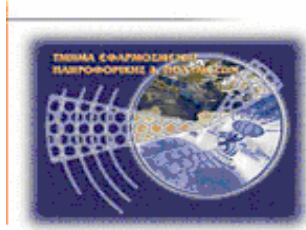




**Τεχνολογικό Εκπαιδευτικό Ίδρυμα Κρήτης**

**Σχολή Τεχνολογικών Εφαρμογών  
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**Bachelor Thesis**

**Τίτλος: Ανάπτυξη εκπαιδευτικού παιχνιδιού για το δίκτυο υψηλής τάσης της Κρήτης (Serious game for power grids)**

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## Abstract

Electrical power is an element of vital importance for human life. Many daily activities are based on it and are achieved with its use. For example, without electricity industries would not be able to operate and people would not be able to work or perform the housekeeping tasks. In other words, without electrical power people would live in a difficult and primitive environment.

Power plants or power stations are responsible for producing electrical power. Each power plant contains one or more generators for converting mechanical power into electrical power. The produced power is transmitted from plants to the consumers, through the electrical power grid. The electrical power grid is a network that carries power from sources to demand centers. Electrical power travels through high voltage lines from power plants to substations and with the use of transformers voltage is degraded and transferred via distribution lines to the consumers.

Education provides knowledge for high voltage power grids in a literal way or by virtual applets. However, it is not possible to achieve the learning process and the acquisition of knowledge for learners with special educational needs. This leads to the implementation of educational games, that combine learning theories with gamification. Thus, students with special educational needs can participate actively in the learning process and acquire the necessary knowledge, despite these needs.

The present thesis aims in designing and developing an interactive educational game for designing and managing high voltage power grids. It focuses on the visualization of the electrical power grid high voltage lines from the power plants, to the power transmission substations. It provides game levels for designing a power grid, building power plants and creating high voltage lines with 2D artifacts in a world map. Furthermore, through game scenarios involving power grid's crisis situations and scenarios for exchanging energy between different networks, users receive knowledge of a power grid's management.

## Σύνοψη

Η ηλεκτρική ενέργεια είναι ένα στοιχείο ζωτικής σημασίας για την ανθρώπινη ζωή. Πολλές καθημερινές δραστηριότητες βασίζονται σε αυτό και επιτυγχάνονται με τη χρήση της. Για παράδειγμα χωρίς την ηλεκτρική ενέργεια η βιομηχανία δεν θα μπορούσε να λειτουργήσει και οι άνθρωποι δεν θα μπορούσαν να εργαστούν ή να εκτελέσουν τις δουλειές του σπιτιού. Με άλλα λόγια, χωρίς την ηλεκτρική ενέργεια οι άνθρωποι θα ζούσαν σε ένα δύσκολο και πρωτόγονο περιβάλλον.

Η σταθμοί παραγωγής ηλεκτρικής ενέργειας είναι υπεύθυνη για την παραγωγή ηλεκτρικής ενέργειας. Κάθε μονάδα παραγωγής ενέργειας περιλαμβάνει μια ή περισσότερες γεννήτριες για την μετατροπή της μηχανικής ισχύος σε ηλεκτρική ενέργεια. Η παραγόμενη ισχύς μεταδίδεται από την μονάδα παραγωγής στον καταναλωτή μέσω του ηλεκτρικού δικτύου. Το ηλεκτρικό δίκτυο μεταφέρει ενέργεια από πηγές σε κέντρα ζήτησης. Η ηλεκτρική ενέργεια μεταφέρεται μέσω γραμμών υψηλής τάσης από σταθμούς παραγωγής ηλεκτρικής ενέργειας σε υποσταθμούς και με την χρήση μετασχηματιστών η τάση μειώνεται και μεταφέρεται μέσω γραμμών διανομής στους καταναλωτές.

Η εκπαίδευση παρέχει γνώσεις για τα δίκτυα υψηλής τάσης με λεκτικό τρόπο ή μέσω εικονικών μικροεφαρμογών. Ωστόσο, είναι αδύνατο να επιτευχθεί η διαδικασία εκμάθησης και η αφομοίωση της γνώσης από εκπαιδευόμενους με ειδικές εκπαιδευτικές ανάγκες. Αυτό οδηγεί στην ανάπτυξη εκπαιδευτικών παιχνιδιών, τα οποία συνδυάζουν θεωρίες μάθησης με στοιχεία παιχνιδιού. Έτσι, οι εκπαιδευόμενοι με ειδικές εκπαιδευτικές ανάγκες μπορούν να συμμετάσχουν ενεργά στη διαδικασία μάθησης και να αποκτήσουν τις απαραίτητες γνώσεις αντίθετα με τις ανάγκες τους.

Η παρούσα πτυχιακή εργασία στοχεύει στο σχεδιασμό και στην ανάπτυξη ενός διαδραστικού εκπαιδευτικού παιχνιδιού για τη δημιουργία και την διαχείριση ηλεκτρικών δικτύων υψηλής τάσης. Στοχεύει στην απεικόνιση των γραμμών υψηλής τάσης ηλεκτρικής ενέργειας από τις μονάδες παραγωγής ηλεκτρικής ενέργειας, μέχρι τους υποσταθμούς μετάδοσης ισχύος. Παρέχονται, επίπεδα παιχνιδιού για το σχεδιασμό ενός ηλεκτρικού δικτύου, για την κατασκευή μονάδων παραγωγής ηλεκτρικής ενέργειας και την δημιουργία γραμμών υψηλής τάσης με την χρήση δυο διαστάσεων γραφικών στοιχείων σε χάρτη πραγματικού κόσμου. Επιπλέον, μέσω σεναρίων του παιχνιδιού που περιλαμβάνουν καταστάσεις κρίσεων του δικτύου και ανταλλαγή ενέργειας μεταξύ διαφορετικών δικτύων, ο χρήστης λαμβάνει γνώσεις διαχείρισης του δικτύου.

# Table of Content

Acknowledgements .....	i
Abstract .....	ii
Σύνοψη .....	iii
1 Introduction .....	1
1.1 Synopsis.....	1
1.2 Thesis motivation .....	2
1.3 Thesis objectives .....	2
1.4 Thesis Outline.....	3
2 Background .....	4
2.1 State of the Art .....	4
2.1.1 Teaching (students) .....	4
2.1.2 Lifelong learning (educate electricians (professionals)).....	5
2.1.3 Game based learning .....	5
2.1.4 Learning Theories.....	6
2.1.5 Geo-spatial Educational games .....	9
2.1.6 Serious games and electricity .....	10
2.1.7 Thesis proposed schedule (Gantt chart).....	11
3 Technologies used .....	13
3.1 HTML5 & CSS .....	13
3.2 JavaScript .....	14
3.3 jQuery.....	15
3.4 OpenLayers API.....	15
3.5 Materialize.css.....	16
3.6 Blender .....	16
3.7 Experience API (xAPI).....	16
4 The “Power Grids EduGame” .....	17
4.1 The Collaborating IOLAOS Platform .....	18
4.2 User and system requirements.....	20
4.2.1 System analysis and design .....	20
4.3 Use cases .....	25
4.3.1 Power Grids EduGame use cases and scenarios.....	26
4.3.2 Use case: User authentication and game’s configuration .....	26
4.3.3 Use case: Level 1: Build the power grid.....	29
4.3.4 Use case: Level 2: Manage crisis situations .....	32
4.3.5 Use case: Level 3: Exchange amounts of electric power through different power grids	35
4.4 The “Power Grids EduGame” General Activity diagram .....	38
4.5 The “Power Grids EduGame” Component diagram.....	40
5 Pilot implementation .....	41

5.1	Implementation of “User authentication and game’s configuration” .....	41
5.2	Create energy plant.....	44
5.3	Inter connection of power plants .....	49
5.4	Useful user – map interactions .....	50
5.5	Insert additional power grid’s components .....	55
6	Conclusion & future work.....	56
6.1	Conclusion.....	56
6.2	Future work .....	56
	References .....	57

## List of Figures

Figure 1: Game Based Learning [31] .....	6
Figure 2: Nielsen's three learning theories.....	6
Figure 3: Examples & applications of behaviorism .....	7
Figure 4: Examples & applications of cognitivism .....	8
Figure 5: Examples & applications of constructivism.....	8
Figure 6 Gantt Chart.....	12
Figure 7 Markup language example.....	13
Figure 8 HTML5 simple example .....	13
Figure 9 CSS simple example .....	14
Figure 10 JavaScript example .....	14
Figure 11 JavaScript inheritance example.....	14
Figure 12 jQuery example.....	15
Figure 13 OpenLayers API map creation example .....	16
Figure 14 IOLAOS platform architecture .....	18
Figure 15 IOLAOS learning session example.....	20
Figure 16 Main requirements diagram .....	21
Figure 17 Game requirements diagram .....	22
Figure 18 GUI requirements diagram.....	22
Figure 19 Maps requirements diagram.....	23
Figure 20 Power grid requirements diagram.....	23
Figure 21 IOLAOS collaboration requirements diagram .....	24
Figure 22 Data requirements diagram .....	24
Figure 23 Dennis forms structure .....	25
Figure 24 Login mockup .....	29
Figure 25 Level 1 mockup (1).....	32
Figure 26 Level 1 mockup (2).....	32
Figure 27 Level 2 mockup.....	35
Figure 28 Level 3 mockup.....	38
Figure 29 Game's activity diagram.....	39
Figure 30 Game's component diagram.....	40
Figure 31 Login implementation.....	41
Figure 32 Response JSON file from IOLAOS .....	41
Figure 33 Level 1 instructions .....	43
Figure 34 Main GUI.....	44
Figure 35 Power plants on map (1) .....	45
Figure 36 Power plants on map (2) .....	45
Figure 37 Power plant's mini - map.....	46
Figure 38 Select artifact on mini - map's toolbar .....	46
Figure 39 Artifacts on power plant's mini - map.....	47
Figure 40 Artifacts popup menu.....	47
Figure 41 Connected artifacts.....	48
Figure 42 Power plant's changed icon.....	48
Figure 43 Substations on map .....	49
Figure 44 Create lines option .....	49
Figure 45 High voltage lines .....	50
Figure 46 High voltage lines on zoom .....	50
Figure 47 Distinct button on main toolbar .....	51
Figure 48 Choose city modal.....	51
Figure 49 Extend button on map and map is centered in unknown place .....	53
Figure 50 Map is extended in default view .....	53
Figure 51 Change map's layer options on main toolbar .....	54
Figure 52 Map with aerial layer .....	54
Figure 53 Map with aerial with labels layer .....	55
Figure 54 Additional artifacts added on map .....	55

## List of Tables

Table 1 Cultural Heritage Learning Environments and Games .....	11
Table 2 Power Grids EduGame use Cases and scenarios.....	26
Table 3 User Authentication and Game's Configuration scenarios and actions .....	27
Table 4 User authentication and game's configuration table of diagrams .....	28
Table 5 Level 1: Build the power grid scenarios and actions.....	30
Table 6 Level 1: Build the power grid table of diagrams .....	31
Table 7 Level 2: Manage crisis situations scenarios and actions .....	33
Table 8 Level 2: Manage crisis situations table of diagrams .....	34
Table 9 Level 3: Exchange mounts of electric power through different power grids scenarios and actions .....	36
Table 10 Level 3: Exchange mounts of electric power through different power grids table of diagrams.....	37
Table 11 Examples of different game's visual configurations.....	42
Table 12 Different usage of GUI's side navigation panel.....	44
Table 13 Two examples of cities lists options.....	52
Table 14 Results of "Fly to" interaction. ....	52



# 1 Introduction

Technology's rate of growth is amazing. Day by day new technologies are coming up and get into people's life. Two of the most common technologies that people use, are computers and the internet. Computers are everywhere and they are capable to make our life easier. In fields like, industries and governments, to hospitals, homes and education they all use computers. In this thesis we will discuss how computers and more specific games are involved with education.

It is true, that education is the most important aim in order for people to learn and improve their minds. People digest and use the information that receive from a body of knowledge, in order to be equipped with the skills they need. But it is true that the learning process needs to be more amusing for the learner, than only read and learn method. According to these reasons, nowadays many countries, with different educational systems, are using game based learning. Game based learning can be used not only in educational institutes, but also in health care and advertising. The main tool for game based learning, are games that target to educate users - learners. These games are called serious games. Serious games can be board games or video games with human – computer interaction.

Serious games have different goals and objectives from common games. Their main objective is to educate, they serve an operational philosophy where learning comes first and then pleasure through the game elements. Also, serious games, use game environments and game techniques to educate users – learners with an interesting and attractive way, for example with “fancy graphics”. A key point, is that users – learners do not remain pathetic in changes and facts that come up during the game, but can actively participate in the flow of the educational game[1].

Connolly et al. [2] concluded: it appears that from the information that users – learners can achieve by playing serious games, they gain the necessary knowledge as well as they elongate their cognitive abilities. Another research and study concluded that there is much information which justify a documented return, but there are fields that need more research [2]. Likewise, Bellotti et al. [3] claim that serious games are profitable in education, but there is no satisfactory evidence. “The learning outcome depends on the appropriate pedagogical and underlying game mechanics and on how the content is incorporated into the game so that learning is inherent in the game. There is no uniform pedagogy in serious or educational games. Previous games tend to be based on a behavioral model. Later games try and incorporate experiential, socially-pedagogical and pedagogical models. The learning outcome depends on the appropriate pedagogical and underlying game engineering and how the content is incorporated into the game so that learning is inherent in the game”[4].

Serious games are still under development and need improvement. Special attention must be given on their design and development. Also, developing factors for public adoption are crucial and therefore must be reconsidered[5]. Due to wrong design, wrong learning method and learning theory, user – learner just play the game for entertainment and as a result does not assume the required knowledge[6].

To conclude, according to Girard et al. [7], serious games are giving learners the ability to be familiar with a variety of learning environments and subjects, such as mathematics or physics. Furthermore, Mouahed et al. [8] maintain, learning through serious games can have value added in education if serious games are consisted of learning theories and in particular constructivist psychosocial theories. Also L. Annetta [9] consider that serious games must have principal parts such as identity, immersion, interactivity, increasing complexity, informed teaching and instructional. But, those elements are ineffective for training through serious games. Consequently, serious games will have added value if learning theories, pedagogical methods and learning styles, evaluation models and curriculums are involved in them. Based upon these motives we developed an educational – serious game for learner's training and specialization on real world power grids and high voltage networks.

## 1.1 Synopsis

People use electrical power in their everyday life. Electrical power is used for instance, from industrial and transportation purposes, to personal uses, like heating and cooking. This ends up, that without electrical power, people's life and world's subsistence could be hard or ever impossible. Electricity travels from production plant to its final destination, which is the consumption, through a network called electrical power grid. This network consists of generators, transformers, high voltage

pillars, solar panels and wind turbines. All these components connected together, describe a power grid.

This thesis presents the design and develop of an educational serious game, for building and managing electrical power grids, the “Power Grids EduGame”. Implementation of “Power Grids EduGame” is based on web technologies and on real world maps. The game’s front - end has been created with HTML5 and CSS. More specific, the Materialize.css framework has been used for the interface’s components and jQuery for user’s interaction with the front - end. Moreover, the Power Grids EduGame is based on a real-world map with the use of the OpenLayers API, a JavaScript open source library for world maps display which also allows the interaction with features and objects on the map. Classes, objects, objects’ methods and additional map interaction methods are developed in JavaScript. For storing information, JSON files are used. As the “Power Grids EduGame” is an educational game, it connects with an educational framework called IOLAOS[10], for user profiling and user data and information exchange. This connection is accomplished with AJAX. Finally, power grid 2D components are all made with Blender.

## 1.2 Thesis motivation

Motivation for prosecution of this thesis was the knowledge and the state of the art experience in areas like: software design, software development, education, game based learning and serious games. Also, a key role was the possibility which was given us, being part of a research laboratory and a research team. In addition, important motivation for this thesis was that games for electrical power grids are using a virtual world map rather than a real-world map, and as a result the power grid is not apply to reality.

## 1.3 Thesis objectives

The main objective of this thesis is to design and develop an educational – serious game for electrical networks and power grids namely the “Power Grids EduGame”. This serious game has three main elements.

**Element A:** Educate and Learn,

**Element B:** Gamify real electricity power grids

**Element C:** Personalize game experiences through the use of extended user profiling

More specific the first element of the game focuses on the learning process. The learning process is supported by the use of learning theories, pedagogical methods and learning styles, which add educational value to the game. To achieve this the game provides power grid component graphical artifacts on a real-world map that can be used to modify the designed power grid through game scenarios with different game levels, that the learner is called to accomplish.

The second element focuses on real electrical power grids. The power grid is captured on a real-world map and transmits it into a game layout in order to be adapted so that it takes on the form of a game. In this arrangement, user – learner creates the power grid and modifies it through game levels and scenarios that s/he is called to accomplish. This thesis presents the implementation of the power grid’s basic use case, which is the production, transmission and distribution of electricity[11]. These parts are the three major distinct parts that describes the use an electrical network. To reach this goal, user – learner adds 2d power grid graphical components on the map, such as generators, transformers and pillars, in order to create the power grid. Afterwards, these components are connected all together, the real high voltage lines are shown on the map and as a consequence the electrical power grid.

