Implemented and Tested Model for Serious Games to increase awareness on Sustainable development

Kamal OKBA[1], Abdelkrim KHARTOCH[2], Asmae BLILAT[3], Mehdi TMIMI[4], Kamar Ouazzani[5], Mohamed BENSLIMANE[6]*

Abstract: Serious games have invaded all areas without exception, and affect various and varied targets ranging from children to company employees, including students, citizens, sick people, military, etc. All current new technologies, such as Analytics, artificial intelligence, and virtual reality, make serious games more user-friendly and more effective in transmitting knowledge and raising awareness on an important subject such as the Sustainable development object of our study. Our sustainable development serious game will offer a platform to enhance awareness of players on a wide variety of sustainability indicators and we will measure the impact on learners and compare it to other SD serious games following specific choosing criteria.

1. Introduction

A game can be defined as 'a structured mental or physical competition with specific rules, designed for entertainment or rewarding participants'[1]. Contemporary research posits games as interactive educational tools capable of both persuasion and instructing, known as Learning Games [2]. Various Learning Games approaches exist, and this study adopts one particular definition: 'A learning game refers to a computer application incorporating playful elements to capture learners' attention and facilitate the learning process. It explicitly aims at educational objectives and finds application in training across all levels' [3]. Recent studies in this field highlight the manifold advantages of Learning Games, including the ability for learners to learn from mistakes through replay without real-world consequences. Overcoming hurdles related to Serious Games adoption involves addressing high development costs, expenses associated with Learning Games design, and the challenge of utilizing existing 'authoring tool' resources without a developer or graphic design background. Our project's objective is to devise a foundational model for serious games in the realm of sustainable development, subsequently developing and testing the serious game.

A game is a structured activity that is typically conducted for entertainment or leisure purposes but can also be used for educational or training purposes [4]; Serious games are a category of video games that are used for educational purposes in different environments [5]. They and gamification have found an important place in the transmission of knowledge in all sectors, and to all potential targets. Their positive impacts on learning are well established and facilitate learning by giving control to the learner, improving their motivation, commitment, and cognitive abilities. These improvements make it easier for the learner to understand the knowledge object of the serious game and put him in an "open mode" ready to assimilate and learn.

This open-mindedness of the player/learner can be used to raise awareness on different topics and increase awareness of topics as diverse and important as sustainable development.

Sustainable development has been a topical subject for the last twenty years and become year after year a national and international emergency. Training, sensitizing, and educating populations on sustainable development can have a significant effect and can facilitate the implementation of sustainable development policies and rules. Serious games can have a significant impact given their capacity to increase awareness but also of their social and contagious effect, through the competition offered by games.

Unlike other games whose primary purpose is entertainment and fun, serious games train and develop skills, attitudes, and behaviors. Coupled with a gamification process, their social impact is increased, facilitating the transmission of knowledge, and increasing for the player the level of interest in the learning which helps to achieve a better learning performance compared to other passive training [6].

Another important point in serious games is the sense of responsibility that they convey to the players, as the latter

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1, 2, 3, 4, 5, 6 Higher School of Technology, Sidi Mohamed Ben Abdellah University, Fez, Morocco
3 ORCID ID : 0000-0002-7950-4126
4 ORCID ID : 000-0001-9311-4346
* Corresponding Author Email: mohamed.benslimane@usmba.ac.ma

become responsible for their learning through their actions, turning mistakes into a learning element and improving problem-solving skills and situational learning [7].

All those parameters are necessary for education on sustainable development and therefore make serious games a major asset to offer good quality learning of sustainable development goals. They will have the advantage of increasing through play the individual and collective awareness of players on such important subjects, and on the actions to be taken. It will also help the development of positive attitudes towards sustainability issues.

The aim of our project is to create a serious game focused on raising awareness about key aspects of sustainable development in daily life.

