



The Crystal Lake's Mystery: Interactive Eco-Crime Game for Learning about Environmental Sustainability

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Abstract

Implementing measures to mitigate the impacts of climate change and its consequences is crucial. Safeguarding, restoring, and promoting the sustainable management of terrestrial ecosystems are essential to combat the decline in biodiversity. This comprehensive action plan aims to enhance the well-being of people, protect the environment, and foster global prosperity.

These critical themes can be thoroughly examined within the framework of "The Crystal Lake's Mystery", an educational eco-crime game, set up for high schools' students. This educational game is a useful tool for making youngsters aware of the complexity and interrelation of science with environmental sustainability issues and with the benefits of the scientific method and multi-disciplinary knowledge.

In fact, "The Crystal Lake's Mystery" incorporates a blend of STEM subjects, emphasizing chemistry and biology, to navigate the investigation so it acts as interdisciplinary educational tool. Participants are organized into teams and tasked with probing four companies near the lake, aiming to uncover the cause, culprit, and process behind the fish mortality that suddenly occurred in the lake. By using a "detective board," teams strategize and evaluate evidence obtained by chemical and biological laboratorial analyses.

This interdisciplinary activity offers a rich learning experience to the participants, merging scientific concepts from chemistry, biology, and environmental subjects, aiming to enlighten students about sustainability, environmental conservation, and responsible resource utilization, fostering a generation committed to a sustainable future. In addition, the playful approach supports students' engagement, motivation, and the creation of a conducive learning environment.

The session culminates in a quiz, determining the successful detective team, encouraging active participation, critical thinking, and problem-solving abilities. This initiative may be a valuable educational tool, capable to promote sustainability and environmental awareness in high schools.

Keywords: *Serious game, chemistry, biology, environmental protection, cross-curricular learning.*

1. Introduction

The urgent need to address the multifaceted impacts of climate change and counter the alarming decline in biodiversity stands as a pivotal challenge confronting humanity in the 21st century. These global phenomena reverberate across ecosystems, disrupting natural balance and significantly impacting human societies on multiple fronts [1], [2].

Climate change, primarily driven by human activities such as excessive carbon emissions, deforestation, and industrialization, is evidenced through rising global temperatures, erratic weather patterns, extreme weather events, and ocean acidification. The consequences, from community displacement due to rising sea levels to the worsening of natural disasters, demand urgent action.

This imperative underscore the critical need for innovative and comprehensive approaches not only to educate but also to galvanize and inspire action among present and future generations, becoming proactive stewards of the planet. The urgency is not merely to understand these challenges but to promote the key role that STEM subjects and scientific methodological approach play to solve environmental issues. In fact, bridging knowledge across diverse scientific domains is essential for tackling environmental issues. The scientific method plays a pivotal role in this process, guiding systematic inquiry, experimentation, and evidence-based decision-making. A successful strategy in the realm of education is the incorporation of gamification – the integration of game elements into non-game contexts – to enhance engagement, motivation, and knowledge retention among students [3]. The utilization of game-like features such as points, badges, challenges, and rewards has been shown



to captivate learners and foster a deeper understanding of complex subjects [4], [5], [6]. This means that in addition to the famous phrase "learning by doing," there is an essential playful and enjoyable aspect, which is central to effective education. Gamification's potential in educational settings lies in its ability to transform learning into an immersive and enjoyable experience, making it a compelling tool for addressing critical issues such as sustainability and environmental awareness. The Crystal Lake's Mystery educational game has been developed in the framework of the project titled "*Change the Game: playing to be trained for the challenges of a sustainable society*" [7]. The latter aims to develop new educational tools based on gamification strategy, to link official curricula developed at school with the European challenges of our society and enhance student motivation in tackling STEM subjects and supporting their future scientific career paths. In fact, the methodological strategy is to create and promote educational games for schools on topics such as sustainability and circular economy, offering young people more motivating learning starting from school, which shows them the fundamental role of science for sustainable development.

2. The Crystal Lake's Mystery

This mystery game, specifically tailored for high school students aged 14-18, is an innovative way to develop deductive reasoning and problem-solving skills while encouraging students' cooperation. In this game, players assume the role of detectives forming 4 or 5 investigative teams (comprising 2 to 5 students each) to investigate an enigmatic fish mortality occurred at Crystal Lake. This allows for a maximum of 25 players to participate, an ideal number for a student class. The objective of the game is to gather and decipher as much information as possible to uncover the cause, culprit, and process behind occurred fish mortality incident. The Crystal Lake's Mystery is structured around a detective board (Figure 1) whose enable students to question suspects by listening to audio dialogues between the detective and the four suspected companies, as well as clue cards offer scientific evidence like laboratory analysis reports or consultations with experts (Figure 2). These clues can be in the form of physical documents or audio dialogues. Besides uncovering clues, captivating participants also entails an intricate plot and interwoven character relationships that build the perfect suspense and allure for unraveling the mystery.