The third, and last element focuses on user – learner profiling and user’s – learner’s needs for game adaptation and personalization. Each user has different needs and different preferences for playing a game. In order to meet those needs the learner must register to IOLAOS educational framework, and create his own profile. His profile contains user’s personal information, like name, age, email etc., and

educational information, like special abilities and learning styles according to educational theories. After learner's registering in IOLAOS, learner's teacher creates game preferences through his profile. Those game preferences concern game's visualization components, such as background color, brightness, sound volume, text size and text color and language. Learner logs in Power Grids EduGame with his email and password, credentials in IOLAOS, and game configures to learner's game preferences.

## 1.4 Thesis Outline

**Chapter 1: "Introduction"**: This chapter is the introductory chapter of the thesis and contains the Synopsis, Thesis motivation, Thesis objectives and outline paragraphs.

**Chapter 2: "Background"**: discusses the background work on issues such as Teaching (students), Lifelong learning (educate professionals), Learning theories, Geo – spatial Educational games, Serious games and electricity, Thesis proposed schedule (Gant Chart) paragraphs.

**Chapter 3: "Technologies used"**: In this chapter we elaborate on the technologies used for designing and implementing the Power Grids EduGame which can be briefly summarized to: HTML5 & CSS, JavaScript, jQuery, OpenLayers API, Materialize.cc, Blender, Experience API (xAPI) paragraphs.

**Chapter 4: "The Power Grids EduGmae"**: focuses on the analysis and the design of the Power Grids Edu Game, described in IOLAOS Platform, User and system requirements and Use cases paragraphs.

**Chapter 5: "Pilot implementation"**: presents the detailed implementation of the Power Grids EduGame. More specific, implementation is explained in Implementation of "User authentication and game's configuration", Create energy plant, Inter connection of power plants, Useful user – map interactions and Insert additional power grid's components paragraphs.

**Chapter 6 "Conclusion & future work"**: This chapter documents the outcomes of this thesis in Conclusion paragraph and the future extensions of the Power Grids EduGame in Future work paragraph.

## 2 Background

In this chapter the background and the state of the art are presented. This thesis incorporates various learning processes such as teaching, lifelong learning and game based learning. Additionally, it harmonizes some learning theories such as behaviorism, cognitivism and constructivism. Finally, reference is made to geo-spatial educational games and serious games about electricity.

### 2.1 State of the Art

#### 2.1.1 Teaching (students)

With the definition “Teaching”, we refer to the process of meeting the human needs, experiences, feelings and taking specific interventions to help them learn specific knowledge. According to Paul Hirst[12] “being clear about what teaching is matters vitally because how teachers understand teaching very much affects what they actually do in the classroom”. It is also mentionable, learning process to include two significant elements. The motivation which has a learner to be part of the learning process and feelings, experiences that a learner has. With those two elements learning process teaches the necessary information and knowledge. In addition, Hattie[13] abuts that one of the outcomes from research in teaching are the clear teaching targets. Clear teaching targets tend to help students and learners to see a point of intervention, to be learning process maintained in a satisfying order and condition and make the difference on what contrasting individuals learn.

Researches have concluded that if a learner or a student is involved actively in learning process, as a result his/her attention and centralization are increasing, are motivated in drilling their critical thinking and provides them with important learning experiences. Educators who adopt the learning process approach that focuses on the learner, are increasing the opportunities of each student – learner participation. Thus, educator, as well as learner, are able to hit the target of subject better. Palmer[14] claims that “good teaching comes from the identity and integrity of the teacher”.

Serious games are connecting directly with teaching. This connection leads to positive outcomes in educational and teaching environments [15]. Learning process is accomplished when serious games are not being used for entertainment, but as a learning method. Moreover, during teaching with the use of serious games, students establish a better short – term and long – term mental retention. Also, they increase their social skills, like the cooperation, and they act together with other students in decision-making to solve a problem. In addition, it has been noticed that students’ levels of self – restraint and troubleshooting have been increased [16][17]. Participation in web games has as main criteria the cooperation in order to create knowledge and at the same time, encourages players to use different types of computing literacy, like search on the internet. Those two criteria are important elements for information research and comprehension [18]. The achievement of using serious games in teaching is in the combination of audiovisual media that are dominant in these games and help user in information and knowledge immersion. A very important factor in order serious games to succeed as teaching means, is the learning module’s subject presentation. This presentation must be included inside a game’s form and as a result, the learner can concentrate more easily and his attention is being improved. Thus, not only information is not restrained, but students are also urged to learn and hence the overall learning experience is improved.[19].

Sorensen and Meyer [20] mention that, education and learning potential of serious games, along with students and presenting subject, have a key role on teaching and education in general. Serious and educational games demand to a large degree the participation of the learner – student. They are able to convert students from passive learning actors, to effective students who participate actively in the configuration of the subject’s aims and consequently play an important role on course’s and subject’s organization and learning process. On the other hand, Michael et al [21], affirm that serious and

educational games manipulate learners or students in designing solutions of problems and applying them so they can reach their goals. Simulation that educational games use, is more simple, obvious and compensatory to learner. Also, Michael et al [21] concluded that serious games are concentrating on teaching rather than the teaching – learning process.

### **2.1.2 Lifelong learning (educate electricians (professionals))**

Lifelong learning documents the "continuous, voluntary and self-propelled" [22] willingness of knowledge for different purposes such as personal or professional. It thus contributes to social inclusion, active participation and personal development, but it also helps him/her in competitiveness [23]. In addition, the term lifelong learning refers to the learner's decision to be enrolled in some training courses in order to keep himself enthusiastic about acquiring knowledge and self-improvement. Learning can keep the body and mind in shape. Research has shown that knowledge and learning have a positive effect on brain cells and promotes mental acuity.

Lifelong Learning (Education and Training) is a continuous process of acquiring, renewing, completing and specializing a person's knowledge and skills so that he/she can be a member of a knowledge-based society. The continuous learning process must be available to all citizens and serve the needs and interests of each individual at every stage of his life. The development of a person's knowledge, skills and therefore the capabilities of them can be the result of all forms of learning.

Nowadays, the profession of electrician is brought about by huge technological developments and by the energy framework. Through lifelong learning, the electrician is repeatedly called upon to handle and equip new possibilities, new materials and technologies, thus confronting the need to reconstruct the methods, knowledge and services he delivers. Continuing vocational education and further training is a necessary condition for maintaining and enhancing his / her scientific knowledge and a strategic factor for his / her professional development. Their continuing education and training is essential for their professional growth and development, and they recognize that this must be done at regular and recurring intervals. Continuing vocational training can also benefit them in acquiring new, specialized knowledge, reorganizing their methods and tools, enhancing their professional development and developing their professional abilities [24].

### **2.1.3 Game based learning**

Game based learning has defined learning outcomes. It is designed to balance the subject with gameplay and the player's ability to maintain and apply this subject to the real world [25]. Game based learning is used to learn specific skills and knowledge by playing a game. On the other hand, nowadays, many are the ones who confuse the concepts of game based learning with gamification, which in fact is about two separate concepts. With gamification, we suggest the use of game engineering and design features in off-game environments. Matching the points for completing a traditional style learning unit is standardization [26]. The Game based learning, on the other hand, includes a real game.

Game based learning offers some basic elements. The first element is competition, which, through competition, reveals some competing elements that help motivate trainees who may not find this motivation in normal learning methodologies. The second element is the person's involvement in the game. When a learner plays a game he automatically develops the element of curiosity and imagination, so he/she does not observe the learning elements. In addition, a third element is the reward you give to the learner as the game progresses or ultimately as a reward, winning the evolution of knowledge that will help him / her in the learning process. Finally, a fourth element is commitment, and through it the trainees entertain and simultaneously coerce the learning, giving them the privilege of freely defining and revising their strategies according to a specific goal.

In the long run, the learner tries hard, persists and proves to understand and be satisfied with what

he/she is doing [27]. According to Kristian Kiili [28], flow feedback has a positive impact on learners' learning and actions, and educational game designers should emphasize at the appearance of the game, involving a story, and have a balance in play to complicate players. Learning can be effectively delivered through educational games by giving them the opportunity to acquire teaching skills, timing and strategy according to Koster [29]. Martens [30], documented by Ulicsak [31], emphasized game based learning as the meeting point of learning, games and simulation. Figure 1: Game Based Learning [31] below presents the interplay of learning process, computer science and games.

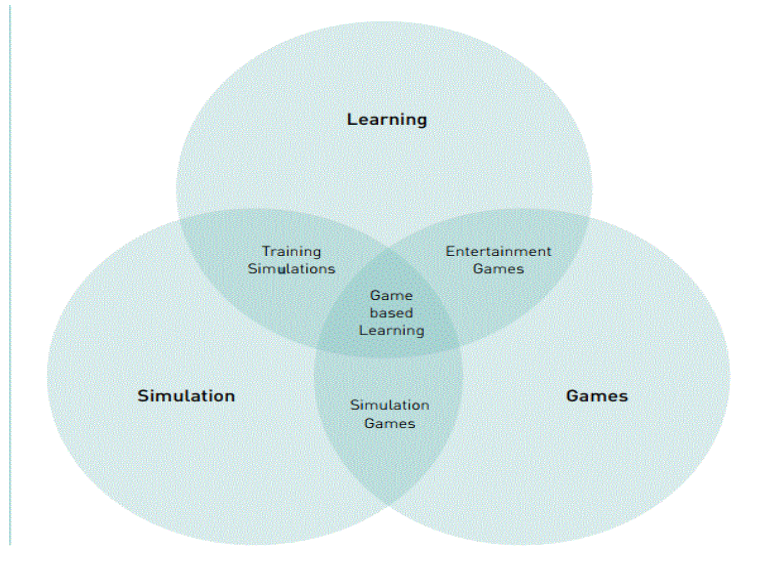


Figure 1: Game Based Learning [31]

S. Erhel et al. [32] have completed some experiments that one of them was a quiz of a digital game based learning that can review learning strategies from learning to teach. This showed that the participants had better comprehension than learning in teaching and that made them less shaken by their insolvency in teaching.

### 2.1.4 Learning Theories

In order serious games to have added values and sustainability in education and learning process, should harmonize and obtain admissible learning theories.

*Learning theories through a set of methodologies describe how humans attain, obtain and recall knowledge. Nielsen [33] focuses on three different learning theories. Those theories are Behaviorism, Cognitivism and Constructivism (Figure 2).*

*Examples & applications of Nielsen's three learning theories are: repetitive practice, bonus points, drill and rote work, participation points linking concepts, providing structure, real world examples etc. These examples and applications have been used to create the diagrams in Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε., Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε. and*

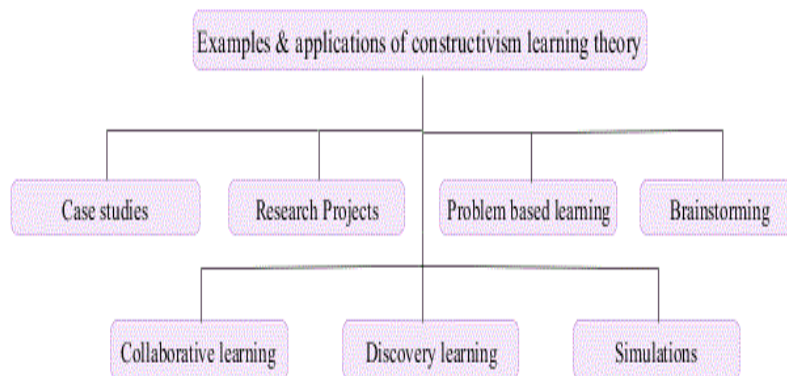


Figure 5.

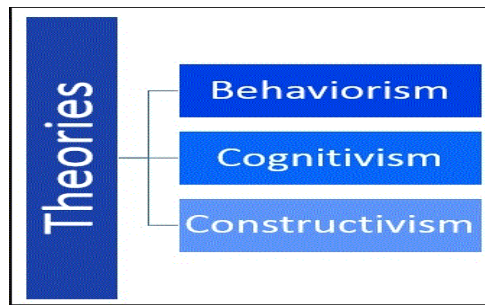


Figure 2: Nielsen's three learning theories

### 2.1.4.1 Behaviorism

Behaviorism bears out that by observing a learner's behavior and attitude, it is possible to come to a conclusion in respect of the learning phenomenon. Emphasis is placed on how information is diffused and how learner's behavior is modified. Namely, learning process is the behavior's alteration according to person's experiences. Behaviorism's epistemology is based on experimental and positivistic approximation. Significant representatives of Behaviorism are: J.B. Watson (founder) [34], E.L. Thorndike[35], I. Pavlov[36], B.F. Skinner (Radical behaviorism) [37], N. Crowder (Programmed instruction) [38], R. Gagne (Designing instruction)[39]. According to behaviorists, knowledge is constituted by ideas that a person's brain obtains. Also, they claim that brain is a tabula rasa where educator or teacher can write knowledge. Moreover, knowledge in behaviorism is reached by repetitive practice, bonus points, drill and rote work, participation points, establishing rules and verbal reinforcement (Figure 3).

In Behaviorism the learning process is a passive as well as a reproductive procedure. Educator or teacher convey knowledge to learner. Moreover, the learning process is static and objective and emphasis is given to knowledge's range and quantity. Effectiveness of the learning process on learners, is directed by advancement tests. These tests are accent on knowledge's content. The educational model which leans on Behaviorism is teacher centered. Teacher, and therefore educator, is considered expert and learners must reproduce the knowledge as it is in the textbooks and transmitted by the expert in the classroom.

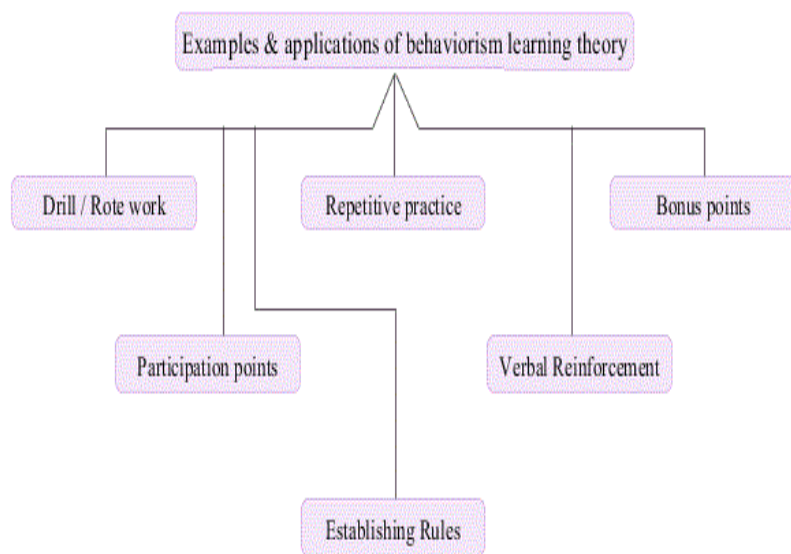


Figure 3: Examples & applications of behaviorism

### 2.1.4.2 Cognitivism

“Cognitive theorists recognize that much learning involves associations established through contiguity and repetition. They also acknowledge the importance of reinforcement, although they stress its role in providing feedback about the correctness of responses over its role as a motivator. However, even while accepting such behavioristic concepts, cognitive theorists view learning as involving the acquisition or reorganization of the cognitive structures through which humans process and store

information”[40]. Cognitive learning theories, recognize that children in early age, before going to school, possess knowledge. As a result, school needs to help them in order to build new insights into the existing knowledge. Cognitivism learning process makes use of classifying or chunking information, linking concepts, providing structure, real world examples, discussions, problem solving, analogies, imaginary and providing pictures and mnemonics (Figure 4). Also, cognitive learning theories focus their interest within a person’s cognitive system, its structure and functionality. Therefore, learning process highly recommends knowledge modification.

In the learning theory of cognitivism, the learning process is focused on how information is received, organized, stored and retrieved by the mind. The key paradigm of this approach is to activate prior knowledge by using past learning as well as impart education through different modalities, i.e., text, pictures, and sounds. Cognitivism is an extension of the behaviorism learning theory rather than a replacement [33][41]. Common examples of how to apply cognitivism theory in games are illustrated in [41], where English expressions are taught using familiar art pictures, while in [33] math lessons include geometry puzzle.

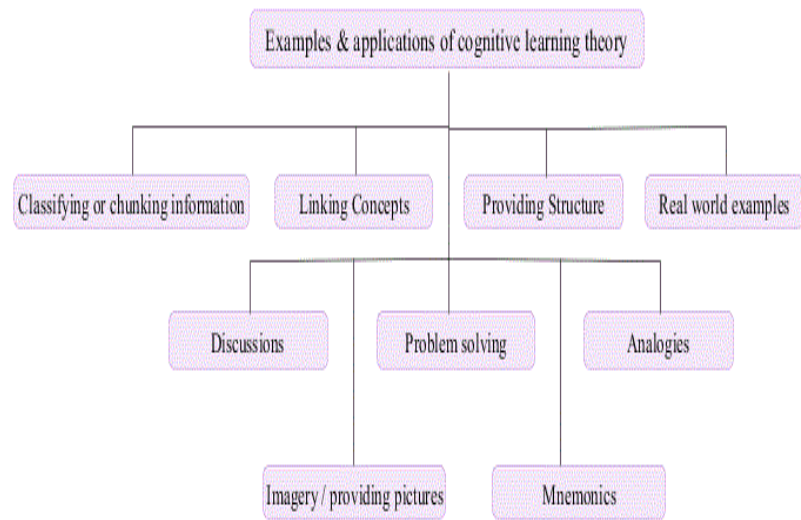


Figure 4: Examples & applications of cognitivism

Cognitivism has been applied in the following games:

**Quest Atlantis of Indiana University**

Utilizing Quest Atlantis, researchers [41] attempted to create a bridge between visual stimuli and language. To achieve this, they presented students with Van Gogh paintings. After examining them, the students tried to explain the paintings using English language. In this learning task, the students successfully used English expressions to explain something visual. Therefore, the study concluded that visual information offers opportunities within education.

