THE GAME OF LEARNING!
APPROACHING ECOSYSTEMS THROUGH BOARD GAME DESIGN

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Abstract

Game-based learning is proven to be a motivational and effective approach, especially in STEM education. However, the process of developing a game is rarely used as an educational tool. Ecology is part of the science curriculum in Italian high schools, but for students results not easy to understand the ecosystem structures and functions from a systemic perspective. Furthermore, addressing ecological issues in a changing world will request them not a reductionist approach but a systems perspective.
In this work our main objective is to consider further possibilities offered by board games, exploiting not only the game experience but also the use of the game design process as an immersive motivational learning tool for science, with a learning by doing approach. Ten students have been engaged (16-18) in two activities: events to test and analyse cooperative board games and a laboratory for the development of a new board game on ecosystems ("YouTopia – La Valle ecosistemica"). Two focus groups were conducted, before and at the end of the laboratory, to test students' engagement and to collect feedback about the efficacy of the method to boost interest and specific knowledge in ecology.
The research reveals that game development can foster system thinking skills among students, and act as a powerful learning tool for complex subjects such as ecology. Results are encouraging and the proposed approach has the potential to be applied and replicated in high school and middle school, to foster students' engagement in tackling and understanding topics such as evolution, genetics other topics characterized by complexity and systemic approach. Preliminary results show as the YouTopia game could be a valid tool for citizenship education. By playing the game, students investigate and practice democracy, the mechanisms of land planning and natural resources protection, and the principle of co-responsibility in making choices for the future.

Keywords: *Game-based learning, system thinking, science didactic, ecology, student engagement.*

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1. Introduction

Game-based learning (GBL) is defined as the use of games as a main lesson or the enhancement of a lesson, while keeping learning as the main, desired outcome (Denham, Mayben, & Boman, 2016, Plass, Homer, & Kinzer, 2015). GBL aims to facilitate learning through the playing of actual games. It fully integrates game characteristics with instructional content so that players will either know something or be able to do something because of playing the game (Craig, Brown, Upright, & De Rosier, 2016). In other words, players learn through playing in the gaming contexts, such that the act of playing the game itself constitutes the learning process. Over the past years, a great number of research has indicated that GBL has the benefit of facilitating learning at all educational level, from primary school to academy. It shows a great potential in STEM education (Bakker, Van Den Heuvel-Oppenhuizen, & Orbitz's, 2016) because GBL can provide a rich learning context to help learners construct higher-level knowledge through ambiguous and challenging trial-and-error and creating immersive and engaging environments it stimulates cognitive and emotional involvements which are critical in the learning process (Cheng, She, & Annetta, 2015, Garris, Ahlers, & Driskell, 2002). In Italy, the study of ecosystems is part of the Science programme in secondary education cycle but is often illustrated in a traditional way and is not sufficiently deepen, in Citizenship and civic education subject, sustainability and nature conservation are discussed but it's just roughly touched the complexity underneath the ecosystem preservation in a future perspective. Addressing contemporary ecological problems in an increasingly complex world requires that the next generation of citizens possess "systems thinking" (ST) skills and deep knowledge of ecology principles. The importance of developing these ST skills is reflected across many sustainability-related educational programs but in the other hands there is still low

attention in teaching ecology principles in a deepen and more concrete way (Wyek et al. 2011). To support the growing of informed and resilient citizens a change in secondary educational environment is needed, especially in science education it is important to enhance approaches not just focus on content, but also allow learners to organize and apply that content in problem-solving, real-life situations thus GBL can be an effective solution. This is more relevant in ecosystem understanding which requires clear understanding of elements and relations among them and energy flow (King et al. 2014). The game development is one of the pedagogical application of games which is increasingly used in education for the high potential of promoting the use of higher-order skills and system thinking skills. Game development is inherently multi-disciplinary, and it is now starting to be used in academic context in a wide range of scientific studies such as Chemistry, Biology, Physics, Software engineer and so on (Rieber, 2005, Bixler, 2006, Burke, Dettori & Settle 2007, Chiarello & Castellano 2016). The game design process took place empirically, through trials, failures, and repeated changes, exploiting some prior experience in the creation of "conventional" board games and always keeping in mind the above-mentioned principles. Special efforts are always required to balance the functionality and playability with the educational needs, and this can be obtained only by a lot of tests and experiments. This development process drives students in two directions; deepen learning of ecosystems concepts and practice system thinking skills.

2. Objectives

As reported earlier, even though there are a considerable number of studies on playing board games in learning activities there are few studies on using game development as didactic tool and examining to what extent the game development process enhances learning of complex subjects as ecology and can unlock system thinking skill. To bridge this gap, the objective of this study is to examine whether developing board game improves students' knowledge in the school subject Ecology and if this approach can be used in approaching complexity of systems in a changing world.

The current study was conceived with the aim of exploring:

1. What are the effects of game development approach in understanding ecology concepts in high school students?

2. What are the effects of game developing, as a creative act, in unlocking system thinking skills in high school students?

