architecture of the ProNature platform.

6 Some Components of Software Platform for Serious Educational Games with Creative Visualization in Selected Eco-context

Taking into account the requirements and specification of the software platform for serious educational games with creative visualization in selected eco-context started building the functional components.

In order to simplify and formalize the process of game creation, we have separated the types of game artefacts in the following categories (Fig. 2):

- 3D objects – this category includes all 3d models which will be used as informational game artefacts.
- 3D environments – a special kind of 3d model which defines the environment where all game artefacts will be placed.
- Players – the player, or the main game character, is the virtual representation of the user who will play the game. Users will be able to choose their character before starting the game.
- Panorama pictures – panorama pictures may be used as scene environments for some more static scenes. Their advantage is that they are easier to build, but they are less attractive as a 3d environment, because only observation, zoom-in and out is available, players are not able to move in such environments.
- Pictures, audio and video media – these are used in order to provide additional interactive information to the players.
- Mini games – a kind of puzzle entity, with a common programming interface which could be integrated in any scene of the game during the gameplay. Mini games will be developed separately and game developers will be able to customize and use them in their scenario.

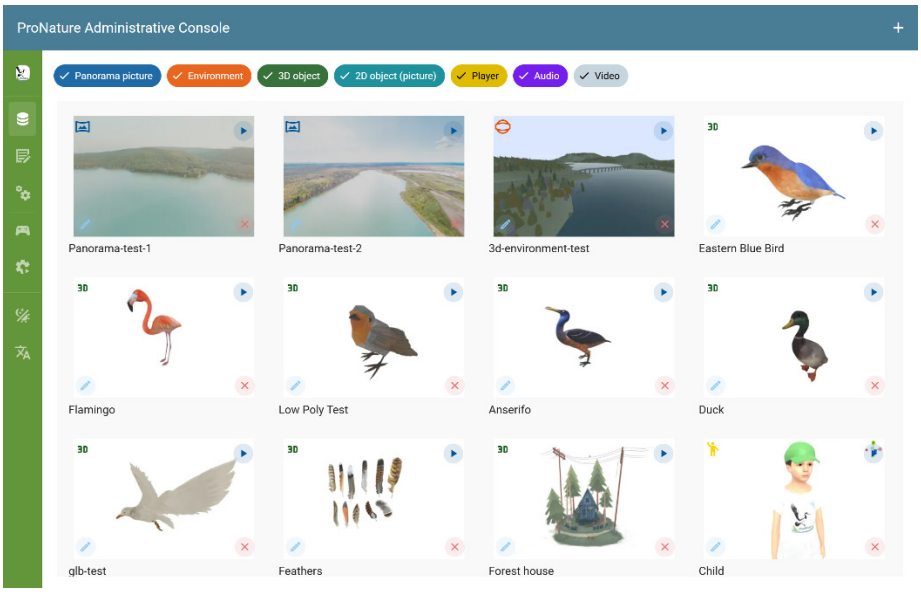

Fig. 2. Game objects repository.

Figure 3 presents the user interface of the game scenario module. Game scenario developers are able to define the gameplay in a drag-and-drop manner using (and reusing) the already added artefacts from the game objects repository.

Figure 4 shows a screenshot from the scene builder submodule as part of the game definition module. All objects available in the scene are loaded from the game scenario definition, and the game developer will be able to position the objects within the scene, to define relations and interactions between the objects, to define the appropriate place and time for all informational artefacts and players tasks. The main goal of this submodule is to become an easy and intuitive tool which could be used by teachers and students in order to create and customize their own games. All 3D content will be available in anaglyph mode and in VR mode for cardboards which will bring more immersive experience to players and game developers.

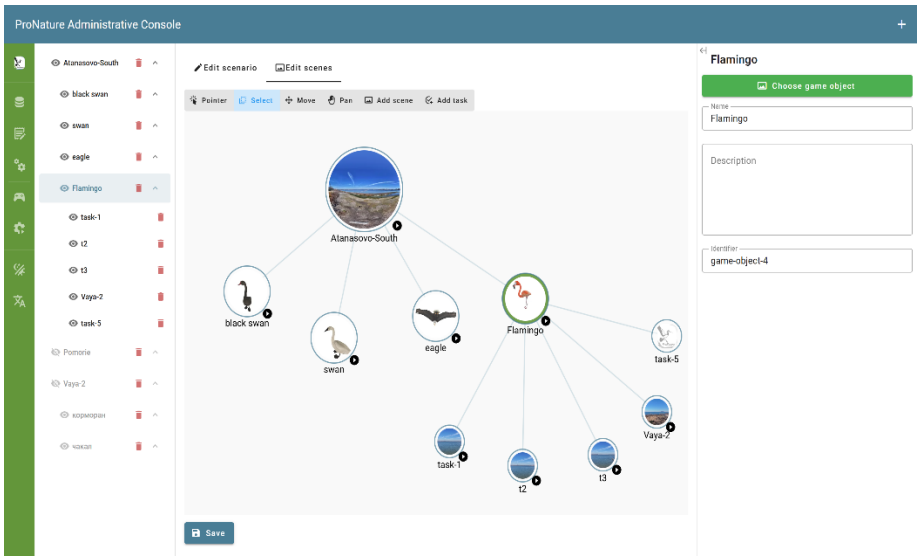

Fig. 3. Game scenario module.

Figure 4: Scene builder.

7 Conclusions and Future Works

Through the proposed software platform and the built serious educational games, significant progress will be achieved in building awareness of natural resources and eco-

systems, practical skills for designing environmentally sustainable solutions and innovative thinking in solving the problems of the future in direction of sustainable management practices in industry and social life. Future work will be performed according to the project plan. After finishing the development of all game components, system and user tests will be performed. The last phases of the project include the implementation of the game scenarios according to the created formal model definition using the developed software. Tests and final evaluations will be executed in order to verify the product compliance with the software specifications.

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