**Super Tangrams**

Super Tangrams[33] is a serious game that utilizes cognitive learning. It achieves this by creating a research-based gameplay involving mathematic and manipulation of geometric shapes. The player has to use his skills to solve puzzles in an ever-growing difficulty setting, moving the shapes in order to fit them together in an outline. Additionally, the game is ludic, engaging students with learning and delivering fun experiences along with educational benefits.

**2.1.4.3 Constructivism**

J. Piaget describes the development of the child’s logical thinking as an evolutionary process formed through different stages, while basic concepts in Piaget’s theory are assimilation, compliance, adaption and shape.



Constructivism [42] argues that learning is an energetic process. People actively construct knowledge through their experience of the world. Knowledge is not just a commodity that is transmitted, encoded, preserved and re-applied. It is a constructive personal experience. The world “is not just there” waiting to be revealed, but it is gradually formed and transformed into shape through the personal experience of a child or a scientist.

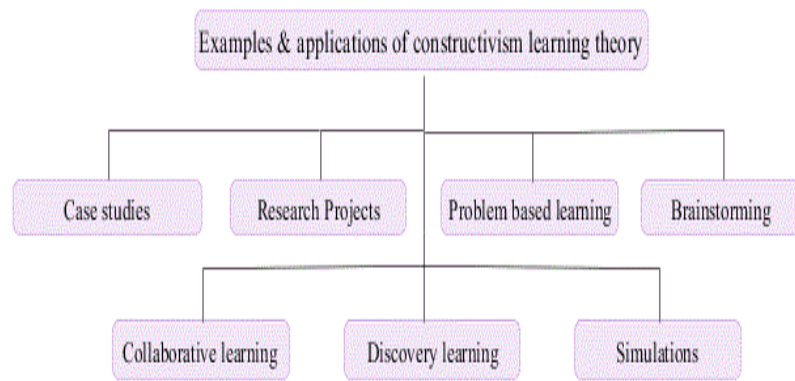


Figure 5: Examples & applications of constructivism

Knowledge is not transferred from the teacher to the students, but is actively constructed by the students themselves. People generally do not accept ready ideas, but construct them. Also, they are not passive listeners and do not memorize but experiment and explore. Students build new knowledge effectively when they are involved in the fabrication of things. Moreover, students are consciously involved in activities that make sense for themselves, for instance making or manipulating a creature like a computer program. As it is shown in Figure 5, applies case studies, research projects, problem based learning and brainstorming in the learning process.

Both Piaget and Papert [43], according to Ackermann [44], consider students as the makers of their cognitive tools and their view of the world. For them, knowledge and the world are both structured and constantly rebuilt through students’ personal experience. Knowledge is not just a commodity that is transported, encoded, maintained and reapplied but it is a personal experience that is built. They also, highlight the process through which people overcome their current views of the world and build deeper understandings for themselves and their environment. This is succeeded through empirical exploration and research. Also, by examining the conditions under which, students may preserve or change their theories about a phenomenon through their interaction with this phenomenon over a period of time.

### 2.1.5 Geo-spatial Educational games

Nowadays, game and cartographic world tend to be different, but with deeper and carefully research some of their similarities are perceived. Improved graphics, atmospheric and particle effects are now used to portray real-world data as well as drastic navigation capabilities. Maps, however, are an essential component of many games.

In addition, maps make up the most basic element of virtual worlds used in games. They are designed as the basis for the creation of imaginary worlds or designed to simulate real-world environments. Geographic data is used as input information during game development phases to provide artists with real-world information to build their maps and imitate real environments to improve immersion and familiarity of players.

There are two categories of games using real-world data, the location-based games and the geospatial games. Location based games incorporate the exact geographic position of the player in the game’s storyline, scenario and processes through localization technologies, such as GPS. The gameplay is extended in the real world or is combined with the real world. In location-based games progress, players visit and interact with real world locations [45]. On the other hand, geospatial games are using the spatial aspect as the core of their virtual world maps. Real-world geographic data are used for the map’s implementation, as well as in the gameplay. The maps being used, simulate fantasy world environments or real-world environments[46]. This thesis is a geospatial educational game, as the main game’s map and gameplay are based on real world geographic data.

An interesting example of educational games that uses world map, is the games provided by World Geography games[47]. World Geography games is a site that contains geography quizzes. It provides quizzes about continents, countries, oceans, mountains, atmosphere, Etc. This website aims to improve user's geographical knowledge. It is addressed in anyone who wants to test his knowledge or learn more about the world. Also, it is a Multilanguage site, providing each quiz in English, German, Spanish, French, Dutch and Polish. World Geography website's quizzes are available for Windows and Mac Os computers and iPad, iPhone and Android devices.

Virtual Warrane III[48] is another serious game which uses world map. It is a first-person game and is based in role playing gaming category. User moves his avatar and interacts with Gadigal people leaving who were living at Sydney's cove. The game environment is based in historical research, artworks, diaries and museum artifacts. User must explore and survive in this environment. By this exploration, user earns historical knowledge by his interaction with Gaidigal and Eora cultural figures.

The ArcUser[49] serious game introduces a world map inside its gameplay. ArcUser is a serious game designed to measure the spatial thinking ability of disaster responders. ArcUser's game scenario simulates a disaster in Rhine River in Bonn, Germany, where toxic substances have polluted river's shore. The game provides a series of questions on the player, who has to reduce the disaster by using ArcGIS tools provided. ArcUser is based on an ArcMap, python programming language for game interactions with the map and it was developed by a team of student researchers at the Rochester Institute of Technology (RIT) with the cooperation of the United Nations University Institute for Environment and Human Security (UNU-EHS) in Bonn, Germany.

As it results from the above-mentioned examples, educational games that use geospatial data can cover different education fields. The player is able to acquire different types of knowledge such as geographic, historical and cultural knowledge as well as environmental and survival knowledge.

## 2.1.6 Serious games and electricity

Serious games are a category of games with educational purposes. Serious games that rely on electricity, aim to explain the vital importance of electricity and also, the player's familiarity with the management and functionality of high voltage networks. For example, a game scenario can be the management of electrical hazards and the save of electricity.

Another aspect, is that serious games about electricity are used to avoid accidents to people working on electrical power grids. By providing them the appropriate training, workers are able to examine the solutions before putting them into practice. Netto et al [50], presented a three – dimensional environment to make decisions about the reduction and loss of electrical networks. Nagelov et al [51], highlighted a layout for power system where 3D objects used for the process of learning and preserving knowledge. Arendarski et al [52], formulated a maintenance and repair system for the analysis of machines, such as transformers and generators.

Two examples of serious games in the field of electricity are the following:

- **Electricity Circuits**

In electricity circuits user is able to learn about electricity circuits and experiment with batteries, voltages and light bulbs. Wiring them in different ways, result surprising outcomes. User can check his model and see how it looks as a circuit diagram. It is provided a variety of challenges that involve changing the circuit, moving switches, replacing bulbs, changing the battery volts and adding longer wires.[53].

[Link: http://www.sciencekids.co.nz/gamesactivities/electricitycircuits.html](http://www.sciencekids.co.nz/gamesactivities/electricitycircuits.html)

- **Power your world - Siemens Energy introduces the new browser game Power Matrix**

Siemens Energy has developed a free online game that challenges the user to design a sustainable energy system for a city. The simulation game Power Matrix aims to generate an

understanding of the mechanisms and rules of the energy market and to provide insights into the interaction between different power generation types and power grids.

Power Matrix is not only geared towards experts and experienced online gamers. In fact, it is primarily intended for members of the general public who are interested in the topic. The player takes on the role of an energy manager in a rural area whose task is to contribute to the growth of a city by creating an intelligent energy mix and providing a stable power supply. Possible energy sources include both conventional technologies and renewables, such as wind and solar power. The better the energy mix you can create by combining the different energy sources, the faster your city grows. You can also collect bonus points by investing in research and development, for example. You must always keep an eye on the available budget however, in order to ensure a sustainable and efficient use of resources[54].  
[Link: https://www.siemens.com/press/en/feature/2013/energy/2013-06-power-matrix.php](https://www.siemens.com/press/en/feature/2013/energy/2013-06-power-matrix.php)

Table 1 Cultural Heritage Learning Environments and Games

Game constituents & fundamentals	Games	NON-commercial games			
	Commercial Games	Electricity Circuits	Virtual Warrane III	World Geography games	Power Grids EduGame
2D	✗	✓	✗	✓	✓
3D	✓	✗	✓	✗	✗
Adventure Game	✗	✗	✓	✗	✗
Virtual Reality	✗	✗	✓	✗	✗
Interactive Game	✓	✓	✓	✓	✓
Accessibility	✓	✓	✓	✓	✓
Dynamic Content	✗	✗	✗	✗	✓
Web	✓	✓	✗	✓	✓
Point to Point Navigation	✓	✓	✗	✓	✓
Support roles for players	✗	✗	✗	✗	✓
Solving Puzzles	✓	✓	✗	✓	✓
Participating in Conversations	✗	✗	✗	✗	✗
Recreate the Plot of a Play	✓	✓	✗	✗	✓
Propagate Knowledge	✓	✓	✓	✓	✓
Support Player's Mission in Doing Something	✓	✓	✓	✓	✓
Multimedia Elements	✗	✗	✓	✗	✓
3D Animations, Translations, Transcriptions and Annotations	✗	✗	✓	✗	✗
Input Devices Support	Mouse	Mouse	Mouse & Keyboard	Mouse & Touch	Touch/Mouse & Keyboard
Collaboration	✗	✗	✗	✓	✓

Puts Students in Creative Role	✓	✓	✓	✗	✓
Sharing Available	✗	✗	✗	✓	✗

### 2.1.7 Thesis proposed schedule (Gantt chart)

The following Figure 6 shows the proposed Gantt Chart timetable of this thesis. The Gant Chart is consisted of five distinct and equally important master work packages

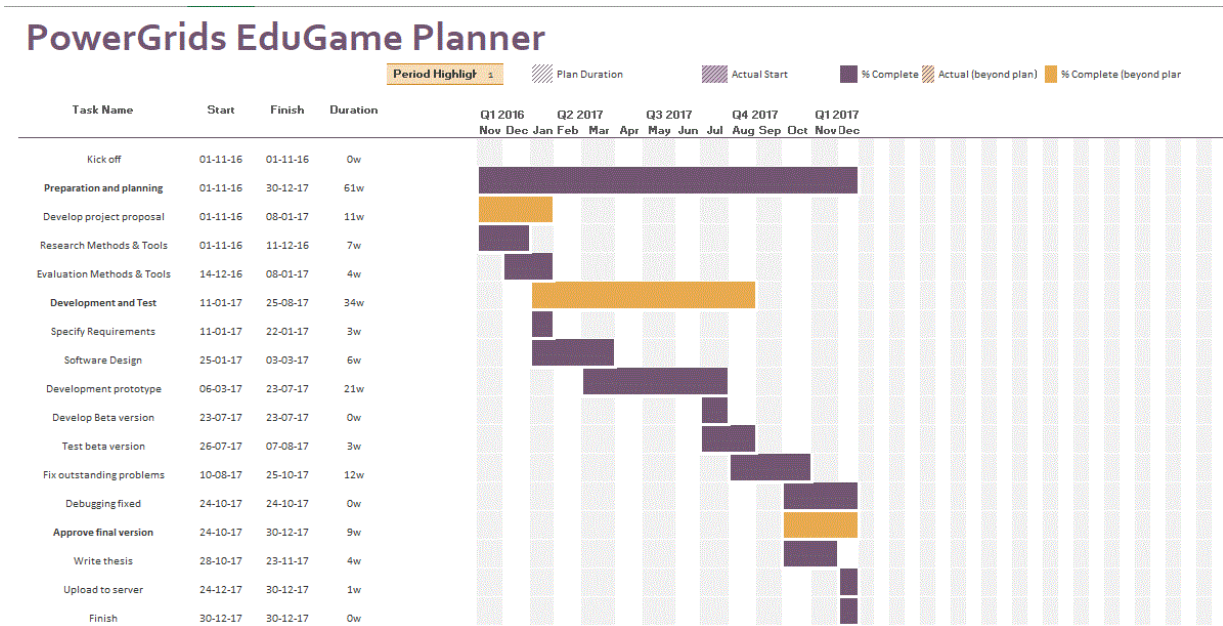


Figure 6 Gantt Chart

### 3 Technologies used

For the development of “Power Grids EduGame” we have used different technologies for the different modules of the game. The different game modules and the technologies used per module are listed below:

- Front end & User Interface: HTML5, CSS and Materialize.css framework,
- Game components: JavaScript,
- Game functionality: Javascript,
- World Maps: OpenLayers API,
- 2D graphical component: Blender.

In the following paragraph we present in more detail the technologies used and their characteristics.

#### 3.1 HTML5 & CSS

**HTML5** is a type of markup languages. A Markup Language marks text so that the computer can handle that text. Markup languages are for instance HTML, XML, XHTML, for web pages creation and are the core language of the World Wide Web. A language of this type is easy for people to understand and read it, because works through annotations that are distinguished from the text. For this purpose, the markup tags < > are been used. Text that is contained inside those tags, is not part of the text but part of the language[55] [56][57].

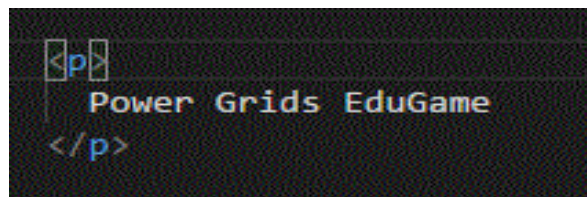


Figure 7 Markup language example

The figure above is a simple example of the markup language, HTML. The tags <p> and </p> describes an HTML paragraph, and the text inside the tags is displayed on the web page. With simple words markup has to do with what HTML tags do to the text inside them.

HTML5 is the fifth version of HTML. With HTML5 we can pass from a web page with reach media support to a web application with user interaction and server connection without installing additional plugins in the browser. Multimedia tags that HTML5 support are: <video>, <audio> and <canvas>. Also supports scalable vector graphics (SVG) content, for graphics and MathML for mathematical formulas. It has three types of code, the HTML5, the CSS and the JavaScript. New page structure elements are presented in HTML5, for example <main>, <section>, <header>, <footer> and more. As a consequence, new APIs have been developed, that can be used with JavaScript. Those new APIs are: Canvas, Drag and drop, Offline, Web messaging, Geolocation, Web SQL database and more. Also, it is a cross-platform language, which means that if a browser supports HTML5 can work perfect, either users have a computer, laptop or a smartphone, tablet[58].

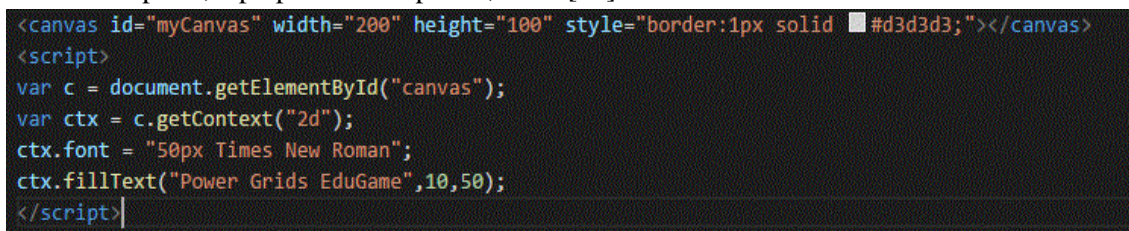


Figure 8 HTML5 simple example

**Cascading style sheets or CSS** is used for control and add style on a document that has been created with a markup language and was invented by Håkon Wium Lie on October 10, 1994. In simple

words, CSS controls the appearance and the visual of a web page, created for instance with HTML5, and makes it presentable. By using CSS, developer handles colors, fonts, components' sizes, backgrounds, borders, animations as well as a variety of many other effects. CSS' syntax is simple and contains English keywords for the properties and works with CSS rules. Each rule or a block of rules composed of selectors and a declaration block. Selectors apply to specific type elements, elements specified by id or by. Declaration block is a list which each declaration is composed of a property, a colon and a value. A CSS rule example is shown above[59][60].

```
.header{
  height: 50px;
  width: 50p;
  background: #f0f0f0;
  border: 1px solid #CCC;
}
```

Figure 9 CSS simple example

## 3.2 JavaScript

As mentioned above, JavaScript is the scripting language for web pages. It is also often mentioned as JS, the first letters from Java and Script. The first name was Mocha, which changed to LiveScript and ended to JavaScript. JavaScript is a lightweight, prototype – based language (object – oriented) and supports functional programming styles. Programming syntax on JavaScript is based on C programming language. If statements, while, do while, for loops are similar in C. Also, syntax is similar in Java and C++. Variables are dynamically typed, rather than each variable has each own expression. For example, a number variable could be easily used and as a string. Variables in JavaScript are all in the same type, “var”.

```
var x = 5;
var y = 6;
var diff = 0;
if (x < y) {
  diff = y - x;
}
console.log(diff);
```

Figure 10 JavaScript example

JavaScript has the ability to be functional as a procedural programming language, as much as an object-oriented language. But there is a popular misunderstanding. Because JavaScript can be object – oriented, many thinks that is simplified Java. What makes JavaScript object – oriented is the prototype – based objects construction for inheritance rather than classes that Java and other object – oriented programming languages use. Prototype object oriented programming creates objects that can be cloned and extended[61], like on the Figure 11 below.

```
1 var vehicle = {
2   speedUp() {
3     console.log("Car is speeding up");
4   }
5 };
6
7 var car = {
8   vehicle: true,
9   __proto__: vehicle
10 };
11
12 var cabrio = {
13   numberOfSeats: 2,
14   __proto__: car
15 };
16
17 cabrio.speedUp(); //Prints Car is speeding up
18 console.log("Sports car is vehicle:" + cabrio.vehicle); //Prints true
19 console.log("Sports car has: " + cabrio.numberOfSeats + " seats."); //Prints 1
```

```
PS C:\Users\Apostolis\Desktop> node index.js
Car is speeding up
Sports car is vehicle:true
Sports car has: 2 seats.
```

Figure 11 JavaScript inheritance example

Furthermore, JavaScript scripts are being included in an HTML document to be executable by the browser, thus there is no need of a compiler. All browsers support JavaScript. To develop in JavaScript, is not needed expensive developing tools to write code in. In a simple text editor, like Notepad, it is possible to write JavaScript code, by saving the file with a name and .js. Also, it can be used from more special editors like Notepad++, Visual Studio Code, Sublime Text, Brackets, and integrated development environments such as NetBeans, WebStorm, Visual Studio, Eclipse and many more.

