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Primary Energy: a serious game to educate how to use energy in a sustainable way

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Abstract

Climate change is worsening every year, increasingly impacting human health. To tackle this issue, the European Union (EU) has funded the Partnerships for Science Education (PAFSE) project. PAFSE is a science education initiative that specifically addresses public health challenges. It involves a partnership with multiple universities from different countries and aims to create awareness among school-age youth about the changing environmental effects on population health. As part of the project, three scenarios have been proposed, each focusing on a different theme. The objective is to educate young individuals about the environmental factors influencing health. The first scenario explores respiratory droplets and the physical process of airborne virus transmission. The second scenario, which this work addresses, revolves around energy sources and their impacts on public health. Lastly, the third scenario delves into the topic of noise pollution. In this work, we focus on developing a game as part of the second scenario. The goal of the game is to raise awareness about the environmental impacts associated with different energy sources, such as carbon dioxide emissions into the atmosphere. To engage the players effectively, gamification components are applied. Specifically, we choose elements that align with educational goals, making the game both enjoyable and educational.

Keywords: Serious Games, Energy sources, Environmental effects, Gamification

Introduction

Nowadays, young people are starting to have more awareness actions with climate change and how this can impact their future. However, it is not enough to say that they should stop producing something that is useful to us. It is necessary to find solutions, think of strategies that can open the horizon prepare for the future, and make today's young people think and create a sustainability strategy.

There are several ways to approach these topics in an educational format, whether through school groups or educational scenarios. However, there is a need to implement them in a real and interactive environment. This is where serious games (Hawthorn et al., 2021) come in, as they contain elements from the real world that are transported into realistic scenarios, presenting relevant scenarios, presenting relevant challenges for the present day. This allows for the development of possible strategies, the transmission of knowledge, and, at the same time, promotes learning in a more enjoyable and educational format.

This paper describes the development of a serious game prototype with the name Primary Energy that contains these characteristics and challenges young people to create strategies to produce a real amount of energy for a given time, reflecting the choices of the types of energy available to produce that amount, managing to minimize the impact that they can cause into the environment and gas emissions into the atmosphere. All these features will contain actual/real values.

During the development of the game, information was collected to obtain the values and impacts of each challenge and, jointly, manage to integrate it into the educational format. Obtaining the opinion of the teachers at the pilot schools to improve it, managing to find a solution so that the game can be played without limitations on technology and game environment.

The application is subject to evaluation in classes and at school events involving students of different ages, managing to draw several conclusions when they played and explored the game from observation and, at the end, they are invited to answer a questionnaire.

Related Work

There are several games (Energy Transition Model Light, n.d.) (Wordwall, n.d.) (Enercities - Paladin Studios, n.d.) (Fate of the World - Wikipedia, n.d.) (Windfall - Games4Sustainability, n.d.) (ElectroCity - Games4Sustainability, n.d.) that approach the theme of energies in various ways, such as the different types of energy available, how to use them, and the economic, social, and environmental impacts that can be caused, regardless of whether they are renewable or not. Two categories of games were selected, serious games (Djaouti et al., 2011), and simulators (Zyda, Michael, 2005).

Energy Transition Model

Considered a simulator game, created by the company Quintel Intelligence, which used real energy data from the Netherlands. This application lets you create a clean energy future for 2023, divided between creating a sustainable city and a home. Upon completing a first level, a set of questions to test knowledge (Energy Quiz) is unlocked.

The engine of the application consists of moving the controllers that affect a certain characteristic, increasing and decreasing the amount. By moving these controllers, the following factors change: carbon emissions into the atmosphere, cost, reliability, renewable (sustainable energy, electricity and gas use) and points.

Wordwall.net application

The wordwall.net site allows you to create various game models with the aim of educating, in the form of a quiz, word games and others. It is possible to obtain games already created with the theme of renewable energy in the form of a questionnaire, letter soup, by dragging an image or phrases to a certain area of the game. These games have some gamification models such as leaderboard, response time, score, freedom to fail.

Enercities

It consists of a serious game, played on the computer, educational for students from the 3rd cycle to the high school. This project was funded by the European Commission, starting in 2007 and lasting until 2011. EnerCities is a game about energy and sustainability, starting with a small area, increasing as the level goes up until you reach level 5. It has a drag-and-drop based interface and allows the construction of structures (renewable energy, green areas, residential and industrial areas). The player’s objective is to maintain a balance between profit, the planet, carbon dioxide emissions and energy production to be able to feed the growing city. These management choices will influence the score, profit, the planet and thus increase the level by getting more space to develop your city. Our proposal has similarities to the Enercities game, but it has not the goal of growing a city.

