Serious games for modelling sustainability skills and competencies

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Abstract

In the last decade, sustainability skills have become critical for preparing the future workforce and efforts have been made to implement sustainability principles across various disciples. In this context, serious games have been promoted as a viable approach that can be used to reshape the learning environments and facilitate the development of sustainability skills and competencies. Serious games are known to make learning interesting and fun, and they have been employed to create engaging spaces for learning, spaces where students have more freedom and take more responsibility. This paper seeks to explore how serious games can foster the acquisition of key sustainability skills and competencies, frequently needed on the labour market. Three games have been analysed starting from their specificity such as the narrative and educational context, the target group, the game mechanics used, up to the identification of sustainability skills and competencies that can be acquired during the game play and the pedagogical methodologies used to acquire certain skills and competencies.

Keywords: Serious games, Skills, Competencies, Sustainability education;

1 Introduction

The concept of sustainability in education implies developing a series of skills which will allow students to face the future challenges that the current globalized labour market, will demand (Picatoste, Pérez-Ortiz & Ruesga-Benito, 2018). Education for sustainability seeks to empower people of all ages to assume responsibility for creating a sustainable future (UNESCO). The current learning environments need a new approach on what constitutes effectiveness and efficiency in learning and serious games support players to get a more motivating and efficient learning experience, delivering multimodal information and disseminating knowledge in a socially complex environment (Gee, 2009). Serious games might be included in every educational environment, as a way to engage students in the learning process and fostering transferable skills and competencies (Gee, 2008; Squire, 2011). Beside the motivational and entertaining aspects, serious games involve factors, such as rules, interaction, and instructional planning, while making learning fun and facilitating the acquisition of sustainability skills and competences that are harder to acquire in a traditional learning environment. Facilitating the creation of rich environments for learning and the acquisition of in-demand sustainability skills, serious games should be incorporated into one of the key learning areas, as either a teaching or learning tool, for assessment or as a learning motivator, to encourage:

- ***Discipline-specific knowledge*** (Koehler 2015) – serious games are designed to teach relevant concepts within a discipline and through the narratives, game mechanics and challenges, the player can extract discipline-specific content;
- ***Creation of sustainable solutions for real problems*** – serious games allow players to experience unfamiliar environments, where they have to think strategically and to make

sustainable decisions. Serious games are developed based on a trial and error approach, allowing players to try different paths to solve a problem;

- ***Active participation*** – serious games facilitate the active participation of the player, through the challenges provided, offering opportunity for practice and repetition;
- ***Behavioural change*** - serious games motivate student to play using challenges, actions or rewards, facilitating behavioural change through experience and engagement;

Starting from the definition of sustainability skills defined in (DT4S Project, 2020), three serious games have been analysed in Chapter 2 to evaluate their capacity to support the development of sustainability skills.

2 Skills and competencies by means of educational games

Games are environments designed for players to experience interactively through play (Stapleton, 2004) and specifically, educational games combine the educational message with the entertaining element, to facilitate behaviour changing or the adoption of new skills or competencies. To create successful learning activities the learning goals must be carefully defined and connected with well-known taxonomies (Gunter, Kenny & Vic, 2006). A frequently used model to define user-centred learning outcomes is the Bloom's Taxonomy of Cognitive Skills, revised (Krathwohl, 2002). The revised model is based on six levels of learning, named as Goals. We linked these goals to different games and game mechanics, to identify the sustainable skills needed (Table 1).

Table 2. Bloom's Goals related to sustainability skills and serious games

Goals	Sustainability skills	Games & Games Mechanics
Remember	Recognize; Recall of information; Observe; Define; Memorize;	**Games:** Quiz; Puzzle; Logic **Mechanics:** Identify; Check; Collect; Match; Drag and drop
Understand	Understand; Interpret; Classify; Summarize; Compare; Explain;	**Games:** Quiz; Puzzle; Logic Adventure; Storytelling; Simulation **Mechanics:** Identify; Check; Collect; Match; Trigger; Moving actions; Listen; Path follow;
Apply	Transferring knowledge to the real world; Problem solving; Demonstrate; Research; Implement an effective solution	**Games:** Logic; Strategy; Simulation; **Mechanics:** Identify; Check; Collect; Match; Trigger; Moving actions; Path follow; Capture/Eliminate; Resource management;
Analyze	Critical thinking; Describe; Categorize, Organize; Prioritize;	**Games:** Quiz; Puzzle; Logic; Strategy; Simulation **Mechanics:** Identify; Check; Collect; Match; Path follow
Evaluate	Evaluate potential solutions; Validate solutions;	**Games:** Quiz; Puzzle; Logic; Adventure/ Exploration; Storytelling; Strategy; Simulation; RPG; **Mechanics:** Identify; Check; Collect; Match; Trigger; Moving actions; Listen; Path follow; Capture/Eliminate; Resource management;
Create	Integrate and synthesize of information;	**Games:** Strategy; Simulation **Mechanics:** Identify; Check; Collect; Match;