Nowadays JavaScript is being used for creating web pages, web applications and web-based applications for smart devices, like smartphones and tablets. JS has become one of the most popular programming languages, as the web is one of the most popular and widely used application development platform. For building and developing for web and rendered in browser, JavaScript is needed. Furthermore, many popular frameworks and libraries are using JavaScript, like Angular.js, Vue.js, React.js etc.

### 3.3 jQuery

As mentioned many frameworks and libraries are using JavaScript. Another JavaScript library, is jQuery. jQuery was actually created as a tool in order to be easier for developers to program with JavaScript and HTML5. Its library contains HTML/DOM and CSS manipulation, HTML event functions, such as buttons event listeners, effects and animations on a web page and JSON files parsing. Also features the communication between server and client using Asynchronous JavaScript and XML (AJAX). It is based on the “Write less, do more” adage. A basic advantage of jQuery, is being cross – platform compatible. Earlier versions of Internet Explorer and Mozilla Firefox browsers, had problems with some features written in JavaScript. With jQuery those issues do not concern the developer, and code is distributed as it was programmed in every web browser. A simple jQuery which adds an Event listener on a button is show in the Figure 12 below.\

```
$('#button').click(function () {
  console.log("Power Grids EduGame");
});
```

Figure 12 jQuery example

### 3.4 OpenLayers API

The demand of using real world interactive maps on applications and web sites has grown through years. In a real-world map it is possible to demonstrate various information, like historical monuments, user’s geolocation, navigation and Global Positioning System (GPS), create games and visualize data.

OpenLayers is a free open source JavaScript library for adding maps on a web site or web application. Provides an Application Program Interface (API) that developers can use to create maps with interactions. OpenLayers API features tiled map layers, that allow developers to choose tiles from many sources like Bing maps, MapBox, Stamen, OSM. Moreover, it provides vector layers for displaying vector data on map from different source, such as JSON, GeoJSON, TopoJSON, KML, XML, WMS files. OpenLayers, use HTML5, CSS, Canvas and WebGL, thus it a cross platform library which can work fluently in any browser and any device. Useful 3d part libraries are being provided for additional functionality. A big advantage that makes OpenLayers API easy to use, is the simple syntax and the variety of code examples that has. There is no need of complex JavaScript knowledge. A simple map creation JavaScript code example is presented below (Figure 13).

```

var map = new ol.Map({
  layers: [
    new ol.layer.Tile({
      source: new ol.source.OSM()
    })
  ],
  target: 'map',
  view: new ol.View({
    center: [0, 0],
    zoom: 2
  })
});

```

Figure 13 OpenLayers API map creation example

OpenLayers use the client – server model. In this model a client - side map application, connects with a web map server that provides data to map, for instance a backend like Bing Maps. But, OpenLayers can use only the client side without a server connection. Static content can be generated in map by parsing GeoJSON files.

The strong documentation of its API, the community behind the API, the large list of examples and the free open source library, prove that OpenLayers is a strong free open source JavaScript library for map development.

### 3.5 Materialize.css

Materialize.css framework, is an open source CSS library based on Material Design. This framework provides rules for CSS code, in order to style and beautify a web page or a web application. To use the Materialize.css Framework, the .html files must include the materialize.css library. It is also a cross platform library, like OpenLayers API, and optimal works in different browsers. Materialize.css provides a wide range of ready to use HTML5 components and CSS rules that developer can use or extend in order to create an interface for a web site or a web application. The detailed documentation and the feedback that Materialize.css provides, helps a new user to begin with. Furthermore, many third - party libraries and extensions based on Materialize.css framework have been developed.

### 3.6 Blender

Blender is a professional open source designing graphics program. It is used for 2D & 3D graphics creation, animations and visual effects, video games and 3D applications with interactions. Different versions of Blender are available for Microsoft Windows, Mac OS and Linux, as well as for 32 & 64 – bit systems. It has two main working modes, the Object Mode and the Edit Mode. With Edit Mode user controls each object individually and changes object’s scale, movement and rotation. On the other hand, Object Mode manipulates different objects a unit of a single mesh. By pressing the “Tab” key, user can switch from object to edit mode and backwards. Blender uses the Python programming language for scripting and has tools for characters and materials design.

### 3.7 Experience API (xAPI)

Experience API, also known as TinCan API, is an e-learning software which allows different systems and contents to communicate with each other. Through xAPI a range of experiences that a user has by using a system, are collected. It is an open source API that uses JSON structure for the collected data and uses the form of statement objects. Statements are using actor, verbs and objects. This allows to capture and record easy any user’s activity and action. User’s experiences are saved in Learning Record Stores (LRS), which is area data store for storing and managing collections of data.



## 4 The “Power Grids EduGame”

As mentioned above, the present thesis aims to the design and development of an educational, serious game namely the “Power Grids EduGame”. The game incorporates three main elements as stated at section 1.3 i.e. element A: Educate and Learn, element B: Gamify real electricity power grids and element C: Personalize game experiences through the use of extended user profiling.

Summing up, our game aims at simulating the creation and management of high voltage power grids in a game based learning environment. The target learner audience are electricians of all ages but also anyone else who wants to learn electrical high voltage power grids. The game is a real world simulation game. This means that power grids are simulated with realistic characteristics in a world map. Those characteristics are:

- Accurate depictions of Power Grid components in 2D drawings, e.g. power plants, generators, pillars. Etc.
- Power grid components positioned in a real-world map.
- Mounts of electrical power production and consumption.
- Visualization of high voltage lines.

According to the game main element B i.e. gamify real electricity power grids, the “Power Grids EduGame” presents and manages an electrical power grid and uses: a world map, user – map interaction facilities, real-world data, 2D component icons and user – component interaction facilities. Different graphical user interface components have been used for all user interactions in the game such as toolbars, side navigation bars, buttons, dropdown menus, popup windows and popup dialogs. The above interaction components – artifacts have been used in all three different game levels.

**First Game Level** is the designing of a power grid and creating its high voltage lines on a specific region. In this level the user initially must add components to the power plants. The components are diesel generators, hybrid generators and transformers. After that the player can connect the generators with one or more transformers inside the given power plant. Thus, the relationship of the connection between generators and transformers is a many to many relationship (NxN). To finish the design of the power grid the user must build and connect all power plant components on the map. When the building is done the user can create a power plan connecting high voltage lines finishing the level one.

**Game Level Two:** The player is asked to manage crisis scenarios and situations on a given power grid. A crisis can be a technical problem that the player has to manage, like a failure of a power plant. In this case, the player must find the most secure and efficient solution in order to make the power grid productive again in the shortest amount of time. Another type of crisis can be an expansion of the power grid. For instance, if the rate of carbon dioxide (CO<sub>2</sub>) is high, the player has to reduce this rate by replacing non-renewable energies and resources with renewable.

**Game Level Three:** This level refers to monetary values of electricity and exchange of electrical power in different power grids. In other words, it seeks to simulate an energy stock market. In this level, different power grids can sell amounts of electricity to other power grids that are in need and vice versa.

The first main element of our game, i.e. Educate and Learn is achieved with the collaboration of the user profiling element, the third element of the game’s objectives. First of all, the educational purpose is accomplished through the knowledge that the player – learner absorbs on electrical power grids. The power grids management and the situations that player is involved in, provide information that the user can adopt and improve on his thinking. Also, as the player can be an electrician, the game focuses on the life - long learning which is described in section 2.1.2.

As mentioned, the educational and user profiling elements, are collaborating. This collaboration is reached by the use of the IOLAOS platform. Power Grids EduGame has a consistent communication

and connection with IOLAOS. Through the connection between game and platform, “Power Grids EduGame” makes use of different learning theories and learning styles. As Mouahed et al.[8]argues, serious games can have an added value by using learning theories and styles. Furthermore, the game – platform collaboration gives the learner the ability to have a personalized game according to his profile in IOLAOS. The personalization of the game refers to visual characteristics, for instance UI components properties. In addition, IOLAOS platform supports different learning theories, like constructivism, behaviorism and cognitivism and learning sessions that learners can play in the game. Description and details about the IOLAOS operation, usage and how the platform cooperates with serious games, are reported in the next paragraph.

### 4.1 The Collaborating IOLAOS Platform

IOLAOS platform[62][63] is an educational environment which supports game based learning. IOLAOS offers services for (a) enabling educational experts to digitalize pedagogics, (b) building user and learning profiles, (c) fostering the creation of virtual classrooms and learning sessions, (d) allowing, in the background, communication with third party serious games, (d) storing and processing game analytics and (d) providing constant feedback and evaluation of IOLAOS affiliated educational games. IOLAOS architecture is shown in the Figure 14 below.

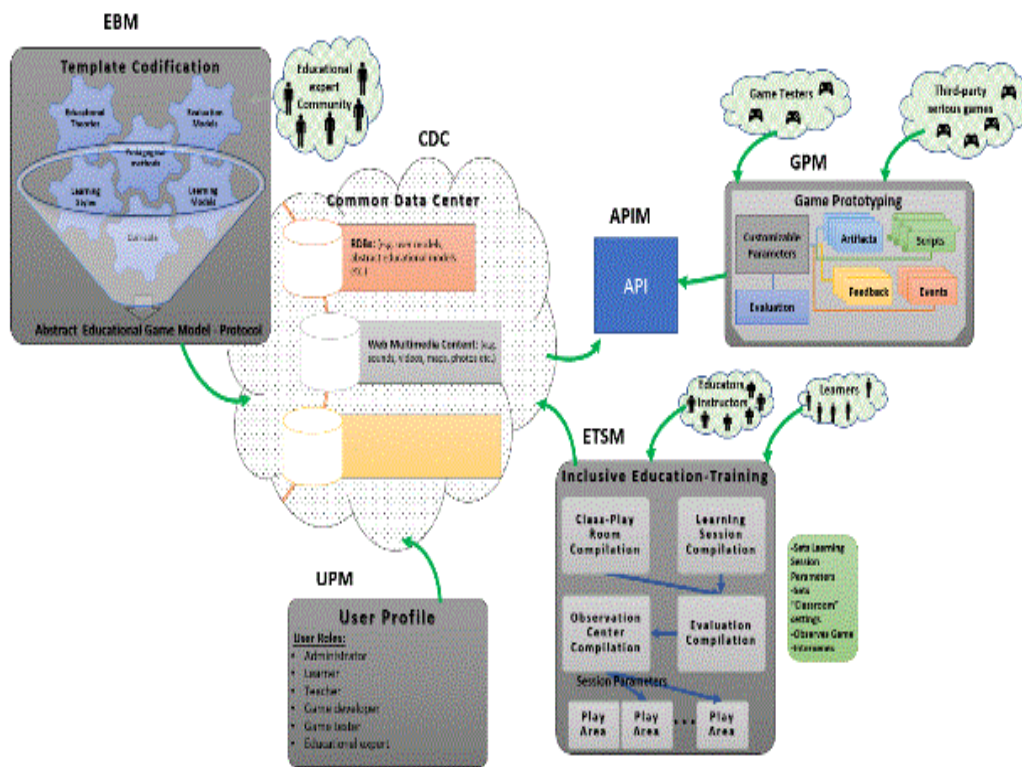


Figure 14 IOLAOS platform architecture

IOLAOS architecture[10] is divided in six parts. The Common Data Center (CDC) is the intermediate that connects all parts of the architecture together. It is responsible for storing different types of data that pertain to the platform. These types of data are:

- Relational databases (RDB)
- Non – relational databases (DB)
- Object oriented databases (OO)
- Structured data files (XML, JSON)
- Multimedia (video, images)

In the figure above, in the upper left corner is the Educational Base Module (EBM). This module permits educational experts to convert learning theories from plain text to a digital form. Theories in EBM can later be used for customizable gameplay.

The User profiling module (UPM) is responsible for managing user centered information such as personal, educational, occupational, needs, habits, etc. The platform supports many different type of roles, like learner, teacher, educational expert, game developer, game tester and administrator.

Regarding educational purposes, IOLAOS supports three types of roles, the learner, the teacher and the educational expert. Learners, are able to register in the platform and create their own profiles. Each learner has a unique profile that is used for educational purposes. This profile contains a wide range of information about learners as mentioned above. In order to create a profile, the user has to fill in different types of information such as contact information and educational information. By creating a profile, the learner can receive an invitation for a learning session and be part of it. Also, he is able to play serious games that are available on the platform. Learners can play games in a formal environment such as a structured learning session or in an informal way independently and outside any formality.

The role Learner is associated with the role Teacher in the Inclusive learning sessions (ETSM). Teachers create virtual classrooms and learning sessions and invite learners to join them. Also, they select the educational game that learners will play in each session. Furthermore, the teacher monitors each learner by camera and share screen. Monitoring the learning session gives the teacher the possibility to evaluate the learning process online or off line and decide whether he/she will intervene by providing help and information to each learner.

As mentioned above, the educational expert is responsible for the creation of game preferences. Each game preference is an outcome from each learner's profile. More specific, an educational expert researches learner's profile and creates game preferences that teacher assigns to the learner, according to learning styles, learning theories and special needs. Each serious game in IOLAOS platform is configured by those preferences and the learner has an own personalized educational gaming experience. In simple words, if a learner's eyesight is weak, the game played is optimized to full brightness.

The games creation (GPM) is associated with two roles, the game developer and the game tester. A game developer can create a serious – educational game and connect it to the platform. The game tester is responsible for monitoring and testing games that game developers create. By testing those games, the game tester is able to assign maturity levels and rate games, as well as write game reviews. Being an "IOLAOS approved" serious game, means that the developer has used the IOLAOS REST API and the game communicates with the platform.

API Module (APIM) is a way for games to communicate and cooperate with the platform. APIM is the link between the Common Data Center (CDC) and the Game Prototyping Module (GPM). It makes use of the REST API and provides functions for communication between the different software modules. The functions perform requests and receive responses via HTTP protocol. IOLAOS REST API, can be used by games that have been developed with different programming languages, techniques or game engines. For instance, login is achieved by using IOLAOS REST API authentication function. The response is a JSON file with user's personal information.

In order for a game to be approved from the IOLAOS platform it must make use of the REST API and establish a connection and cooperation with the platform. Thus, different serious games are able to make requests and receive responses. An example is the game initialization according to user profile. The JSON with user's personal information that receive a game as a response, can be used for personalizing the game and in extension to the game based learning experience.

The "Power Grids EduGame" is a game developed according to the IOLAOS framework following its REST API protocol and has been assigned a maturity level after the game test process. In order to play the game, a learner must have a valid user account in IOLAOS. When a learning session (see

Figure 15) is initiated with the “Power Grids EduGame” and specific learners the game is constructed for each learner independently and according to its user profile. The visual, audio, content and other characteristics of the game are set up according to the learner’s profile and thus gives a personalized learning experience.