Our primary objective is to develop a robust model for assessing the game's impact on players. This model will involve analyzing data from player interactions with the game, including their success rates, failures, learning durations, and more.

The game will be connected to a database summarizing the matrix of environmental impacts making it possible to calculate the scores in respect of the 3 dimensions of sustainable development, namely Environmental, Economic and Social.

2. Definition of Serious Game

Serious games, also referred to as educational games or immersive learning experiences, incorporate an educational framework and mechanisms for monitoring learner progress. Their primary objective is to integrate serious educational content with the engaging and enjoyable elements found in video games [8]. These games are known by several names, including edutainment, adaptive educational games, and digital game-based learning. They serve as innovative tools for education and training, providing interactive and captivating experiences for learners.

Today a search in google for the term "serious games" renders about 1billion hits when in 2007 it rendered 1,1 Million only [9], which shows the huge interest in serious games in the last decade. According to Statista serious games market is expected to grow from 3,5 Billion Dollars in 2018 to 24 billion dollars in 2024.

In many of these games, a game scenario, one or more potential objectives, and various learning technologies can be found. Serious games have a broad reach, appealing to a wide range of end users, including students, employees, managers, individuals with disabilities, patients, illiterate individuals, teachers, and children. The application of serious games is widespread in today's world, spanning across nearly every industry and field. They are utilized in a diverse array of areas and sectors, including:

- Language [10][11]

- Health [12][13]

- Security [13][14]

- Leadership [15][16]

- Social events (violence/Addiction...) [17][18][19]

- Human resources management [20][21]

- Industry, Logistics. . . [22][23]

- Science, Mathematics. . .[24][25]

- Psychiatry [26][27]

- Sustainable development [28][29]

- Culture, Museum, Literature. . .[30][31]

- The health of the elderly [32][33]

Integrating digital technologies into the creation of serious games allows developers to embed intelligence in the educational concepts transmitted through the game. The use of analytics enables the real-time monitoring of the player's actions, allowing serious games to adjust to the player's skill level [34], as well as their mood and engagement, providing tailored feedback as needed.

Additionally, there is a growing interest in "mini-games" within the realm of serious games as a means to efficiently convey very specific knowledge. Mini serious games can be swiftly developed and adjusted, featuring a basic game structure with simple mechanics and a limited number of educational elements. They offer flexibility and can be utilized to raise awareness on various subjects.

The primary differentiation, from our perspective, lies in the network's inherent need to handle change. Change is an essential aspect of networks, constituting a mandatory phenomenon, whereas it may not be as crucial in distributed systems.

3. Sustainable development Problematic

Sustainable development, as outlined in the 1987 Brundtland report "Our Common Future" by the World Commission on Environment and Development, refers to development that meets the current needs without jeopardizing the ability of future generations to meet their own needs. [35]

The term "Sustainable Development" was initially introduced in 1980 in the World Conservation Strategy, a publication by the International Union for Conservation of Nature (IUCN).

Unlike economic development, sustainable development is a development that considers three dimensions: Economic, Environmental, and Social.

Sustainable development considers social equity, economic

efficiency, and environmental quality to ensure economic development. The combination of these three pillars is based on four fundamental principles, namely: solidarity, precaution, responsibility, and participation.

The aims of sustainable development encompass five key objectives:

- Mitigating climate change.

- Preserving biodiversity, ecosystems, and resources.

- Fostering social cohesion and solidarity among communities and generations.

- Ensuring the holistic development of all individuals.

- Promoting a development dynamic centered on responsible production and consumption practices.

Education for Sustainable Development (ESD) equips learners with the knowledge, skills, values, and attitudes needed to make informed decisions and undertake responsible actions for environmental integrity, economic viability, and sustainability.

Education for Sustainable Development is recognized as a key enabler of all Sustainable Development Goals. It ensures a transformation of societies while respecting the basic principles of sustainable development. It empowers everyone, regardless of their gender and age, for present and future generations. It strengthens the cognitive, social, emotional, and behavioral dimensions of learning.