Primary Energy

The serious game proposed in this paper, with the name Primary Energy, consists of a game for the 3rd cycle, students of the 7th,8th and 9th years of schooling aged between 12 and 16 years old. The idea is focused on energy sources such as: petroleum, natural gas, coal, solar energy, wind energy and hydroelectric energy, raising awareness of the impacts that can be caused using one of these energies to be able to produce enough to feed, for example, a country.

The game challenges players to apply their knowledge in order to successfully accomplish missions. Each mission will have a specific time frame (beginning and ending) and require a certain amount of energy to be produced during that period in order to complete them.The player has six different types of energies available that they can select to be able to produce the amount of energy requested in the mission.

Each type of energy source contains advantages and disadvantages when the player chooses to use them to produce the amount of energy needed to finish the mission. This game aims to challenge players to devise strategies that minimize environmental impacts, such as reducing carbon dioxide emissions or minimizing land occupation, while successfully completing missions. At the end of each mission the player can gain or lose points and coins, depending on the strategy chosen to complete it and, at the end, the next mission is unlocked.

Players can utilize coins to purchase energy and fill the storage tanks for storable energy sources, or acquire solar panels and wind turbines for non-storable energy options. Additionally, they have the opportunity to earn coins by selling stored energy.

To produce the desired amount of energy, players need to select one of the energies icons and drag it to the game area and then choose the desired amount. This choice will cause changes in certain indicators or parameters within the game.

If a player is not satisfied with their choice, they have the option to remove the energy from the game area by dragging it to where it was removed and choosing the amount you want to remove.

At the beginning of the game, a maximum amount of storage is available in the deposit of some energies and also a set of solar panels and wind turbines are available. The amount of the storable energies used to complete the mission is withdrawn and reflected in the next missions.

Game Development

The game was developed using a user centred methodology. During the analysis phase, it was necessary to understand the user needs and what is intended in the game. The choice of gamification components that would be used in this educational game and the first drawings of the prototyping of the game screens were defined in the design phase. In this phase, the main ideas about the game to develop, obtained during the analysis phase, are carried out to paper, to facilitate the visualization and to help trying to understand the location of each component that will be positioned on the screen.

During these phases, meetings were held with teachers representing the pilot class involved in this project. These meetings were held in presentations showing what was going to develop and the challenges that the game was going to submit. In the first meetings, some aspects of gamification were discussed, including the ranking, which raised some problems that were later resolved and explained in the section of the Gamification components. In later meetings, as the game was already mostly implemented, the game engine and how to play were presented. During that presentation, several criticisms arose, one of which was clicking several times to add the amount of energy that was intended when dragging energy to the game area. Therefore, two more ways were included to be able to add the desired amount. Another criticism is that several images of the same energy appear in the game area, making it confusing to know the total that energy is producing. The solution was to have only one card for each energy source, with a caption indicating the total amount of electricity it produces, carbon emissions and land occupation. The solutions to the criticisms are represented in the User interface design section, where the steps taken to reach the user interface screens are represented.

Gamification components

There are several gaming components that can be used in a game, depending on the type of gamification that one intends to apply and what is the objective.

As mentioned, there are several components, such as, instant feedback to challenges, applying a ranking or an avatar. The game is intended to have gamification components, one of which was included in a challenge format consisting of several missions, some of which are more difficult than others.

Another component is related with the rewards, in this case, two types are included: coins and points. The player can gain or lose coins and points, if he/she manage to successfully complete the mission based on the decisions he/she makes choosing the energies.

The last component that was chosen was the ranking, and here in the public context for everyone who registered in the game, only the first three places will appear, not including the others because it clouds influence the user's self-esteem, being their ranking position visible to everyone. However, the user can see his ranking in the most reserved context, choosing whether to see it when he finishes a mission.

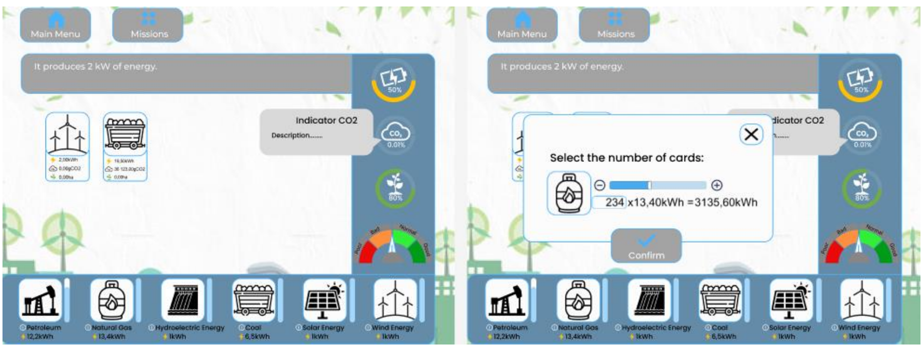

Figure 1. Game screens.