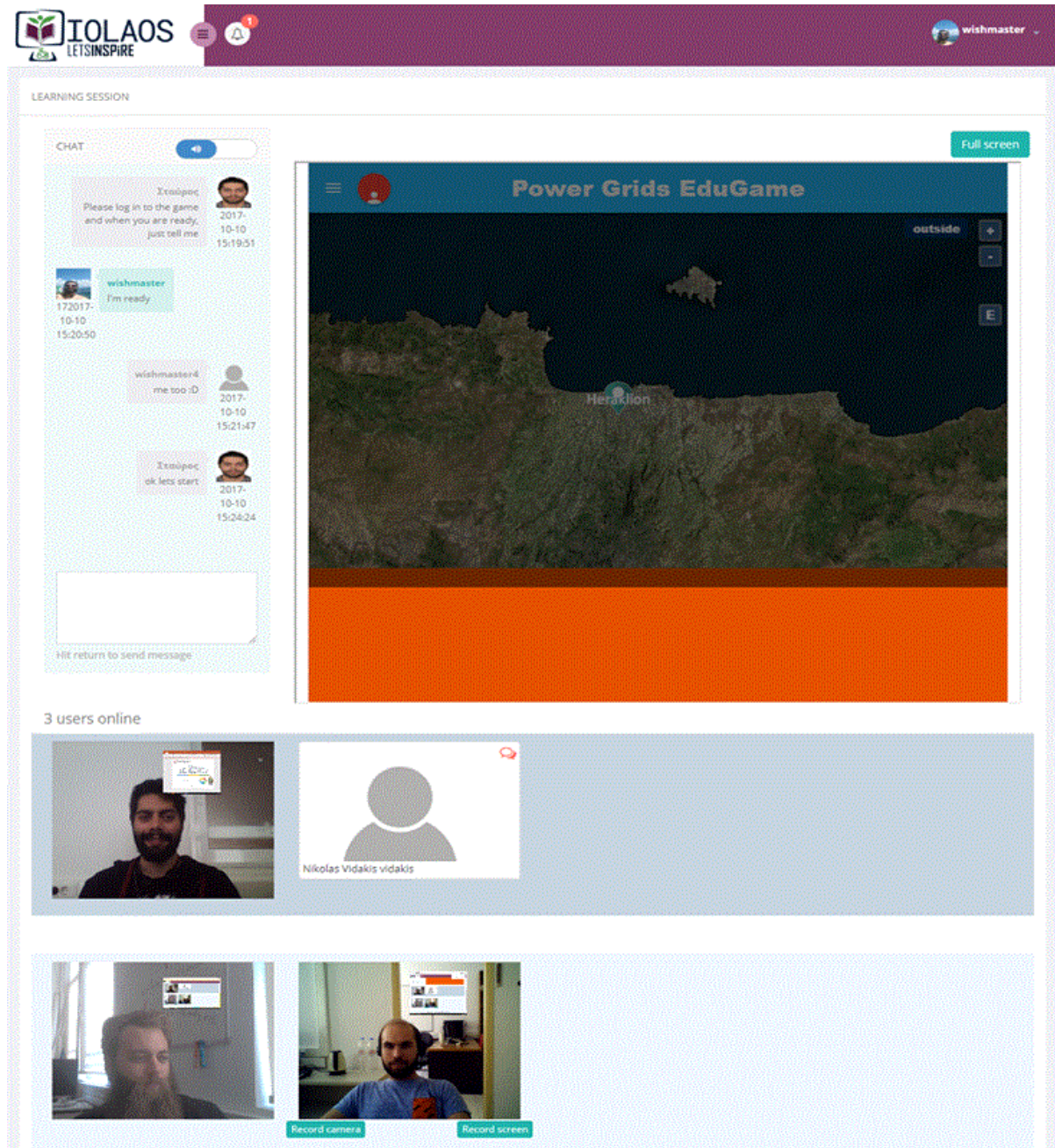


Figure 15 IOLAOS learning session example

## 4.2 User and system requirements

### 4.2.1 System analysis and design

The design of the Power Grids EduGame started by looking into game technologies and focused on game engines, like Unity 3d Game Engine and Unreal Engine, as well as game development areas like web - based games, developed with JavaScript and HTML5. At the same, a research in education areas and fields was being accomplished. Education fields that examined were:

- Game based learning

- Serious games
- Learning theories
- Learning methods
- Games developed for educational purposes.

The Next stage, as the Power Grid EduGame uses real – world maps, was the research in map APIs and frameworks. Initially, the plan was to create a real-world map game through a game engine. After, a deeper research it ended up that maps APIs and libraries for game engines were still under development or not free of charge. On the other hand, there were many developed and reliable map libraries based on web technologies, like HTML5 & CSS, JavaScript. According to this, the design focused on web-based map APIs. The need of an API with strong documentation led to Google Maps API, Mapbox API and OpenLayers API. Examples were developed with these libraries and OpenLayers API was selected. The basic reasons for this selection were that all features of the library are free of charge, the strong community and strong documentation of the API, the support of different types of maps as well as the support of importing different types of data in map. Also, the graphical unit interface was designed in order to be user friendly. Moreover, the user interface designed was configured according to the user profile. The communication with IOLAOS platform and the connection with a common data space were main parts of the game’s design. Furthermore, game’s functions, interactions and levels were analyzed. According to all mentioned, it ended up that Power Grids Edu Game requirements are:

- Game functionality
- Real world maps
- IOLAOS collaboration
- Data
- Graphical user interface

The requirements diagram for the list above is shown in the Figure 16 below.

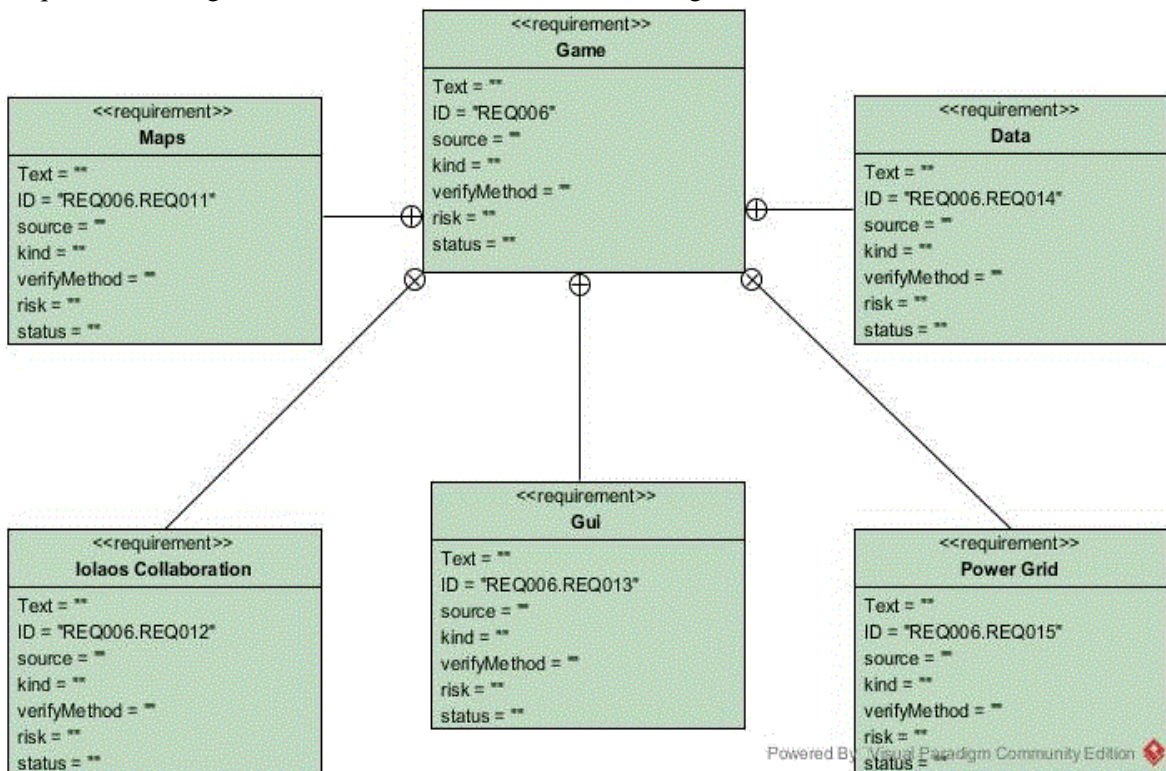


Figure 16 Main requirements diagram

As it is presented on the Figure 16 above, game requirement is the core and is surrounded by Maps, IOLAOS Collaboration, Graphical user interface (GUI), Power Grid and Data. Each component on this

diagram includes sub – requirements diagrams.

- **Game requirements diagram**

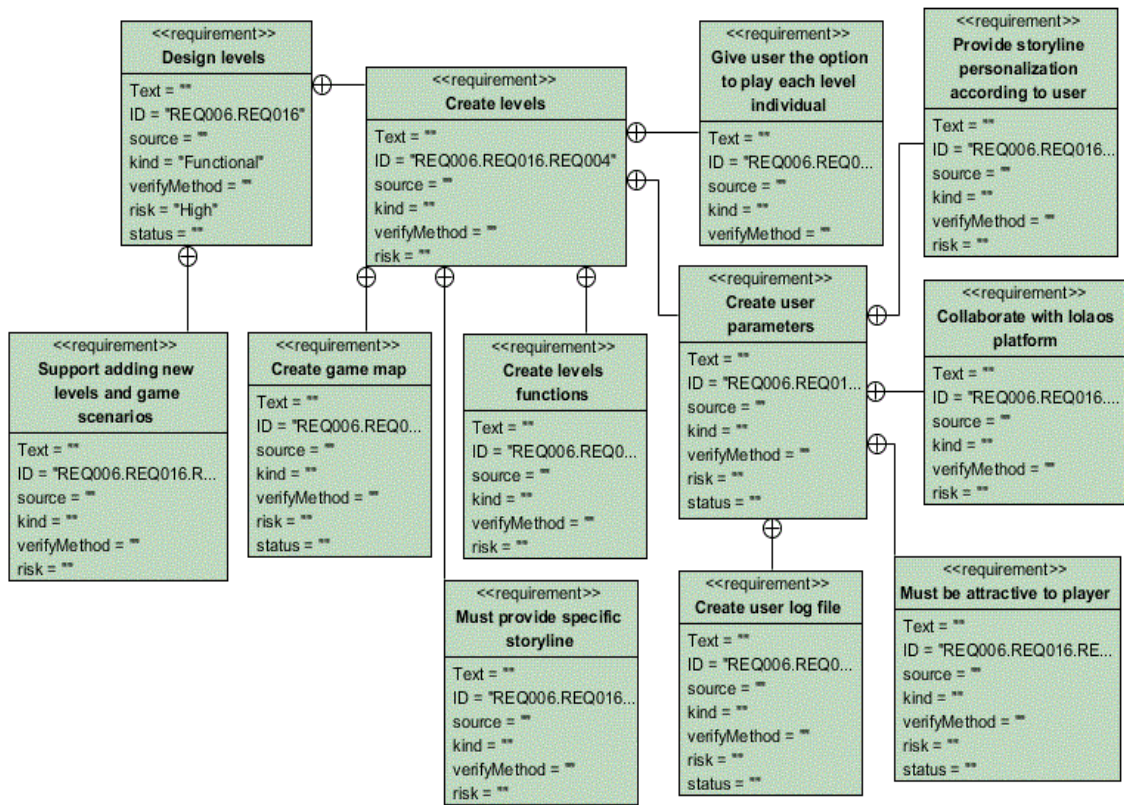


Figure 17 Game requirements diagram

The implementation of game requirement, as shown in Figure 17, features as the source the Design levels requirement. Design levels is connected with Support adding new levels and game scenarios and Create levels requirements. Create levels requirement contains the requirements Create game map, Must provide specific storyline, give user the option to play each level individual and Create user parameters. Create user parameters is consisted of Provide a storyline personalization according to user, Collaborate with Iolaos Platform, create user log file and Must be attractive to player.

- **Graphical user interface requirements diagram**

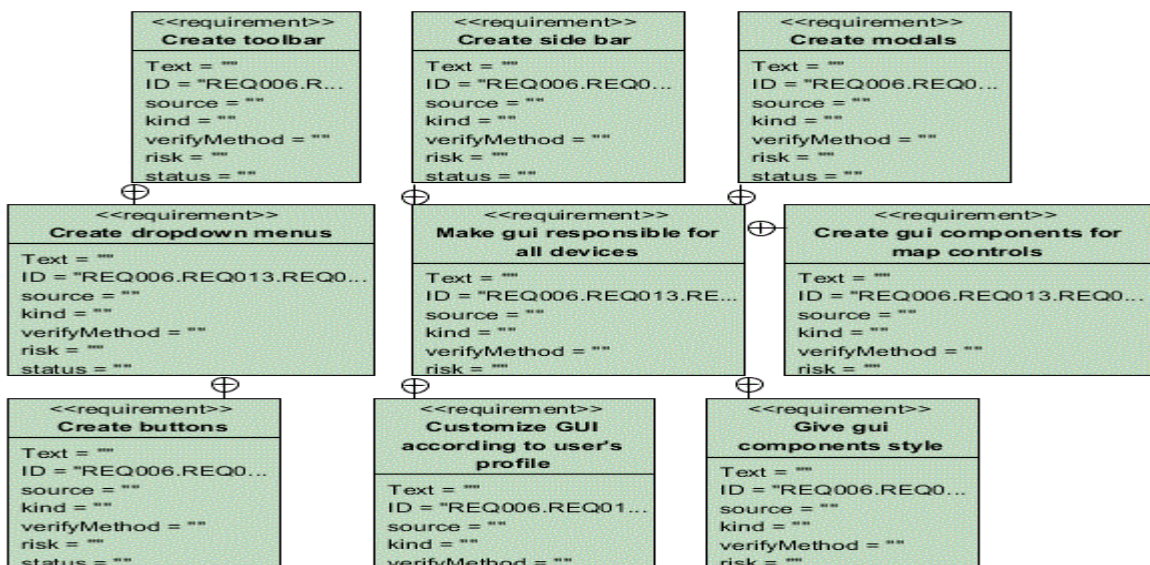


Figure 18 GUI requirements diagram

In the middle of Figure 18 we have drawn the “Make gui responsible for all devices” requirement. In order for this requirement to be GUI responsible, the Create side bar, Create modals, Create gui components for map controls, Give gui components style, Customize GUI according to user’s profile, Create toolbar, Create dropdown menus and Create buttons requirements must all be implemented.

- **Maps requirements diagrams**

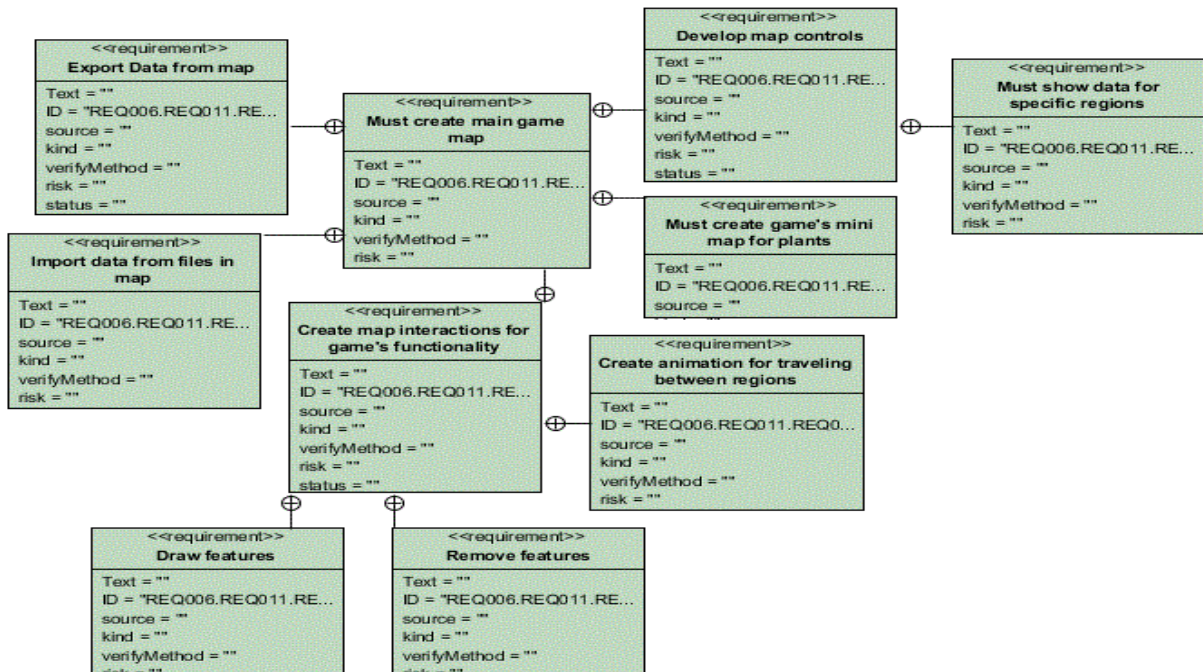


Figure 19 Maps requirements diagram

Maps is the game’s core. As Figure 19 presents the main requirement from Map requirement, is the Must create main game map. The map creation is followed by the implementation of Export data form map, Import data from files in map, Develop map controls and Must show data for specific regions, Must create game’s mini map for plants, Create interactions for game’s functionality, Create animation for travelling between regions, Draw features and Remove features requirements.