4. SG and sustainable development

Enhancing awareness of all to build a fair society is a challenging role of ESD and this pushes us to think of a different way to deliver ESD using new technologies and a new mode of learning.

How seriously games can use their power to teach different sustainable development fields?

How we can take advantage of a moment of play to deliver awareness on such an important subject?

How SG social impact can be used to spread the knowledge on SD across the population?

Gamification and serious games leverage gaming processes within an educational framework, turning play moments into learning opportunities by capitalizing on the curiosity and motivation of the "player".

The evolution of Information and Digital Technologies today profoundly shapes the learning experience.

Serious games generate as shown in [36] to the players positive psychological-social effects influencing their intention to use the game for learning. Many reviews [37] [38] have referenced hundreds of games on sustainable development in different formats (Websites, Mobile Games, Card Games, computer games. . .) touching the different dimensions of sustainable development (Environmental, Social, Economic) and different domains such a climate change, saving water, and other resources, reducing power consumption, recycling, waste management, agriculture, urban planning. . .

Many websites offer serious games concerning sustainable development like www.games4sustainability.org.

Raising awareness is one of the main objectives in all those projects despite their differences in game design and on the platform, they had been developed on (Mobile, PC, Card. . .).

In terms of technologies, developers have consistently integrated every possible technological innovation into serious games. Some noteworthy examples include:

- VR

- AI

- Robotics

- Engagement in SN (Social Media Participation)

There's also a notable interest in serious "mini games" as a swift means to convey highly specific knowledge through serious gaming. Mini serious games can be developed and adjusted rapidly [39]. They typically consist of a fundamental game with simple mechanics and a minimal number of educational elements. Their flexibility allows for quick adaptation, making them effective for raising awareness on various subjects.

5. AI : Definition

The Larousse dictionary defines artificial intelligence as "A set of theories and techniques implemented to produce machines capable of simulating human intelligence." The inception of artificial intelligence marks the realization of one of humanity's most ambitious dreams: the development of machines possessing a "mind" akin to that of humans.

According to John McCarthy, one of the pioneers of the A.I concept in 1955, "any intellectual activity can be described with sufficient precision to be simulated by a machine."

The primary goal of artificial intelligence is to replicate mental activities, including understanding, perception, and decision-making, using machines as closely as possible to human capabilities.

In today's era, the exponential growth of data stemming from various applications, programs, and machines has rendered Artificial Intelligence indispensable. Its role is pivotal in aiding humans to augment their capabilities for processing and analyzing enormous volumes of data.

The rise of Big Data has presented challenges, necessitating the integration of intelligence in data processing algorithms

to extract value from the massive amounts of data generated by robust servers and interconnected applications spanning diverse fields.

Artificial intelligence comprises various algorithms that, based on the specific needs of applications, capture, process, interpret, and exploit different types of data:

- Information interpretation
- Sensory perception, particularly audio and visual
- Language comprehension
- Utilization of vast databases

Artificial intelligence draws upon various sciences for its existence [40], including:

- Mathematical principles and statistical methods
- Human sciences encompassing cognitive studies, psychology, and philosophy
- The study of neurobiology
- New technologies utilized for intelligently capturing or facilitating data processing

AI can be categorized into four hierarchical domains [40]:

- Solutions: These are utilized by customers and include chatbots, autonomous vehicles, robots, recommendation systems, customer segmentation tools, predictive marketing, and cybersecurity solutions.
- Tools: These are the instruments used to create solutions, such as speech recognition, artificial vision, machine translation, automatic forecasting, expert systems, and segmentation tools.
- Techniques: These encompass machine learning methods, neural networks, various deep learning methods, and rule engines.
- Data: This includes various data sources and associated sensors or interconnected objects.