Since the four suspected companies work in different fields, students explore various topics during the investigations to solve the case, such as the dynamics of dissolved oxygen in surface water, the mechanisms underlying fertilizers, the characteristics of cyanobacteria, the phenomenon of eutrophication, and the distinct habitats of salmonid and cyprinid fish. In details:

- Plast&BIO* is a leading company engaged in the development and production of sustainable bioplastics from renewable plant resources
- Sulfur Corporation* offers products and services for the inorganic chemical industry and oenology, and many others.
- The Grapes'*, is an agricultural company that produces high-quality wines obtained exclusively from its own vineyards.
- Luxe Soil* produces bio-stimulants and products with specific action, organic and organo-mineral fertilizers, for both conventional and organic agriculture.

The game can conclude either after 50 minutes, allowing adaptation to standard school timing, or upon the examination of all cards placed on the detective board.

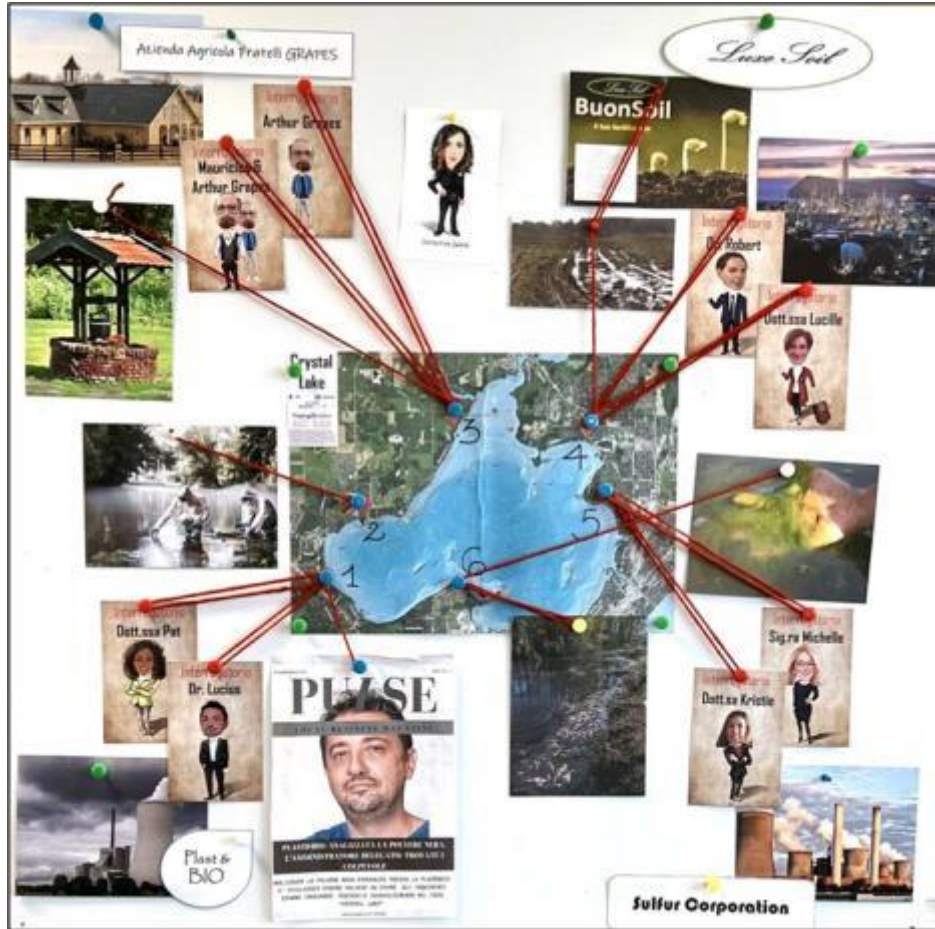


Fig.1. The Detective Board with the four suspected companies.

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SUBJECT: Analysis of surface water, Crystal Lake.
Transmission of analytical reports.

The results of the chemical analyzes carried out on the water samples taken on 23 October 2023 from the lake in question are transmitted.

Due to technical problems, some analyzes are still underway.