- **Power Grid requirements diagram**

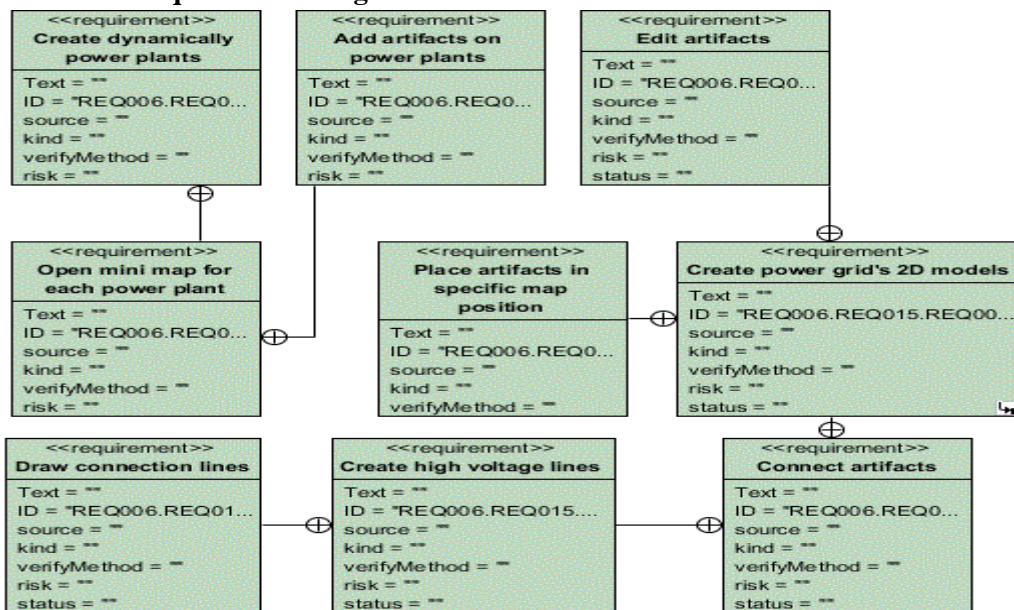


Figure 20 Power grid requirements diagram

In Figure 20 above, the Power grid requirement has the Create dynamically power plants as the main requirement. The Open mini map for each power plant, Add artifacts on power plants, Draw connection lines, Create high voltage lines, Connect artifacts, Create power grid's 2D models, Place artifacts in specific map position and Edit artifacts requirements must be implemented in order power grid to be created.

- **IOLAOS Collaboration requirements diagram**

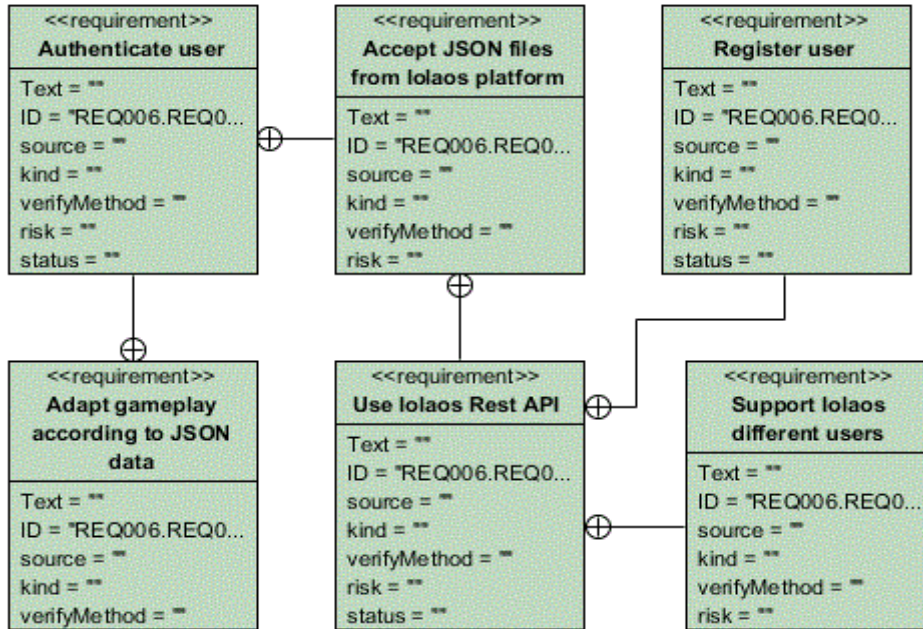


Figure 21 IOLAOS collaboration requirements diagram

The Power Grids EduGame collaborates with Iolaos Platform. The Iolaos Collaboration requirements are shown on Figure 21above. For the collaboration Authenticate user, Adapt gameplay according to JSON data, Accept JSON files from Iolaos platform, Use IOLAOS Rest API, Register user and Support Iolaos different users requirements must be developed.

- **Data requirements diagram**

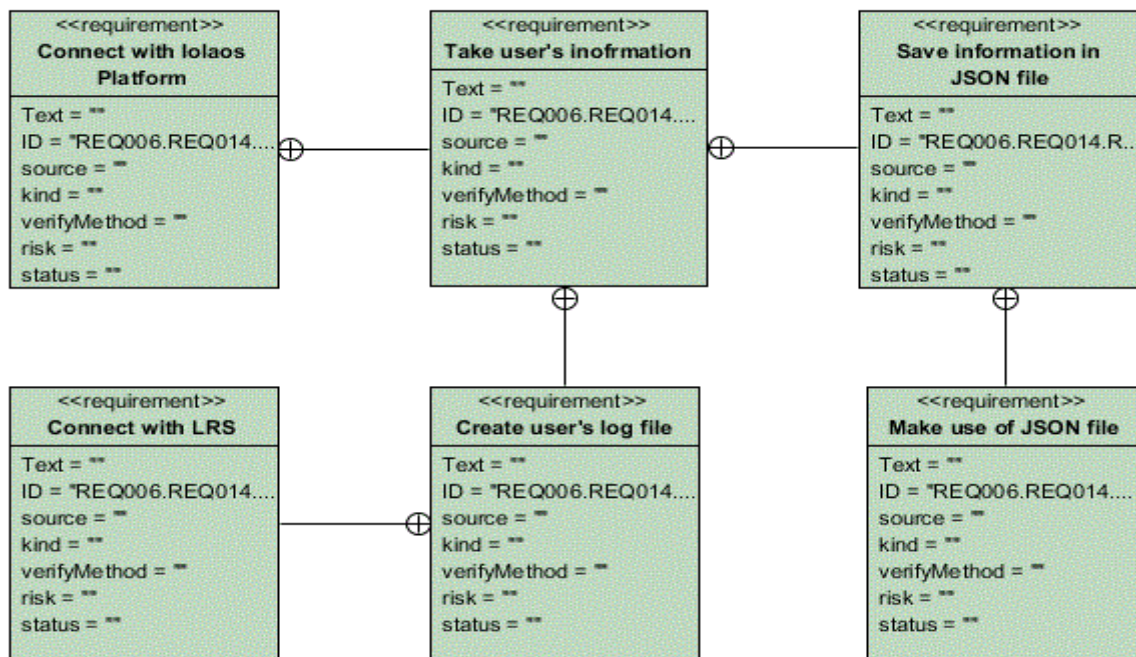


Figure 22 Data requirements diagram



The Last requirements diagram is the Data requirements diagram (Figure 22). Data requirements diagram is depended on the implementation of Connect with Iolaos platform, Take user’s information, Save information in JSON file and Make use of JSON file, Create user’s log file and Connect with LRS requirements.

### 4.3 Use cases

A use case is a description of a specific scenario or a set of scenarios in the software. It plays a significant role on software development, as being part of software design. A use case defines the interactions between users (actors) and software services. This means how the software will be used in order to reach specific purposes and aims. Many use cases handle all the system requirements and software functionality. Use cases are descriptions with specific structure. This structure contains:

- Use case name
- Use case description
- Actors involved in the use case
- Viewpoints that associated in the use case
- Scenarios in the use case
- Normal flow of events
- List of use cases that this use case extends
- List of use cases that this use case includes

Dennis forms is a structure to describe a use case. An example is presented on the Figure 23 below.

Use Case Name:	ID:	Importance Level:
Primary Actor:	Use Case Type:	
Stakeholders and Interests:		
Brief Description:		
Trigger:		
Relationships: (Association, Include, Extend, Generalization)		
Normal Flow of Events:		
<u>Subflows:</u>		
Alternate/Exceptional Flows:		

Figure 23 Dennis forms structure

Use cases can be described by many different ways, like:

- Text
- Numbered sequence of steps
- Structured form
- Narration
- Use case model
- Scenario diagram
- UML diagrams

The Next paragraphs in this chapter, describe the three use cases of the Power Grids EduGame:

- User Authentication and game’s configuration.
- Level 1: Build the power grid.
- Level 2: Manage crisis situations.
- Level 3: Exchange mounts of electric power through different power grids.

For the use cases presentation, we choose tables, Dennis forms, narration, UI mockups and UML diagrams.

### 4.3.1 Power Grids EduGame use cases and scenarios

In this paragraph, the next table presents the Power Grids EduGame use cases and scenarios that are involved in the gameplay. Each row of the table is divided in use case’s name on the left side and scenarios of this use case on the right side.

Table 2 Power Grids EduGame use Cases and scenarios

Use case	Scenario
User Authentication and game’s configuration	<ul style="list-style-type: none"> <li>• Login</li> <li>• Request to IOLAOS Platform</li> <li>• Receive response JSON file with user’s profile data</li> <li>• Configure game according to user’s profile data</li> </ul>
Level 1: Build the power grid	<ul style="list-style-type: none"> <li>• Insert components in power plants</li> <li>• Connect components in power plants</li> <li>• Create high voltage lines</li> </ul>
Level 2: Manage crisis situations	<ul style="list-style-type: none"> <li>• Find defective power grid components</li> <li>• Replace defective power grid components</li> <li>• Connect components</li> <li>• Make power grid productive</li> </ul>
Level 3: Exchange mounts of electric power through different power grids	<ul style="list-style-type: none"> <li>• Find power grids with additional electrical power (seller)</li> <li>• Deliver the amount of electricity in the requested power grid (buyer)</li> <li>• Create the channel for power transmission</li> <li>• Money transaction between sellers and buyers</li> </ul>

### 4.3.2 Use case: User authentication and game’s configuration

From the use cases table, occurs that for the user authentication and game’s personalization the user, game, IOLAOS platform, and also a flow of procedures are involved. Those procedures are:

- Login
- Request for authentication to IOLAOS platform
- Receive response JSON with user’s profile data
- Configure game according to user’s profile data

The use case is presented in the form below.

<b>Use Case Name: User Authentication and Game’s Configuration</b>	<b>Importance Level: High</b>
<b>Primary Actor: User</b>	<b>Use Case Type: Functional</b>

<b>Stakeholders and Interests: IOLAOS platform</b>
<b>Brief Description:</b> <i>For user authentication and game's configuration the following actions are executed: Login, Authentication and Configuration.</i>
<b>Trigger:</b> User request for access in game.
<b>Normal Flow of Events:</b> <ol style="list-style-type: none"> <li>1. Login</li> <li>2. Request to IOLAOS platform for authentication</li> <li>3. Receive response JSON with user's information</li> <li>4. Game's personalization according to JSON file</li> </ol>

• **List of User Authentication and Game's Configuration scenarios and actions**

*Table 3 User Authentication and Game's Configuration scenarios and actions*

<b>System: Power Grids EduGame</b>		
<b>Actors: User, IOLAOS Platform</b>		
<b>Use case: User Authentication and Game's Configuration</b>		
<b>Scenarios</b>	<b>Actions</b>	<b>Description</b>
Login	<ul style="list-style-type: none"> <li>• User inserts username and password</li> <li>• Press login button</li> </ul>	For access and play "Power Grids EduGame" the user has to complete the login process. User inserts in the login form the email and the password t used in order to register to IOLAOS platform. If the user is not register, he must press the register button and register to IOLAOS. After registration is completed they may then return to the login. To complete the login the user has to press the login button.
Request to IOLAOS platform for authentication	<ul style="list-style-type: none"> <li>• Game sends request for user authentication to IOLAOS platform</li> <li>• IOLAOS platform sends a response JSON file with user's profile information</li> </ul>	When user presses the login button the game sends a request for authentication in IOLAOS platform. The game communicates with platform with its unique game token. IOLAOS responds to the authentication request with a JSON file. This file contains user's profile data.

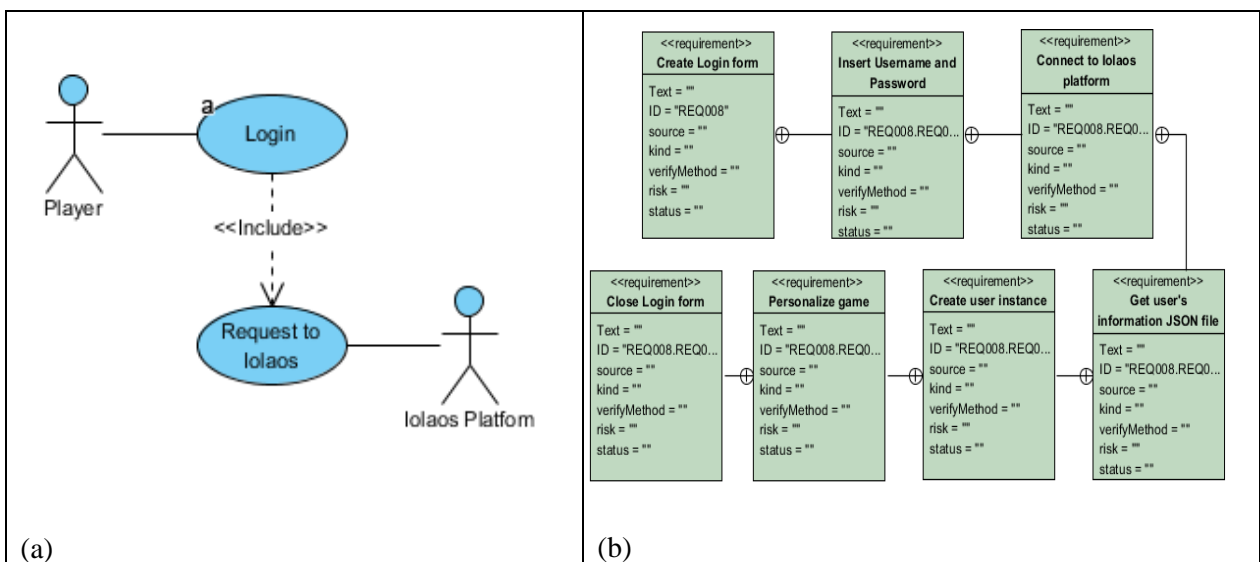
Receive response JSON with user's information	<ul style="list-style-type: none"> <li>• Game receives the response JSON file form IOLAOS platform</li> <li>• Creates a user instance with those information</li> </ul>	After receiving the response JSON file, the game creates a user object that contains user's data that the file includes. Those data are responsible for the game's configuration according to user's profile.
Game's personalization according to JSON file	<ul style="list-style-type: none"> <li>• Personalize game according language, colors, text options, UI components options</li> </ul>	Last scenario is the game's configuration. The software analyses the content of the response JSON file. Values that are responsible for configuration are identified and game's visual characteristics initialized

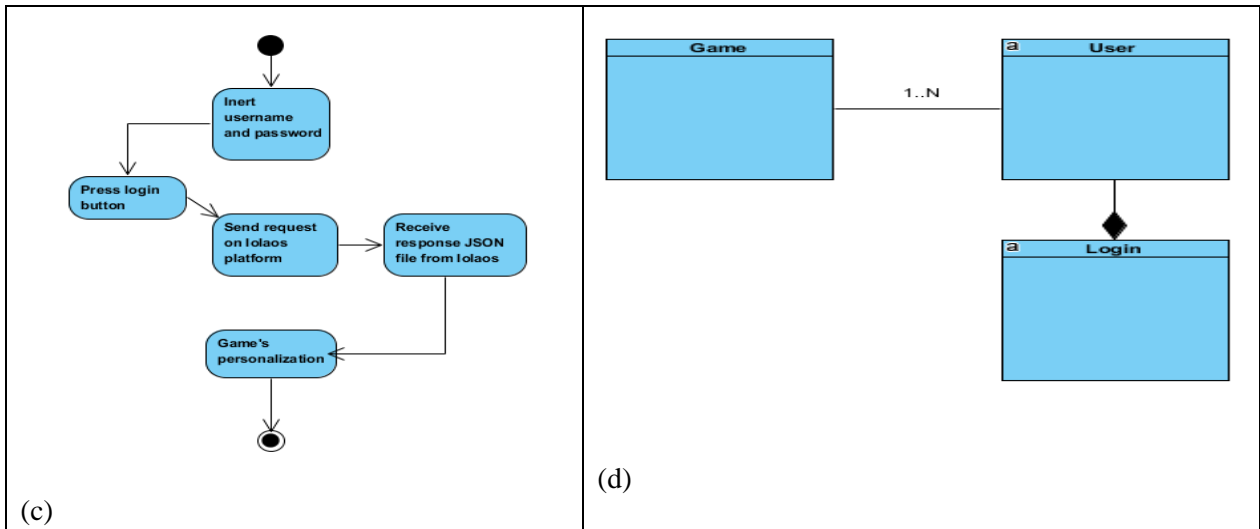
### Use case related diagrams

In the table below the use case's diagram, the requirements diagram of the use case, an activity diagram, and the classes that are involved in a UML class diagram and a UI mockup for the use case User authentication and game's configuration are presented.

From the table results that the (a) diagram is the use case with actors the user and the IOLAOS platform. The requirements for the use case are the create login form, insert username and password, connect to IOLAOS platform, get user's profile data JSON file, create instance of user class and personalize game (b). The activity diagram presents the actions in the use case's normal flow of events (c). The classes that implement the existing use case are the game class, the user class and the login class (d). In the Figure 24 Login mockup, after the table, presented is a UI mockup of the implementation granted.