	Generate new ideas;	Path follow; Capture/Eliminate; Resource management;

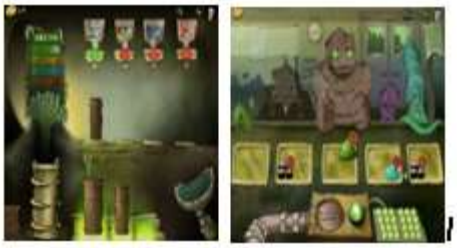
Starting from the structure offered by this model, three educational games have been analysed: *Lure of the Labyrinth*, *Eye of the Donkey* and *Generic Quiz* (customizable). We divided the analysis in two parts, one for the structure of the game and the other one for identifying the skills and competencies that can be obtained during the play and the pedagogical methodologies that can be used to develop the listed skills and competencies.

2.1 Game Structure

Lure of the Labyrinth

Lure of the Labyrinth, a game developed within the Learning Games to Go (LG2G) project, funded by a Star Schools grant from the U.S. Department of Education, is a math-based game, where students are asked to solve math problems to complete the tasks in the game. The game is a story-driven approach and can be used as a full game, where the students must solve the challenges, following the storytelling, or as standalone activities, accessing only the puzzles and not following the story on the game.

Table 3. Lure of the Labyrinth game structure

Target Group	6^{th} – 8^{th} grade
Type of Game	Logic
Purpose	The game is structured in three sections, named "wings", related to different mathematics subjects which are part of a typical curriculum  **Figure 13. Lure of the Labyrinth quests**
Narrative flow	Your beloved pet is missing and your mission is to find it. Before you know it, you are teleported to a world where your only friend is a mysterious girl with wings. She says there are others ... others, what? Other pets? Well, there sure are plenty of monsters. They are all over the place, stinking up the joint and forcing you to do crazy jobs.  **Figure 14. Lure of the Labyrinth storytelling**
Game mechanics	Avatar creation; Click; Select; Drag and drop; Type; Path follow

Rewards	Coins; Pets
Technical details	Web browser; Flash Player plugin; Internet connection
Assessment	Teacher can track the progress of each player in many aspects of their work and performance
Customizable	No

Eye of the Donkey

Eye of the Donkey, created by Nobel Media AB based on the 1993 Nobel Prize in Chemistry, awarded for the invention of PCR, is a knowledge testing quiz game in the field of the forensic science, where the player must use the basic principles of the PCR methods to copy a DNA, in order to collect enough material to use as evidence in a crime. Same as the previous game, the Eye of the Donkey game is also based on a story-driven approach, but the player is not allowed to play the challenges independently and must follow the narrative part, to advance in the game.

Table 4. Eye of the Donkey structure

Target Group	11th – 12th grade; University
Type of Game	Quiz; Hidden object; Simulation
Purpose	The game is a short one and is structured in two parts: the first part presents information about PCR, DNA and forensic science in a quiz type game and the second part, based on hidden object quests and a simulation, regarding the PCR method.  Figure 15. Eye of the Donkey quests
Narrative flow	A crime took place in a Museum. Unware of it, you attend the last lecture at a Forensic Lab course. After the lecture, you leave the auditorium and a car stops next to you. You are asked to help the Forensic Lab to collect evidences to solve the crime.  Figure 16. Eye of the Donkey storytelling
Game mechanics	Click; Select; Drag and drop; Type;
Rewards	-
Technical details	Web browser; Flash Player plugin; Internet connection;

Assessment	No
Customizable	No

Generic Quiz

Generic quiz, developed within the BEACONING project, funded by the European Union, through the Horizon 2020, is a knowledge testing quiz game. In the game, the answers can be formed by choosing the correct answer or by drag and drop actions of the correct answers in the blank spaces, where the educational content must be defined by the teacher. The game it is not based on a story-driven approach but the BEACONING platform offers the possibility to create a story-driven lesson plan, by using one of the game plots available. For the purpose of this analysis, we created a gamified lesson plan using a game plot and the mini game subjects are geography and natural hazards.