CHEMICAL PARAMETERS	RESULT	LIMIT OF DETECTION (LOD)
Total Chromium (Cr)	<LOD	1 µg/L
Manganese (Mn)	<LOD	1 µg/L
Cobalt (Co)	<LOD	1 µg/L
Mercury (Hg)	<LOD	0,1 µg/L
Lead (Pb)	<LOD	1 µg/L
Arsenic (As)	<LOD	1 µg/L
Cyanide (CN ⁻)	<LOD	50 µg/L
Dissolved Oxygen	2,5 mg/L	0,2 mg/L

SAMPLE IDENTIFICATION
Sample N° 1908PT20_A
Withdrawal date: 10/23/2023
Pickup time: 9:15am

NOTE:

DISSOLVED OXYGEN	CHARACTERISTICS
0.2 mg/l	not enough to sustain life
2-4 mg/l	only a few fish and aquatic insects manage to survive
4-7 mg/l	sufficient for many aquatic animals
7-11 mg/l	ideal for most freshwater fish

Fig.2. An example of a clues: analytical report related to the analysis of the Crystal Lake water.

To find, mitigate, and eliminate potential issues, so reaching a good quality in the prototype developed, some tests were implemented. In fact, testing is one of the critical processes accompanying the design and development of an educational game. The testing process was carried



out by organizing some Focus Groups which played a role, especially in the initial stage of game design. These focus groups consisted of meetings with CNR researchers and students providing feedback, likes, and dislikes on the upcoming game topic and allowed iterating on existing ideas more effectively (Figure 3A). In addition, these groups allowed to perform a simple Quality Assurance Testing aimed not to play and enjoy the game but to identify all the major problems and make sure the game meets all the predetermined requirements as well as check the educational contents.

The final prototype of the game was used with success in two informal settings, such as a science fair and a conference for schools which offered the opportunities to the participants for learning beyond traditional or “formal” schooling. In fact, the Crystal Lake’s Mystery was officially presented at the Genoa Science Festival, a fixed point of reference for science dissemination in Italy (26th October_5th November 2023, engaged more than 580 students) and during a workshop organized for high schools during the XX Conference of the Research Language organized at the CNR Research Area in Bologna for the celebration of the centenary of CNR (Figure 3B). The students were observed while playing the game and making some comments about their experience.



Fig.3. A) Game testing session with a Focus Group and B) Game session during the XX Conference of the Research Language.

3. Learning goals

The objectives of this serious game encompass a variety of aspects. Primarily, the game intends to serve as an educational tool for high school students, aiming to familiarize them with the critical importance of safeguarding, restoring, and promoting sustainable management practices for terrestrial ecosystems. By doing so, it addresses the pressing challenges posed by environmental issues like climate change and biodiversity decline and it establishes a direct link to the European Union Green Deal [8], its Zero Pollution Action Plan [9], and the United Nations Sustainable Development Goals [10].

Secondly, this game serves as a platform that provides valuable insights and opportunities for students to explore and deepen their understanding of fundamental concepts in chemistry, biology, and environmental science. Additionally, the game covers aspects of the circular economy. It is structured in a way that facilitates learning about bioplastics and the methods used to reclaim waste from the wine industry's supply chain. The specially designed plot of the game serves as an engaging tool through which students can practically apply these scientific principles within interactive scenarios. This hands-on approach aims to deepen their understanding and foster a more contextual grasp of these subjects.

Furthermore, the game is designed to foster the development of crucial skills among students. By engaging with the gameplay, students have the chance to improve their ability to interpret complex results derived from investigations. Additionally, they will learn effective techniques to extract essential and pertinent information from various sources, thereby honing their analytical skills.

Moreover, this gaming experience aims to actively stimulate and enhance students' critical thinking abilities. By navigating through the challenges presented in the game, students are encouraged to analyze situations, make informed decisions, and think critically to solve problems effectively within the context of the game's scenarios.

Considering the conventional compartmentalization of school activities into distinct disciplines, exists a specific need for connections between subjects and interdisciplinary programs that reflect the ever-



changing and intricate nature of today's society. The game covers a spectrum of fields including chemistry, geology, biology, and environmental science. This emphasis on multiple disciplines and interdisciplinary learning aims to bridge the gaps between narrowly focused school subjects and the real-world scenario, naturally interconnecting these fields and mirroring the complexities of the world.

4. Conclusions

Overall, The Crystal Lake's Mystery stands as an engaging, interdisciplinary educational tool fostering environmental awareness, scientific knowledge, critical thinking, and practical skills among high school students, addressing pressing environmental issues while aligning with global sustainability goals.

Acknowledgements

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