Table 4 User authentication and game's configuration table of diagrams





## LOGIN FORM

USERNAME   
 PASSWORD   
 Fullscreen selectbox

Figure 24 Login mockup

### 4.3.3 Use case: Level 1: Build the power grid

Next use case is the Level 1: Build the power grid. The actor involved is only the user – player. The scenarios in the “Build the power grid” use case are:

- Insert components in power plants
- Connect components in power plants
- Create high voltage lines

As a result, the from is:

<b>Use Case Name: Level 1: Build the power grid</b>	<b>Importance Level: High</b>
<b>Primary Actor: User</b>	<b>Use Case Type: Functional</b>
<b>Stakeholders and Interests: Power Grids EduGame</b>	
<b>Brief Description:</b> <i>For building the power grid and level 1 integration the following actions are executed: Insert, Connect and Create</i>	
<b>Trigger:</b> User game startup	
<b>Normal Flow of Events:</b>	
<ol style="list-style-type: none"> <li>1. Insert components in power plants</li> <li>2. Connect components in power plants</li> <li>3. Create high voltage lines</li> </ol>	

• **List of Level 1: Build the power grid scenarios and actions**

*Table 5 Level 1: Build the power grid scenarios and actions*

<b>System: Power Grids EduGame</b>		
<b>Actors: User</b>		
<b>Use case: Level 1: Build the power grid</b>		
<b>Scenarios</b>	<b>Actions</b>	<b>Description</b>
Insert components in power plants	<ul style="list-style-type: none"> <li>• Click on map to show the grid's power plants</li> <li>• Click on power plant to open its mini map</li> <li>• Choose between generators or transformer from toolbar to add</li> <li>• Click on mini map to append the chosen component</li> </ul>	User clicks on the map and through a JSON file the real - world power plants on the region that clicked are shown on the map. To add components in each power plant user clicks on the plant. The mini map of the interior part of each plant opens. In the mini map UI exists a toolbar where user chooses which component will append to power plant. Those components are diesel generators, hybrid generators and transformers. User has to click on the option and next click on the point of the mini map to add it.
Connect components in power plants	<ul style="list-style-type: none"> <li>• Right click on a generator to open its popup menu</li> <li>• Choose transformers to connect from a dropdown list</li> <li>• Press connect button for connection with the desired transformer(s).</li> <li>• Close mini map</li> <li>• Continue the same steps to all asked power plants</li> </ul>	When the user has added the components that are needed , has to connect them. The connection can be only from generators to transformers. The relationship is many to many. By right clicking on a generator a menu that contains a list and a button is showed up. From the list can choose the transformers to connect the generator and then press connect button to connect them. When the connection is done user can close the mini map and do the same workflow to all asked power plants
Create high voltage lines	<ul style="list-style-type: none"> <li>• Press create lines button and the real high voltage lines will be created</li> <li>• Parse JSON file of lines</li> </ul>	The final scenario of the use case, is the creation of the high voltage lines. When all power plants are constituted

	<ul style="list-style-type: none"> <li>• Create instances of file's lines</li> <li>• Draw them on the main map</li> </ul>	<p>by components, user from the main toolbar by pressing a button automatically creates the real power grid's high voltage lines. The lines are included in a JSON file, and the software by parsing creates instances of high voltage lines and draws them on the map.</p>
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### Use case related diagrams

The (a) figure in the table contains the use case diagram. The actor that involved is the player, the mini map and the map. The actions between the actors are the inserted components, connected components and created high voltage lines. Next to use case diagram, is the requirements diagram. The requirements for this use case are the map, the mini map, the 2d graphical components, a JSON file and toolbars. The workflow of the use case is presented on the activity diagram in the cell (c). The classes that implement the use case are in the (d) diagram. In the next page, after the table, two UI mockup of the implementation (

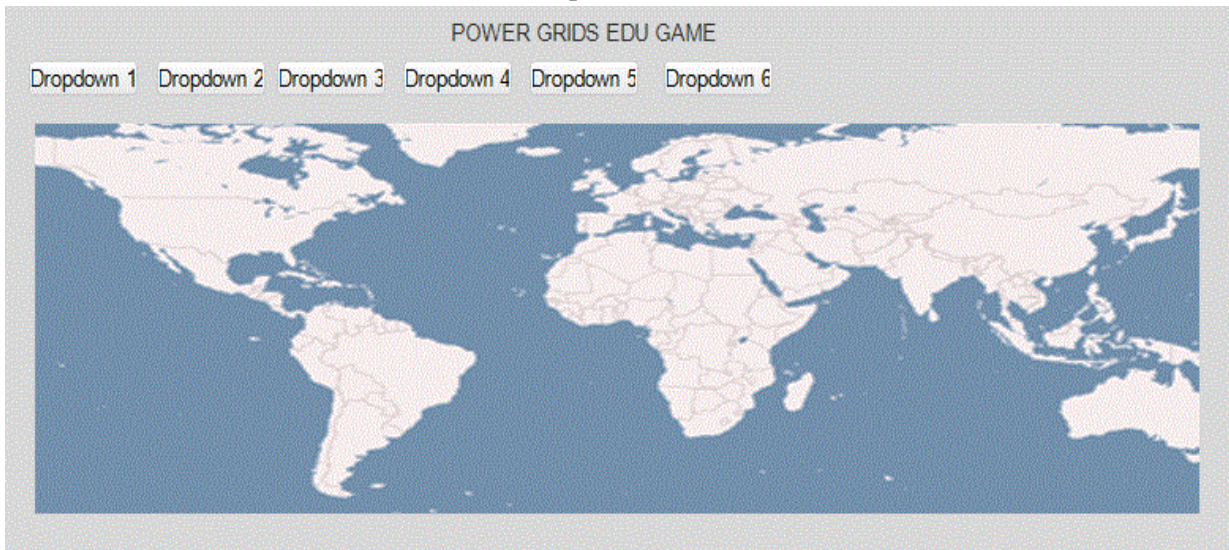
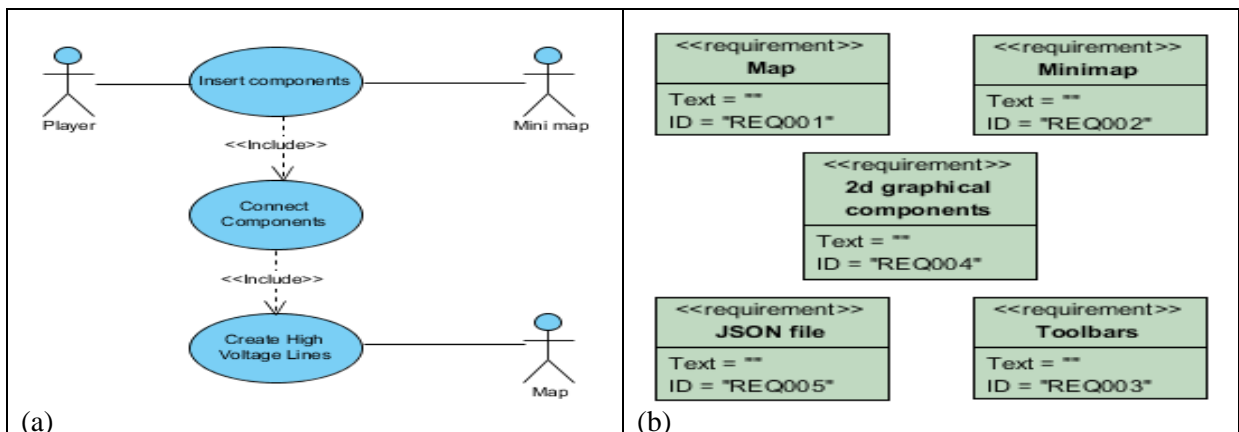


Figure 25 Level 1 mockup (1), Figure 26 Level 1 mockup (2)) are presented.

Table 6 Level 1: Build the power grid table of diagrams



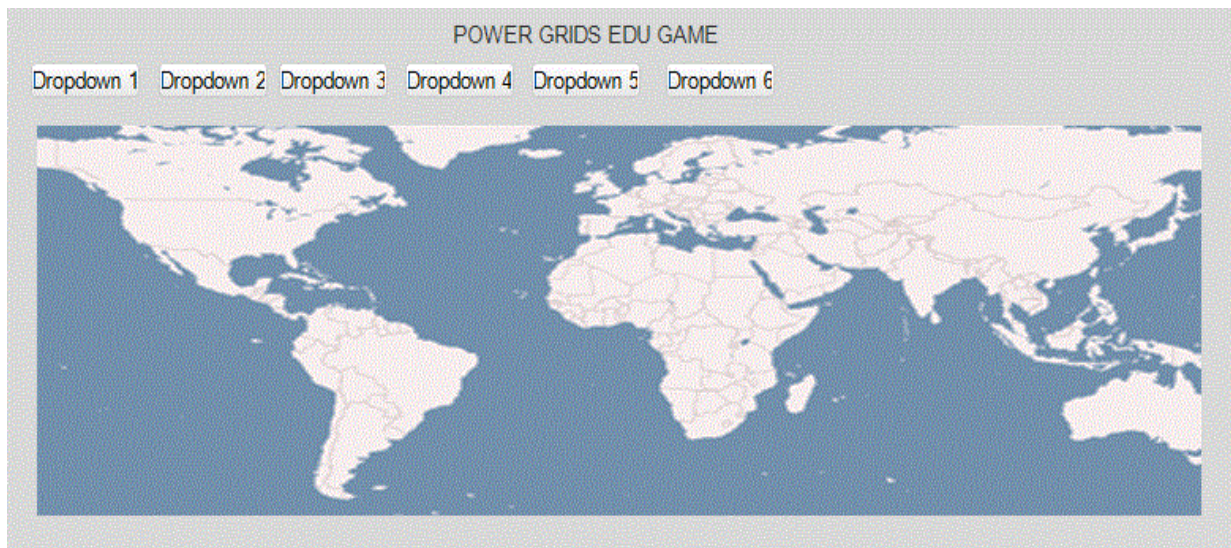
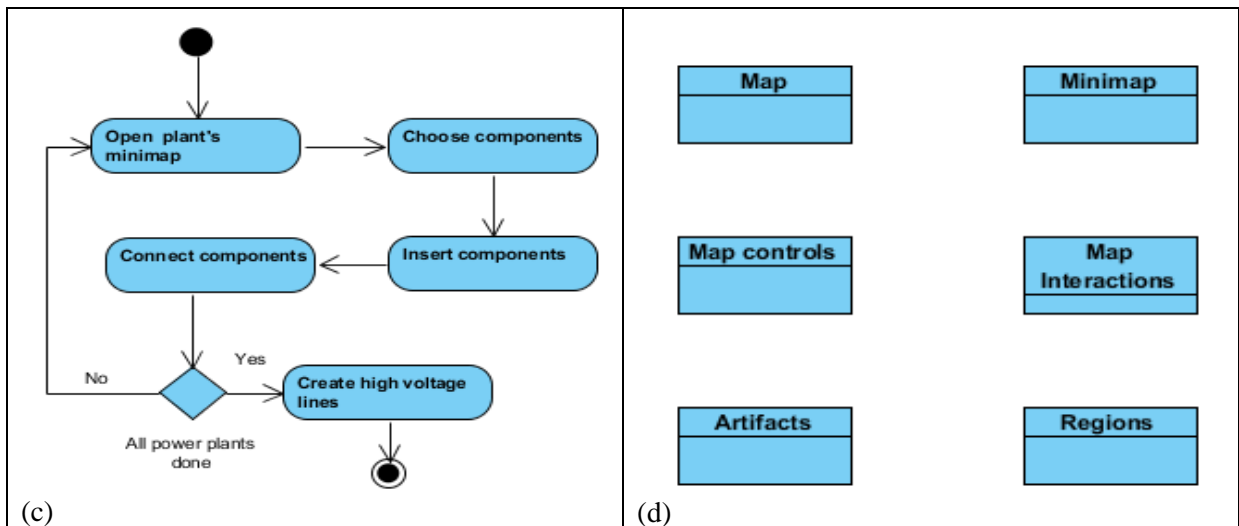


Figure 25 Level 1 mockup (1)

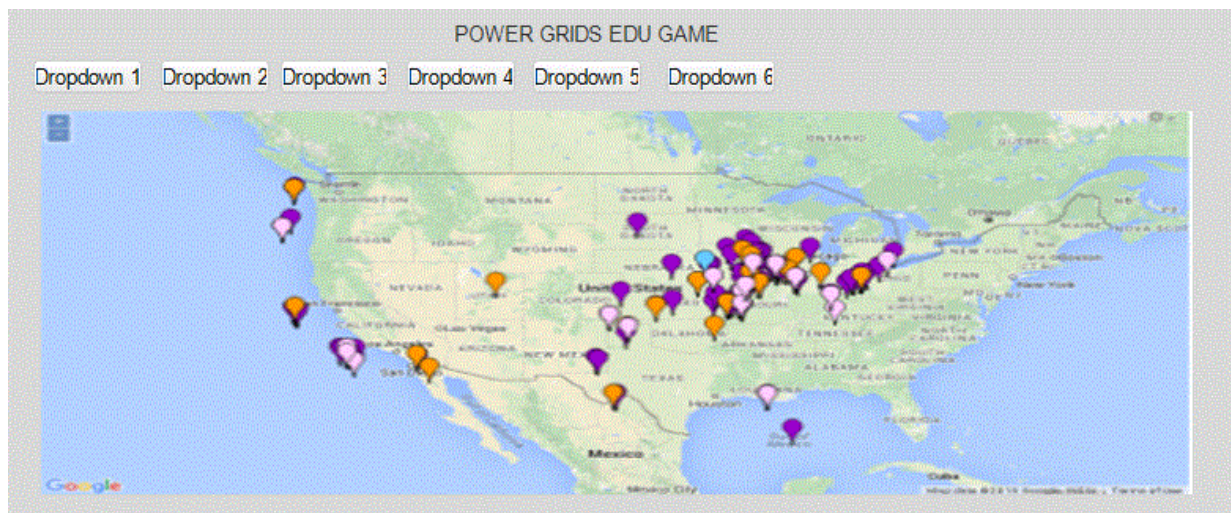


Figure 26 Level 1 mockup (2)

### 4.3.4 Use case: Level 2: Manage crisis situations

Third use case is the Level 2: Manage crisis situations. The actors involved is only the user – player.



The scenarios in the “Manage crisis situations” use case are:

- Find defective power grid components
- Replace defective power grid components
- Connect components
- Make power grid productive

As a result, the from is:

<b>Use Case Name: Level 2: Manage crisis situations</b>	<b>Importance Level: High</b>
<b>Primary Actor: User</b>	<b>Use Case Type: Functional</b>
<b>Stakeholders and Interests: Power Grids EduGame</b>	
<b>Brief Description:</b> <i>For managing crisis situations and level 2 integration the following actions are executed: Find, Replace and Connect</i>	
<b>Trigger:</b> User game process	
<b>Normal Flow of Events:</b> <ol style="list-style-type: none"> <li>1. Find defective power grid components</li> <li>2. Replace defective power grid components</li> <li>3. Connect components</li> </ol>	

- **List of Level 2: Manage crisis situations scenarios and actions**

Table 7 Level 2: Manage crisis situations scenarios and actions

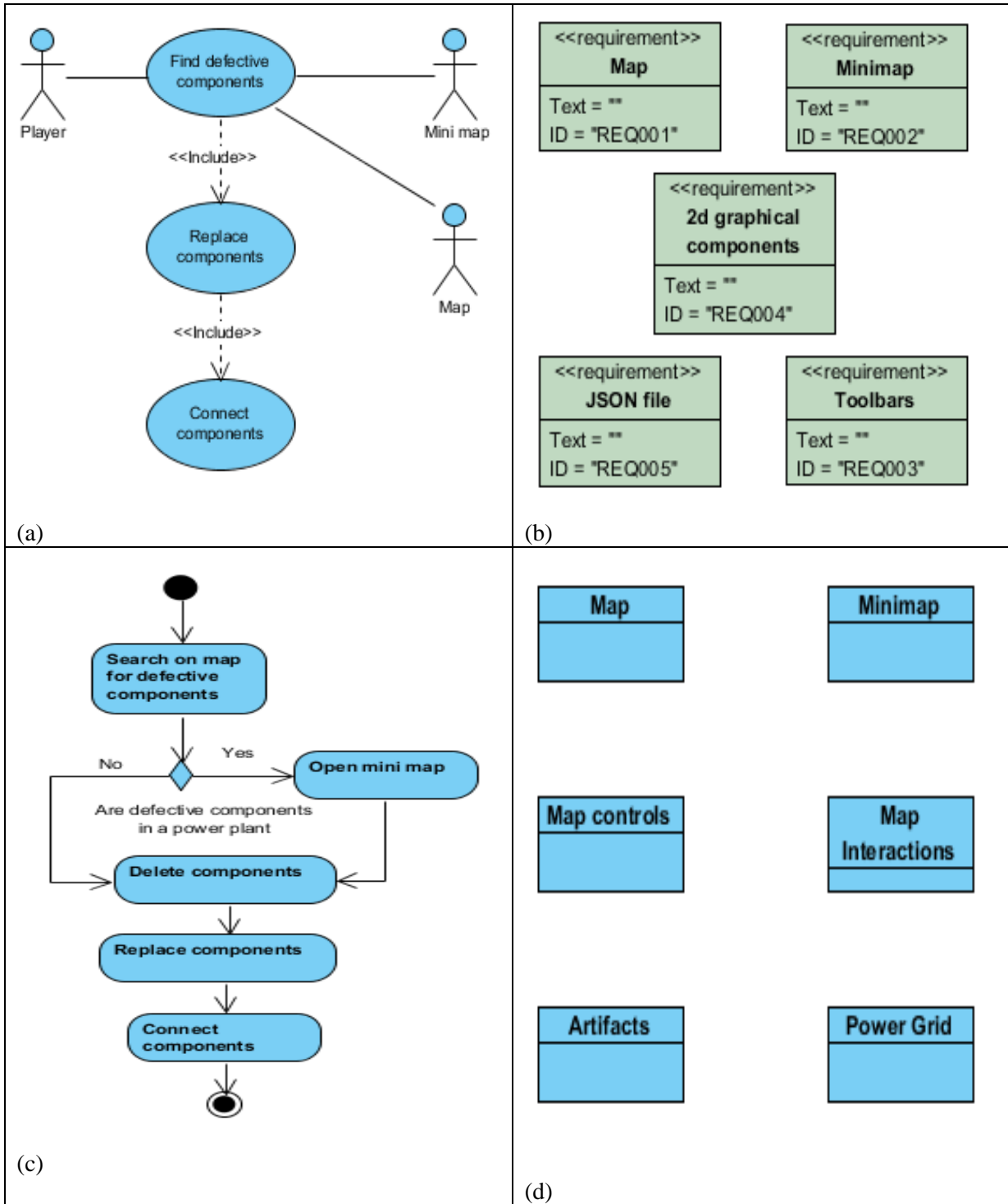
<b>System: Power Grids EduGame</b>		
<b>Actors: User</b>		
<b>Use case: Level 2: Manage crisis situations</b>		
<b>Scenarios</b>	<b>Actions</b>	<b>Description</b>
Find defective power grid components	<ul style="list-style-type: none"> <li>• Search on map to find the defective components</li> <li>• Delete those components from the grid</li> </ul>	In this scenario the electrical power grid is given to user. User has to search on the map and on the power plant’s mini map to find the defective components on the grid. Once he finds the components he must delete them from the map. The deletion is done by right clicking on the component to open the properties menu and press delete button.
Replace defective power grid components	<ul style="list-style-type: none"> <li>• Choose from the toolbar the replacement component</li> <li>• Append it to map</li> </ul>	When the component is deleted from the map, user chooses from the toolbar the component to replace the deleted