Table 5. Generic Quiz structure

Target Group	5^{th} – 8^{th} grade
Type of Game	Quiz
Purpose	The game flow takes place during 6 narrative scenes, each scene having attached a quiz-type mini game. Notions regarding natural hazards are tested.  **Figure 17. Generic Quiz quests**
Narrative flow	The game plot presents the story of Professor Tibia who was once a human named Tobias. He started an expedition on a different planet, where he meet a strange squid creature. This creature was chased by an unidentified object which wanted his translator device. Instead of attacking the creature, the unidentified object attacked Tobias and as a result, he woke only with his bones.  **Figure 18. Generic Quiz storytelling**
Game mechanics	Click; Drag and drop; Type
Rewards	-
Technical details	Web browser; Flash Player plugin; Internet connection;
Assessment	The game provides at the end of each session a summary of the

	results for each question. The teacher can track the progress of the students.
Customizable	Yes

2.2 Skills and competencies

Lure of the Labyrinth

The game is based on fun challenges divided in puzzles, which become increasingly complex and difficult to solve, as the player progresses in the game. The challenges are not really well explained and the player must experiment different moves to understand what is going on. This can be useful to encourage learning by trial and error and to obtain skills such analytical thinking skills, judgment, problem solving. According the Bloom's taxonomy, the following skills and competencies can be acquired during the game play.

Table 6. Sustainability cognitive skills from Lure of the Labyrinth game

Sustainability cognitive skills	**Methodologies**
Remember: Recall of information; Observe; Define; Memorize;	Project/Problem -Based Learning; Cooperative Learning; Gamification; Design Thinking; Competency-Based Learning
Understand: Compare; Explain;	
Apply: Problem solving; Implement an effective solution	
Analyze: Critical thinking; Organize; Prioritize;	
Evaluate: Evaluate potential solutions;	
Create: Innovative thinking; Integrate and synthesize of information;	
Other skills: Digital literacy; Information and media literacy; Independent and autonomous learning; Creativity; Storytelling skills;	

Eye of the Donkey

The game is divided in two parts, one presenting information about PCR and providing two-question quizzes and the second part is represented by a virtual lab simulation of PCR. The game provides clear instruction of a three step PCR method, but it does not give clues about the order of the steps to be followed, thus requiring the player having to use the information obtained during the classroom, in this situation. This interpretation of the game is useful for developing skills and competencies, which can be subsequently applied in a specific setting.

Table 7. Sustainability cognitive skills from Eye of the Donkey game

Sustainability cognitive skills	**Methodologies**
Remember: Recall of information; Observe; Define; Memorize;	Project/Problem -Based Learning; Design Thinking; Competency-Based Learning
Understand: Understand; Interpret; Compare; Explain;	
Apply: Problem solving; Implement an effective solution	
Analyze: Critical and analytical thinking	
Evaluate: Evaluate potential solutions; Validate solutions;	
Create: Innovative thinking; Integrate and synthesize of information;	
Other skills: Digital literacy; Information and media literacy; Independent and autonomous learning; Creativity; Storytelling skills; Transferring knowledge to the real world; Following systemic design processes	

Generic Quiz

Being a customizable game, the teacher can create as many games as it is needed and can adapt them according to the lesson plan. The Generic Quiz used in this analysis, includes six questions, divided for the 6 interactive areas of game plot. Generic quiz provides a useful template to create a knowledge-testing quiz, focused more on communication skills such as speaking, writing and listening.

Table 8. Sustainability cognitive skills from Generic Quiz game

Sustainability cognitive skills	Methodologies
Remember: Recall of information; Memorize;	Competency-Based Learning
Understand: Understand; Interpret; Explain;	
Apply: Demonstrate; Research	
Analyze: Describe; Prioritize	
Evaluate: Evaluate potential solutions; Validate solutions;	
Create: Integrate and synthesize of information;	
Other skills: Digital literacy; Information and media literacy; Independent and autonomous learning; Storytelling skills;	

3 Conclusions

Serious games are considered effective tools for teaching and learning. They can be used as bridge between theory and the real-life situations and for better understanding of concepts learned through traditional teaching methods. By analyzing different educational games, which addresses different topics, we wanted to show how educational games could foster the acquisition of sustainability skills and competencies through the game mechanics, the narrative structure and the pedagogical approach used by each game.

For example, analyzing the *Lure of the Labyrinth* game, we identified that through its levels that increase in difficulty, problem solving and critical thinking is promoted and the students must connect the knowledge learned previously with new knowledge as they move through the game. In addition, the game through its different scenarios based on user input, encourage the trial and error learning for finding the best solution. Students can acquire intrapersonal skills and competencies, such as initiative, openness to criticism/ feedback, flexibility and adaptability. The *Eye of the Donkey* provides students with a virtual lab, where they can apply the knowledge acquired in a safe and protected environment, while training technical skills. The game promotes the acquisition of problem-solving skills and competencies, such as the ability to transfer knowledge to the real world, the ability to follow systemic design processes, the ability to evaluate potential solutions. The *Generic Quiz* game, through it customizable structure, can be used for a wide range of study topics, pursuing the acquisition of technical skills and competencies and meta- cognitive skills and competencies such as willingness to learn and independent and autonomous learning. Therefore, the games analyzed and educational games in general, are not just for learning different subjects, but they are also used to familiarize the students with a certain level of thinking, to make sense of information, experiences and ideas.

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