6. SG and AI

The rapid advancement of technology and the widespread availability of various modes of information access have led to the widespread adoption of serious games across nearly every field imaginable. As serious games have proliferated, they have generated a wealth of data, captured during gameplay or the learning process of engaged players. In recent years, game developers have employed algorithms to analyze this collected data, harnessing its potential for the benefit of users and educators alike. Ever since the introduction of artificial intelligence in the 1950s, developers have been interested in creating "smart" games that challenge human intelligence, akin to chess. We have observed games adapting their content based on the player's

proficiency level, learning pace, reactions, and even their mistakes. The possibilities are limitless.

The integration of Machine Learning and artificial intelligence algorithms into serious games holds promise for numerous applications that can enhance the efficacy of knowledge transmission in ongoing learning. The data derived from a player's interactions with a serious game provides educators with a valuable decision-making tool, utilizing insights from AI algorithms embedded within the game. This real-time understanding of the player's proficiency level empowers educators to dynamically enhance the learning process, adapting it as needed on an individual basis. In the academic literature, the term EDM, or Educational Data Mining, has emerged to encompass the concept of enhancing learning through the analysis of data collected from student/player actions. The aim is to derive valuable insights to improve the success rate of training through serious games. Numerous studies have highlighted the positive impact of integrating AI and Learning Analytics into serious games [41] [42].

A study by [42] detailed various techniques used to leverage Machine Learning for effective learning through serious games. These techniques include decision trees, linear prediction algorithms, neural networks, factor analysis, performance analysis, and monitoring. By making serious game data exploitable and beneficial for both learners and educators through the application of artificial intelligence, several advantages can be realized:

- **The Learner:** The integration of artificial intelligence enables real-time error correction for the learner. This fosters improved interaction with the game, helping the learner to stay focused on the learning objectives of the serious game.

- **The Educator:** Educators benefit by gaining a deeper understanding of individual learners. Insights drawn from the data allow educators to tailor messages and adapt content more effectively based on each player's proficiency level.

- **Developers and Designers:** The vast amount of collected data offers valuable insights for game developers, designers, and content creators. These insights contribute to ongoing learning and improvements in the development and design of serious games.

Our Project to use SG to increase awareness in SD

The objective of our work is therefore to develop a sustainable development serious game. The main objective of which will be to make the players aware of some important fields of sustainable development in everyday life.

In our works [43][44][45], we implemented adaptive

pedagogical hypermedia, integrating the notion of learning and adaptation with 3 Models: Learner, Domain, Adaptation. We will develop an effective model for measuring the impact of the game on players by processing the data of interactions with the game (success, failure, learning time ...).

Criteria that we will use in our model are choosing from the work [46] based on literature and developing a tool to evaluate serious games for Education for Sustainable development. We will incorporate the maximum criteria (Table 1) of this study in our game to give it the best potential score and best possibilities to succeed in transmitting the learning to players.

Table 1. The study criteria

C1. The holistic approach of sustainability	C5. Problem Solving	C9. Rules	C13. Levels
C2. Knowledge	C6. Systems thinking	C10. Class-Collaboration	C14. Sett the param
C3. Attitudes-Behaviours	C7. Active participation	C11.Evaluation of knowledge level	C15. Save
C4. Values	C8. Game's goals	C12. Score	C16. Represent s

Fig. 1. Ecosystem Maintainer game

Fig. 2. The construction game illustration

The game will be connected to a database summarizing the matrix of environmental impacts making it possible to calculate the scores in respect of the 3 dimensions of sustainable development, namely Environmental, Economic and Social.

6.1. Description of the Game

Ecosystem Maintainer (Figure 1) is a construction game where the player will harvest resources from their surroundings to construct infrastructures (houses, buildings, schools. . .). This exploitation of resources (Figure 2) must be wise and well thought out to respect the environment following the best standard that will be defined and stored in a database connected to the game to calculate real-time scores.

If one of the ecosystems implemented in the game is disturbed, the player will be informed about the error (Figure 3) and push him with learning that will guide him in the next rounds.