User interface design

Primary Energy is designed to be used in PCs. Thus, we started by putting the ideas on paper, not including the graphic environment or more details, such as colour or font. To arrive at the outline of the screen where the missions are carried out, it was necessary to think about how to place the six energies distributed in the environment, the mission text, the indicators, and the area where the energies can be dragged. The following screen built was the outline of the screen where it shows the rewards at the end of each mission, including the ranking, the number of points and coins. There was a need to show the information of the energies that contain storage, showing the summary of the values before and after the amount available for each energy. Screen sketch link shows sketches of each of the screens that have been explained.

For the creation of the Wireframes, the Figma tool was used to obtain a more realistic perspective of the possible screens. The illustrations of the outlines of the screens for the respective Wireframes are presented in link screen Wireframe.

Applying the artistic components to the screens, starting with the multimedia, icons and imagens were chosen to identify the main buttons, indicators and the six energies. There are three types of background that will characterize when the user is making the right or wrong decisions to carry out the mission. Icons used in the game link shows the icons, images and indicators that were selected to be used in the game.

Figure 1 presents the representation of the game screen for carrying out the mission, together with the solutions that were quoted and referred to, with the caption of the amount of energy, carbon dioxide emissions and land occupation, in each energy. Also includes representation of the three ways to select the amount of energy that was dragged, being done from the plus and minus icons, the text box and the slider bar.

Table 1. Characteristics of the energies of the quantities produced.

	Storage	Energy	CO2 emissions	Land occupied	Store
Petroleum	12 200 kWh	12,2 kWh	29,915 kgCO2	-	Buy and sell
Natural gas	13 400 kWh	13,4 kWh	25,4 gCO2	-	Buy and sell
Coal	6 500 kWh	6,5 kWh	12,041 kgCO2	-	Buy and sell
Solar energy	715 solar panels	7 kWh	-	-	Buy
Wind energy	910 wind turbines	5,5 kWh	-	-	Buy
Hydroelectric energy	31 374 kWh	1 kWh	-	0,038 ha	-

Game components

The information that is represented in the game is close to a real scenario, trying to simulate the energy production for an hour using the available energies and a set of elements to show the impacts that can cause when using a certain energy. Therefore, the components that involve this game will be presented to be able to simulate a real scenario to produce energy.

As indicated Primary Energy will have six energies: petroleum, natural gas, coal, solar energy, wind energy and hydroelectric energy, represented in Figure 1. Each one of them will have the identification of the amount of energy that is equivalent to that amount when carbon dioxide is released and its occupation of the soil. Also, it contains information on how much storage the deposit has and how many solar panels and wind turbines are available. These dates were acquired by measurements and estimates taken in the year 2021 (World Energy Statistics | Enerdata, n.d.). Table 1 contains information on the amount of storage in the depot, carbon dioxide emissions and land occupied.

Table 2. Amount of energy production per hour for solar and wind energy.

Hours	Solar %	Solar value kWh	Wind %	Wind value kWh

00h-01h	0	0	100	5,5
01h-02h	0	0	100	5,5
02h-03h	0	0	98	5,4
03h-04h	0	0	92	5,1
04h-05h	0	0	89	4,9
05h-06h	0	0	87	4,8
06h-07h	5	0,4	81	4,5
07h-08h	20	1,4	76	4,2
08h-09h	35	2,4	63	3,5
09h-10h	50	3,5	45	2,5
10h-11h	65	4,6	27	1,5
11h-12h	80	5,6	14	0,8
12h-13h	100	7	10	0,6
13h-14h	90	6,3	7	0,4
14h-15h	70	4,9	12	0,7
15h-16h	50	3,5	16	0,9
16h-17h	30	2,1	20	1,1
17h-18h	15	1,1	18	1,0
18h-19h	5	0,4	20	1,1
19h-20h	0	0	20	1,1
20h-21h	0	0	27	1,5
21h-22h	0	0	32	1,8
22h-23h	0	0	38	2,1
23h-24h	0	0	36	2.0

The energies represented as kWh in the storage correspond to the capacity that the deposit of this energy can store. As for solar and wind energy this quantity is the initial one and can later increase if there is a purchase of this material.

In renewable energies it is assumed that no CO2 emissions are produced. In land occupation, hydroelectric energy is the only one that occupies it, assuming that each use of this energy is equivalent to a discharge of water. Wind and solar energy, on the other hand, does not occupy land, since the installations in solar panels are supposed to be carried out on the roof of houses and wind turbines occupy a bit of land, but allow for return and on the return, it is possible to use it.

In the purchase and sale of energy, hydroelectric energy is the only one in which an option is not allowed, as being a natural resource based on water, it does not assume the sale and purchase. For solar and wind energy, it is only allowed to buy the material and for non-renewable energy, both options are possible.