3. Design and methods

This case study was conducted at La Rosa Bianca high school, located in a rural valley in Trentino (Northeast of Italy). A group of 10 students from different classes (16 -18 years old) and from two curricula (Science and Engineer) from March to June 2021, for a total of 40 extracurricular hours, voluntarily participated in the "GameDev Lab" with the mandate of developing a board game, possibly cooperative, for educational purposes and targeted for teenagers, fully focused on ecosystems and sustainability.

At the beginning of the laboratory students participated in a focus group to explore their knowledges in ecology, specifically in Alpine ecosystems and ecosystem services, and their system thinking skills.

During the laboratory activities, the creative and cooperative parts of the process have been videorecorded and a logbook was compiled over the whole project with the support of a teacher.

A focus group was conducted at the end of the laboratory to collect students' perceptions and feeling about the creative process of game development and to explore what they learned about how ecosystems work, how they provide vital services for humans, how anthropic activities affected ecosystems functionality and how our choices could positively or negatively affect ecosystems and the future and changing scenarios.

3.1. The "GameDev Lab" process

As kick off activity of the GameDev Lab, students take part in a focus group and the most relevant answer emerged from the focus-group are included in table 1. Additionally, at the beginning of the laboratory, students played three cooperative board games (Forbidden Island, Pandemic and CO_2 second chance) to figure out how a coop game is, which are the most common rules or mechanics, and to boost their group working skill.

For the game development part of the laboratory, students firstly worked together in the definition of didactic objectives, main theme and the main story of the board game then they were split in three groups; the *design team* worked in storylines and mechanics, the *art team* picked up the themes and set by the design team to create assets and the engineering team worked in parallel with the art team to create any infrastructure or content creation tools.

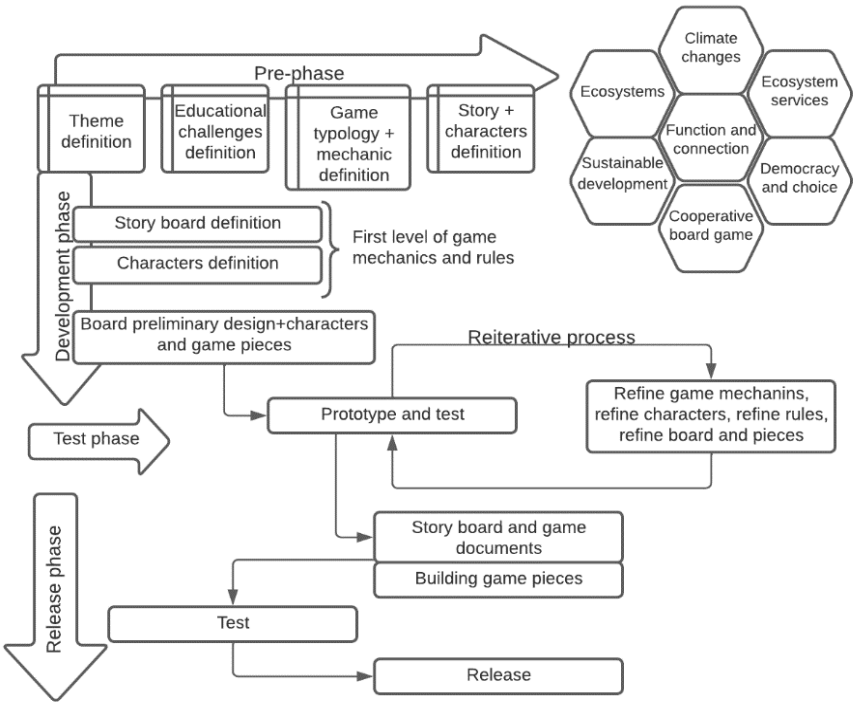
Table 1. Results of the focus-group before the GameDev_Lab.

Questions	Students' answers
Can you define what ecosystems are?	"Ecosystems are made by animals and plants and water and other "natural" things". "Ecosystems are part of the planet with something in". "Ecosystems are part of the nature".
Do you know what a habitat is?	"Is a part of the ecosystems" "Is a physical place where animals and plants live and interact".
Do you know what ecosystem services are?	Nobody knew the meaning and definition of ecosystem services
Does forest depletion affect your villages and rural economy of your valley? How?	"If you are asking me this question I assume yes, the forest reduction affects the rural economy and probably because we can't sell wood". "Also for the tourism isn't good have less forests for bikers and tourists". "Less mushrooms or other things we collect in the forests and we can lose animals and is not good at general level".
Do you know how ecosystems works?	"An ecosystem has an internal set of rules and relations". "Humans can act from outside the system as a perturbant". "In the end humans can be considered part of the ecosystem". "There is also energy and chemical interaction to consider as part of the ecosystem mechanic"
If you will be the major of your town and you must decide if build or not a new infrastructure, which will be your main criteria?"	"How much does it cost and if it's really relevant for local economy". "Costs and benefits for the community". "We should consider also the ecological impact". "Possible economic income and cost for ecosystems". "The long-term effect for local communities and for the environment"

The creativity process was conducted with the design project method modified to fit better students' and educational needs, as indicated in the flowchart presented in Figure1.