Fig. 3. Example of ecosystem disruption with excess CO2

The process of designing a serious game is intricate, requiring the harmonization of two seemingly conflicting elements: the playful aspect and the learning scenario. In their definition, [47] describe 'Game Design' as the procedure through which a designer crafts a game intended

to be experienced by a player'. Now, how does 'Game Design' differ from 'Serious Game Design'? [48] has delineated 'Serious Game Design' from 'Game Design,' emphasizing cultural and practical aspects. As previously stated, a Serious Game is expressly crafted for a serious purpose, demanding that designers not only prioritize creating an entertaining game but also ensuring it serves a specific utilitarian goal. This highlights that the process of developing a 'Serious Game' isn't equivalent to creating a 'video game animation.' Streamlining the time and cost of Serious Game design is crucial, posing a challenge for both SG manufacturers and researchers in the field. To address this, we propose the following model (Figure 8) as the conceptual foundation for serious games in the sustainable development domain and the basis for our specific serious game, that we can easily integrate into the design of the domain model of our proposed adaptive hypermedia in our work [49].

6.2. Integration of A.I and Learning Analytics in Our Serious Game Development Project

Adaptive hypermedia are platforms learning processes in which expectations, motivation, learning styles, habits and needs of learners are increasingly taken into account. These platforms can adapt the learning content at any time according to the preferences, pace and level of the learner.[50]

This hypermedia can contain all types of media: videos, images, text, animations, serious games, etc.

In our research endeavors [43][44], we have implemented an adaptive pedagogical hypermedia, incorporating the concepts of learning and adaptation at three distinct levels:

- **Learner Modeling:** This involves structuring the key elements that characterize the learner, encompassing personal information, proficiency levels, skills, interaction history, psychological profile, cognitive capacities, and emotional statuses (Figure 4).

Fig. 4. Learner Modeling

- **Domain Modeling:** This entails structuring the learning elements within the domain, including text, videos, questionnaires, exercises, and more (Figure 5).
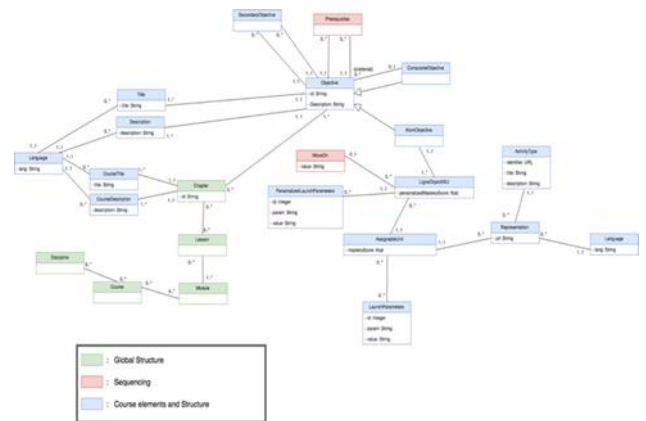

Fig. 5. Domain Modeling

- **Adaptation Modeling:** This phase involves representing various mechanisms for adapting and personalizing the content as well as structuring the learning process (Figure 6).
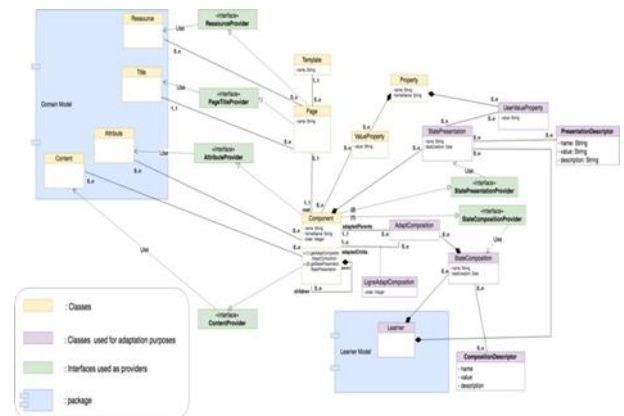

Fig. 6. Adaptation Modeling

Strengthening the adaptive capabilities of our modeling through the integration of artificial intelligence is anticipated to enhance learning outcomes and facilitate the educator's role.