Primary Energy will provide 24 missions and a tutorial that will explain how the game works and the rules, whereas these 24 missions correspond to the 24 hours of a day. As in a day the climate can change in the case of exposure to sunlight and wind, so the amount of energy that is represented in Table 1 for solar and wind energy varies over the 24 hours. This amount of energy for both energies correspond to the maximum peak it can produce. Table 2 shows the percentages per hour and the energy value resulting from part of the maximum energy value.

These percentages shown in table 2 refers to a day in May of this year in Portugal when wind and solar energy was produced (REN Data Hub, n.d.).

To be able to attribute the rewards and penalties when a mission ends, the strategy that was taken is based on the carbon dioxide quota and land occupation that was established in each mission.

As the energies are selected to produce the desired energy, the indicators for CO2 and land occupied will change, if this energy has impacts related to these two indicators. In other words, if the strategy that was taken approaches the land occupied quota that was placed as 332ha or the carbon dioxide quota that was 7536964gCO2, the penalties that can be obtained begin to count.

Solution architecture

The architecture of the solution to develop the game is shown in Figure 2. As indicated the game was developed to be played on the computer and was programmed on the Unity platform. There are two types of databases, one in the cloud where the information of players who register in the game is stored, such as the player "id" that is generated during registration and their points. The other type of database is local, which will contain two files with JSON format, one of them will be read-only and will contain game information, such as energy and mission information. The other file is a read-write file that will contain player information, points, coins and completed missions.

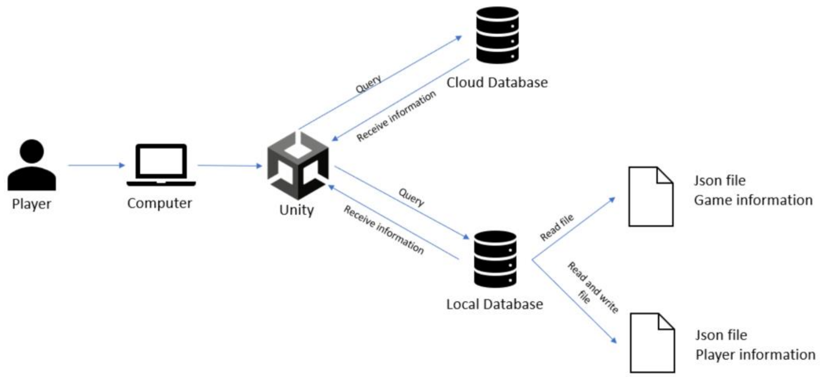

Figure 2. Diagram of the architecture of the proposed solution.

The application was designed to behave in a hybrid format, in other words, it can be played without needing an internet connection. The use of the internet is necessary to view the first three positions in the ranking, when the user finish the tutorial, for the player "id" to be registered and when the player want to see its position in the ranking. When registering, the user does not need to have a Hotmail, Facebook or Gmail account. Registration is done locally, generating an "id" that will be sent to the cloud database. In carrying out this strategy, users who have limited access to the internet can play.

Evaluation

The game was evaluated in terms of usability and playability with 31 participants. A class of 23 students and an additional 8 students from school events took part in this evaluation. All of them students with ages between 12 and 18 years old. We first explained the game and then asked them to experiment it while we are observing.

During the evaluation of the game, it was possible to observe the actions that users performed in a task such as dragging energy to the game area or how they choose the amount of energy, thus allowing us to perceive that a given task is performed differently or badly done only realizing it in another attempt, thus giving the vision of points that have to be improved in terms of gameplay. It also served to be able to detect possible errors that sometimes happened during the missions.

At the end of the section, they were asked to complete a questionnaire, in which it was not yet possible to collect all the answers, and together, two direct questions were asked, if they thought it was fun and if they had noticed the impacts that each energy had when using them. The majority, about 80%, said they found the game fun, but there were certain aspects that could be improved to make it less boring, such as not having to drag the same energies on the next mission again. In the educational aspect, they realized the impacts of each energy and some mentioned that they acquired more knowledge about the energies.

The next steps to be taken are to gather this information and be able to apply in the game effectively and undergo a new evaluation.

Conclusion and future work

Applications that address these themes of public health, science, and technology for teaching require many difficulties to reach a final product, as it involves different profiles of several students, as well as involving them in real scenarios and conceptualizing for recurrent themes. The development of this game tried to focus more on being fun, educational and, in the end, by meeting all the challenges, being able to understand the impacts of each energy and what it takes to produce an amount of energy per hour, making us reflect together and see what could be improved. The evaluation done until now gave us positive information to improve the game. Nevertheless, for future work, more consistent evaluation needs to be done, in particularly, the evaluation of the educational component.

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