At the end of the game development process the students participated in a focus group in which the same questions posed at the beginning were asked again to assess whether there had been a change in term of knowledge and in ST attitude.

Figure 1. Flowchart of the GameDev Lab creative process.



4. Results

As results of the GameDev Lab the board game "YouTopia – la valle ecosistemica" was finalized and delivered. Also results in terms of knowledge, ST skills and engagement have been evaluated.

4.1. YouTopia – la valle ecosistemica, story, characters, and game mechanic

After more than 30 work hours conducted at school with students and with the support of the science teacher and of the technic and engineer teacher, and after more than 5 tests and different version of the prototype, the game was ready to be produced.

YouTopia is a cooperative board game for six players or group of players, to learn how to manage human activities and ecosystem services conservation in a changing world. Each character has as a different role (major, economist, geologist, activist, biologist, and climatologist) and each one has a single or two special abilities to spend during the game. The board simulate a mountain valley with lakes, glaciers, forests, plateau, peaks and open areas and the game's underlying story is: six characters represent six pioneers arriving the YouTopia valley for the first time and they must build up a new city supporting local economy and preserving ecosystems and their services. Each human action has an impact, assigned with different scores, in terms of local economy or for ecosystems and each decision must be justified to the other gamers and when an adverse event occur (geological events, extreme weather events or biodiversity losses). To enliven the game, there is also a deck of cards containing unexpected events and challenges related to ongoing environmental and social changes that can be addressed by making choices that can have different impacts. All players can make different choices with different long-term effect they have to argue, which are also criteria for choosing the solution they prefer and that can be put in place after. All gamers win if after the occurrence of all the changes the final score in sustainability will be maintained as well as the score in economy benefits.

4.2. Learning and skills improvement

After the board game development, the students participated in a focus group using the same questions done during the first focus group and the most relevant answers gave by students are reported in table 2.

Table 2. Results of the focus-group after the GameDev_Lab.

Questions	Students' answers
Can you define what ecosystems are?	"Ecosystems are a complex of biological and abiotic elements interacting among them". "Ecosystem is a geographic area where biotic and abiotic elements interact and evolve in a complex network".
Do you know what a habitat is?	"Is a geographic area where organism live and interact". "Is a geographic area, part of an ecosystem, where a specie lives and where interact with other species".
Do you know what ecosystem services are?	"Are services that and ecosystem provide us, such as food, water, support for our economy and wellness". "Ecosystem services are what ecosystems provide us just existing and we can have for our
Does forest depletion affect your villages and rural economy of your valley? How?	"Because of the networking beneath of each ecosystem yes, an effect can be clear also a lot of time after the last thing we do". "Yes, cultivated forests of the valley are an example, we cultivate our forest thus we had a lot of income from wood, but we lost biodiversity and we are now more vulnerable to the extreme weather events and climate change"
Do you know how ecosystems works?	"Each ecosystem is a network; it means that each element can interact with more than one and in different ways". "Also, energy and chemical processes are part of the network and influence or are affected by other elements".
If you will be the major of your town and you must decide if build or not a new infrastructure, which will be your main criteria?"	"Economic incomes but not more than sustainability and ecosystem services" "Ecosystem services conservation, community wellness and economic benefits".

5. Discussion and conclusion

Bearing in mind that the above refers to a case study involving a small number of students, we can consider the results achieved as valid and especially promising and useful guidelines for possible future research. Results appear encouraging, is remarkable how much the students deepen the knowledge of ecology principles by themselves, just as consequence of the needs of game development process. Also

notable is the positively active approach they have shown in seeking, exploring and grasping the complex nature of the mechanisms underlying ecosystems. By a learning point of view thus the approach seems to be effective. The game development process was too engaging for students, and it also help them in experimenting the group working and negotiations abilities. An additional point is the mind change students have in approaching games, from a competitive perspective they experiment cooperative games and the effect of playing these games changed their approach at the team working.

ST skills might help to unlocked by the creative act of the game development and by the prevision skills needed in developing game mechanics and in matching them with scientific concept. However, a more focused work on the system theory could be improved to reach a higher level of awareness in systems understanding. It is encouraging the possibility of the YouTopia game to be used in citizenship programs as a tool to experiment the democratic decision process, active citizenship and the mechanisms underlying the sustainable land management.

Critical aspects of this approach are the timing because as each creative activity needs time and the learning process need time. Additionally, the game development process requires a lot of different competencies and could be tough for young students.

An advancement that will start in the on-field phase in October 2022 is the use of the YouTopia game as game to play to test its effectiveness in learning sustainability concepts in Citizenship and civic education classes. This preliminary research was a start point for future research which can focus on validation of the game development as tool for some specific learning objectives, on feasibility of this approach in supporting students with special educational needs and on the creative act as necessary part of the process to boost ST skills and learning.

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