We conducted a comprehensive analysis of state-of-the-art algorithms to augment the development of our adaptive hypermedia, a crucial component in the creation of our serious game.

A noteworthy concept highlighted in the study [51] is the presence of an open-source "Marketplace" on the European platform "gamecomponents.eu." This platform offers modules that can be utilized by serious game developers, encompassing a diverse array of A.I modules.

Presently, this platform showcases around a hundred modules, providing various solutions categorized by the author of the study [51] into the following three categories:

- PEM: Player Experience Modeling

- NLP: Natural Language Processing

- NPC: Advanced Non-Playing character

The significance of these components for serious games is grounded in the educational context, specifically the role of a supervisor (NPC) overseeing and assessing the learner (PEM). The supervisor offers support when needed through interactions (NLP).

For each of these modules, we identify some of the crucial artificial intelligence components that can contribute to the development of serious games, including:

- Facial Recognition

- Emotion Analysis

- Behavioral and Sentiment Analysis

- Adaptation and Evaluation

- Speech/Lip Synchronization (for avatars)

We plan to integrate these A.I components into the overall architecture of our adaptive hypermedia system [44]. This incorporation will enhance the processing of collected data at the Process/Engines level, aiding in the analysis of data derived from user interactions with the serious game. (Figure 7)
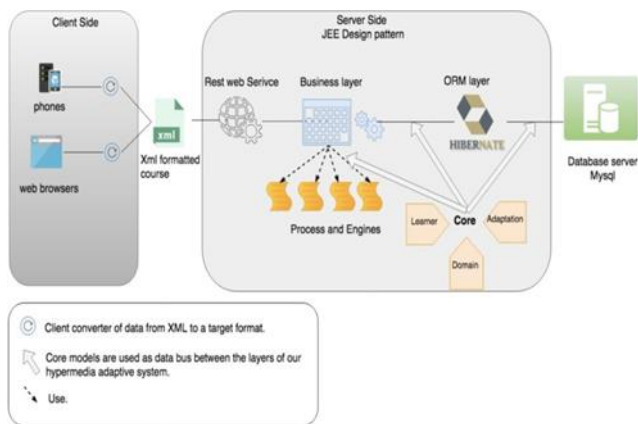

Fig. 7. Architecture of our solution

In our design, each learner (Learner Class) can have several profiles (player) with which he can have several territories. A territory is defined by a collection of contiguous positions (Position class) (coordinates) represented in 3D space. The "Z" axis is ignored at this time.

A position can be either empty or occupied by a player's construction (Concrete Construction class), or it contains a resource that can be harvested (Concrete Spawned Object class).

Notice that we have implemented inheritance for the two-parent classes 'Construction' and 'Spawned Object'. This makes our design expandable, and we can add new types of buildings, resources, etc. at any time.

Finally, regarding ecosystems, we have a class "Ecosystem Reference" which is supposed to represent an ecosystem name and its reference values. And we have assigned a set of values (State class) to these ecosystems for each player territory, which will take information from our evolutive database summarizing the matrix of environmental standards.
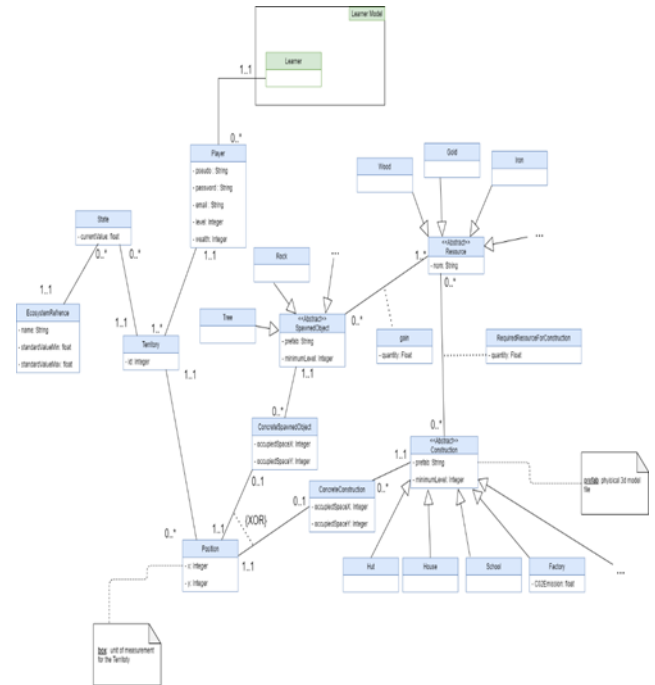

Fig. 8. Class diagram of the proposed model of our game

6.3. Description of Sustainable development Matrix

To make our game evolutive with the possibility to add as many sustainability indicators as possible, we will follow the work done in the online serious game SEGAE [52] which aim to improve awareness on agroecology, with a similar approach to define the impact of player actions on sustainable indicators and with the difference is that our matrix will be evolutive to support as much ecosystem, territories, and resources as possible in our game. In our game, we will be able to deal with any kind of sustainable development (wood, water, reducing power consumption, carbon emission. . .)

Construction of this matrix will be done with expert teams from each field of sustainable development that we will cover and will integrate Moroccan or international standards for each sustainability indicator.

The impact of player action on the game will be assessed and calculate the game score in respect of the value in the matrix as defined by the expert.

Depending on the score, the game will give feedback to the player, congratulating him if standards are respected and if not, the player will receive instruction to understand the negative impact of his action on the three dimensions of

sustainable development: Environmental, Societal, or Economic. The player will be invited to re-play the game and will be assessed again. All player's interactions with the game will be stored for further analysis to take the maximum insight on the positive impact of the game on awareness of the player to sustainable development problematics.

6.4. Comparison with other games

In our game, we will incorporate criterias from the study (48) to give it the best potential score and best possibilities to succeed in transmitting the learning to players. We will, the 14 below criteria:

C1: incorporate all 3 dimensions of sustainable development (environmental, societal, economics)

C2: Knowledge will be provided in the first levels to proceed and will be constructed by users in advanced levels

C3: The game will promote specific attitudes and behaviors

C4: The game will promote specific values

C5: Players have to solve problems, invent solutions by using provided information by game

C6: In the first level, Game progress depends on one factor. In advanced levels, the game progress depends on various interrelated factors

C7: The game progress depends always on the user's decisions

C8: Game's goals are always displayed

C9: Rules are discovered during the game

C10: All Player's tasks will be assessed

C11: Players will see their score constantly

C12: The game will be composed of different levels

C13: The progress depends on some given scenarios

C14: Game can be saved and continued later

Ensuring that those assumptions are taking in our game, will give it a good score compared to other sustainable development serious games and enhance the education aspect of our serious game.

7. Conclusion

The development of Information and Digital Technologies today strongly influences the learning experience. Serious games represent a big asset to enhance awareness on sustainable development topics.

This article presented a view of serious games, sustainable development, and the mix of the two subjects. We presented our serious game in development and how we will make it a successful tool to enhance education in the different fields aiming to protect our environment in the respect of earth resources, social and economic impact in respect to the 3

dimensions of Sustainable development.

In the next step, we will finalize our matrix of sustainability indicators with an expert in the domain and we will finalize the first version of our serious game. We will then test it on different groups of learners and measure the impact on their awareness of sustainable development problems.

Finally, when the game will be tested and approved, we will integrate it with our adaptive hypermedia in a course of sustainable development.

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