		<p>one. By clicking on map the component is appended. The procedure is the same on use case Level1: Build the power grid at insert components on scenario Insert components in power plant, but with one difference. In this scenario user can append components on the main map too.</p>
<p>Connect components</p>	<ul style="list-style-type: none"> <li>• Connect the components that are replaced with the entire grid</li> </ul>	<p>After user has completed the replacement of the components, the connection between new components must be accomplished. In this scenario user can make connections through components on the main map, as well as on the power plant's mini map. The actions for the connection are the same as use case Level 1 on scenario Connect components in power plants. There is a difference between those two scenarios. In this scenario the connections refer to high voltage lines too and not only connections between two components. By this difference occurs that user must make attentive changes on the power grid and on power grid's properties, in order to make it productive again.</p>

### Use case related diagrams

The (a) figure on the table is the use case diagram. The actors involved are the player, the mini map and the map. The events between the actors are finding defective power grid components, replace defective power grid components and connect components. Next to use case diagram, is the requirements diagram. The requirements for this use case are the map, the mini map, the 2d graphical components, JSON file with the electrical power grid and toolbars. The workflow of the use case is presented on the activity diagram at the cell (c). The classes that implement the use case are in the (d) diagram. in the next page, after the table, a UI mockup of the implementation (Figure 27) is presented.

*Table 8 Level 2: Manage crisis situations table of diagrams*



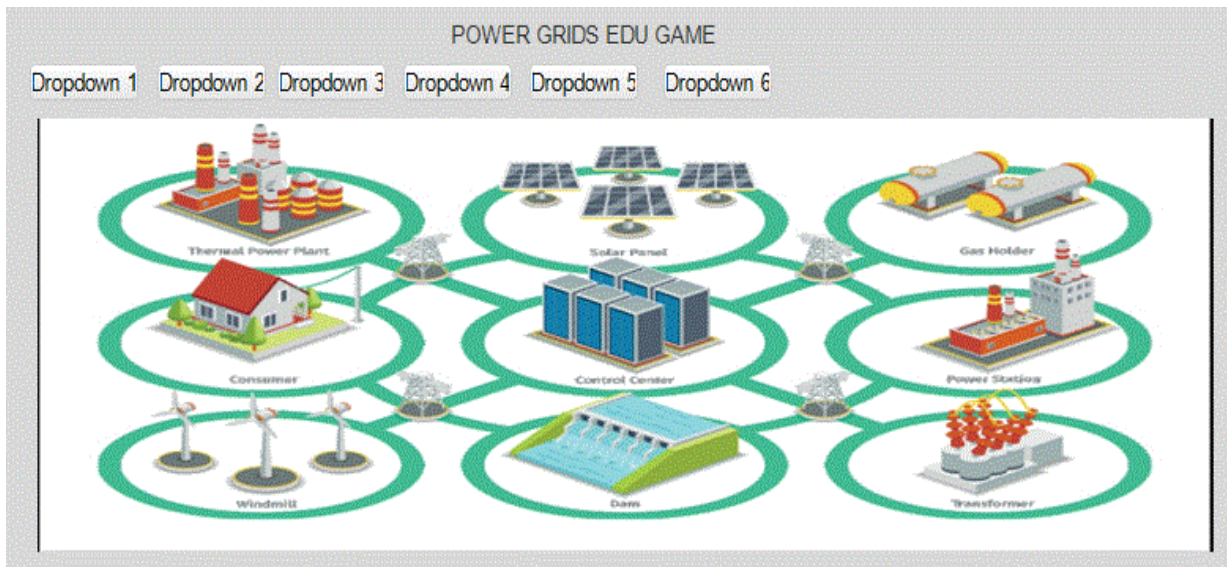


Figure 27 Level 2 mockup

### 4.3.5 Use case: Level 3: Exchange amounts of electric power through different power grids

Next use case is the Level 3: Exchange amounts of electric power through different power grids. The actors involved is only the user – player. The scenarios in the “Level 3: Exchange mounts of electric power through different power grids” use case are:

- Find the power grids with additional amounts of electricity (Seller)
- Modify the seller power grid’s components
- Connect the seller with the buyer

As a result, the from is:

<b>Use Case Name: Level 3: Exchange amounts of electric power through different power grids</b>	<b>Importance Level: High</b>
<b>Primary Actor: User</b>	<b>Use Case Type: Functional</b>
<b>Stakeholders and Interests: Power Grids EduGame</b>	
<b>Brief Description:</b> <i>For exchanging amounts of electric power through different power grids and level 3 integration the following actions are executed: Find, Modify, Sell.</i>	
<b>Trigger:</b> User game process	
<b>Normal Flow of Events:</b>	
<ol style="list-style-type: none"> <li>1. Find the power grids with additional amounts of electricity (Seller plant).</li> <li>2. Modify the power grids’ components.</li> <li>3. Sell and commercial transaction of electricity</li> </ol>	

- **List of Level 3: Exchange mounts of electric power through different power grids scenarios and actions.**

Table 9 Level 3: Exchange mounts of electric power through different power grids scearios and actions

<b>System: Power Grids EduGame</b>
<b>Actors: User</b>

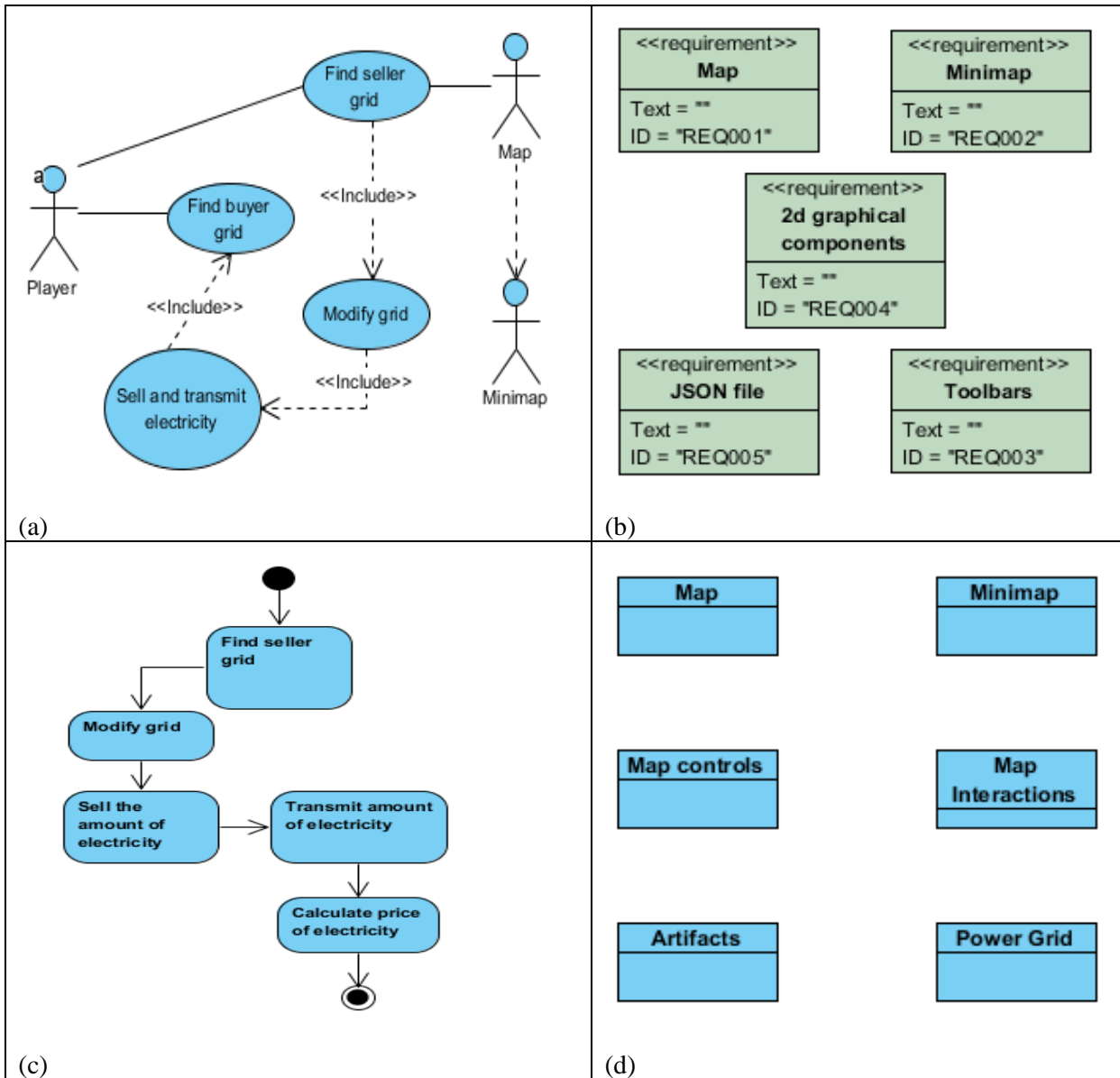
<b>Use case: Level 3: Exchange mounts of electric power through different power grids</b>		
<b>Scenarios</b>	<b>Actions</b>	<b>Description</b>
Find the power grids with additional amounts of electricity (Seller).	<ul style="list-style-type: none"> <li>• Search on map for power grids that have additional amounts of electricity</li> <li>• On these grids search for the power plant(s) that are more productive</li> <li>• Subtract the amount from plant's total energy amount.</li> </ul>	When a power grid is low in electricity production, requests for additional amounts of electricity at other power grids (buyer). User searches the map for grids that can provide electricity (seller). Inside those grids user must find the plants that are more productive. Next, subtracts from the total power plants' energy amount the energy amount that buyer requested.
Modify the power grids' components	<ul style="list-style-type: none"> <li>• Insert transformers for the bought electricity distribution. (Seller plant)</li> <li>• Insert transformers on the buyer plant</li> <li>• Make connection between those transformers</li> </ul>	User inserts transformers in the seller's power plant to "send" the bought electric power to the buyer. Also, inserts in the buyer's power plant transformers in order to receive the amount of electricity he bought. For the transmission of energy from the buyer and the seller, user creates a high voltage line between the two power plants.
Sell and transaction of electricity	<ul style="list-style-type: none"> <li>• Calculate the price of transformed electricity</li> <li>• Exchange between buyer plant and seller plant</li> </ul>	The amounts energy transformed are calculated and the price of energy is estimated. The price is estimated with real financial rates. Finally, the buyer power plant exchanges with the seller the cost of the amount of energy that bought.

### Use case related diagrams

The (a) cell in the table contains the use case diagram. The actors involved are the player, the mini map and the map. The events between the actors are the find seller power grid, find buyer power grid, modify seller power grid and sell and transmit electricity. Next to use case diagram, is the requirements diagram. The requirements for this use case are the map, the mini map, the 2d graphical components,

JSON file with the electrical power grid and toolbars. The workflow of the use case is presented on the activity diagram at the cell (c). The classes that implement the use case are in the (d) diagram. In the next page, after the table, a UI mockup of the implementation is granted (Figure 28).

Table 10 Level 3: Exchange mounts of electric power through different power grids table of diagrams



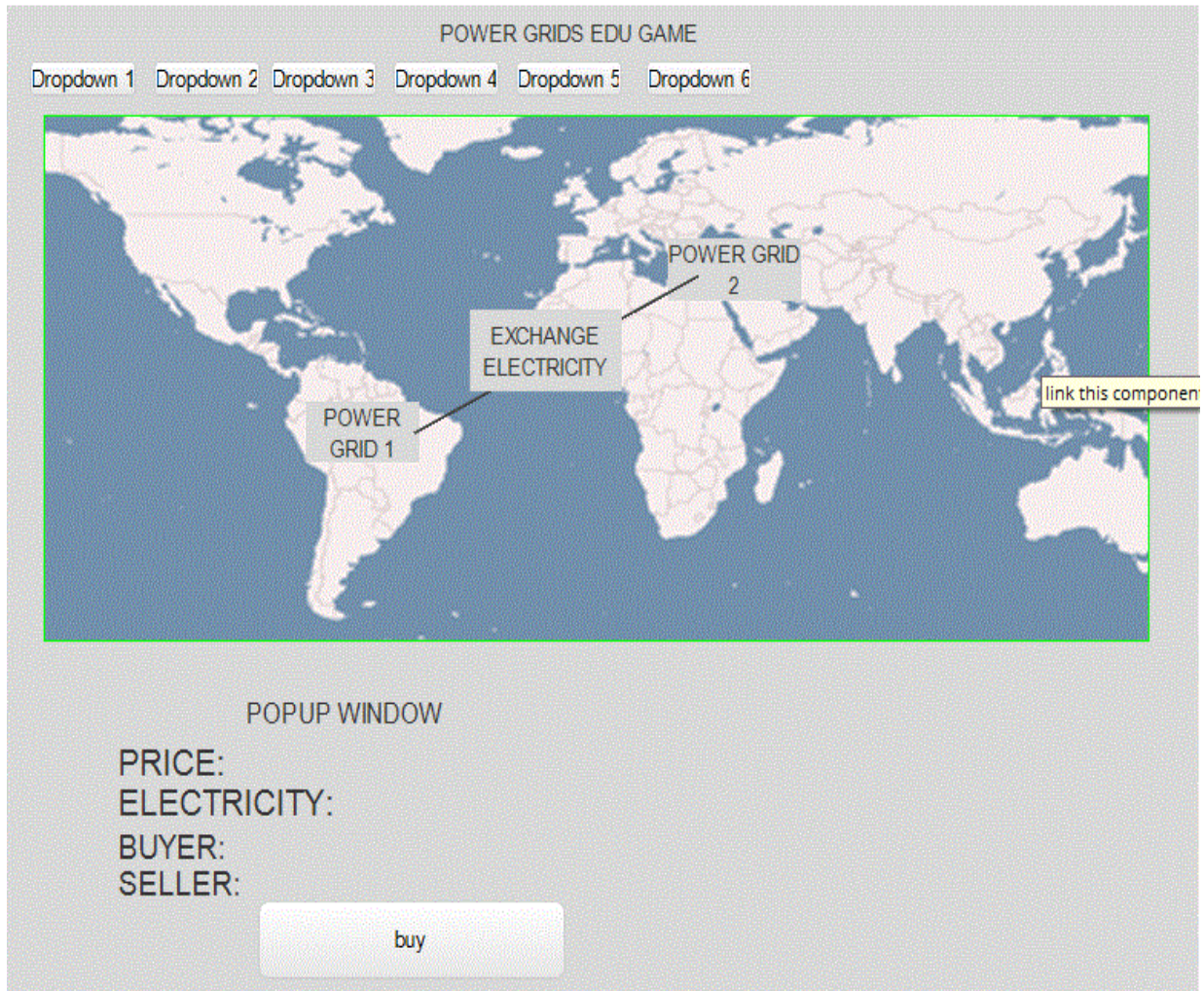


Figure 28 Level 3 mockup

#### 4.4 The “Power Grids EduGame” General Activity diagram

Another part of the software analysis, was to present user’s activities and actions through a model. For this purpose, activity diagram, has been used. Activity diagram has different type of shapes. Rounded rectangles represent actions. Diamonds represent decisions. Bars represent the start (split) or end (join) of concurrent activities. A black circle represents the start (initial node) of the workflow and an encircled black circle represents the end (final node). The game’s workflow through an activity diagram is shown on the Figure 29below.

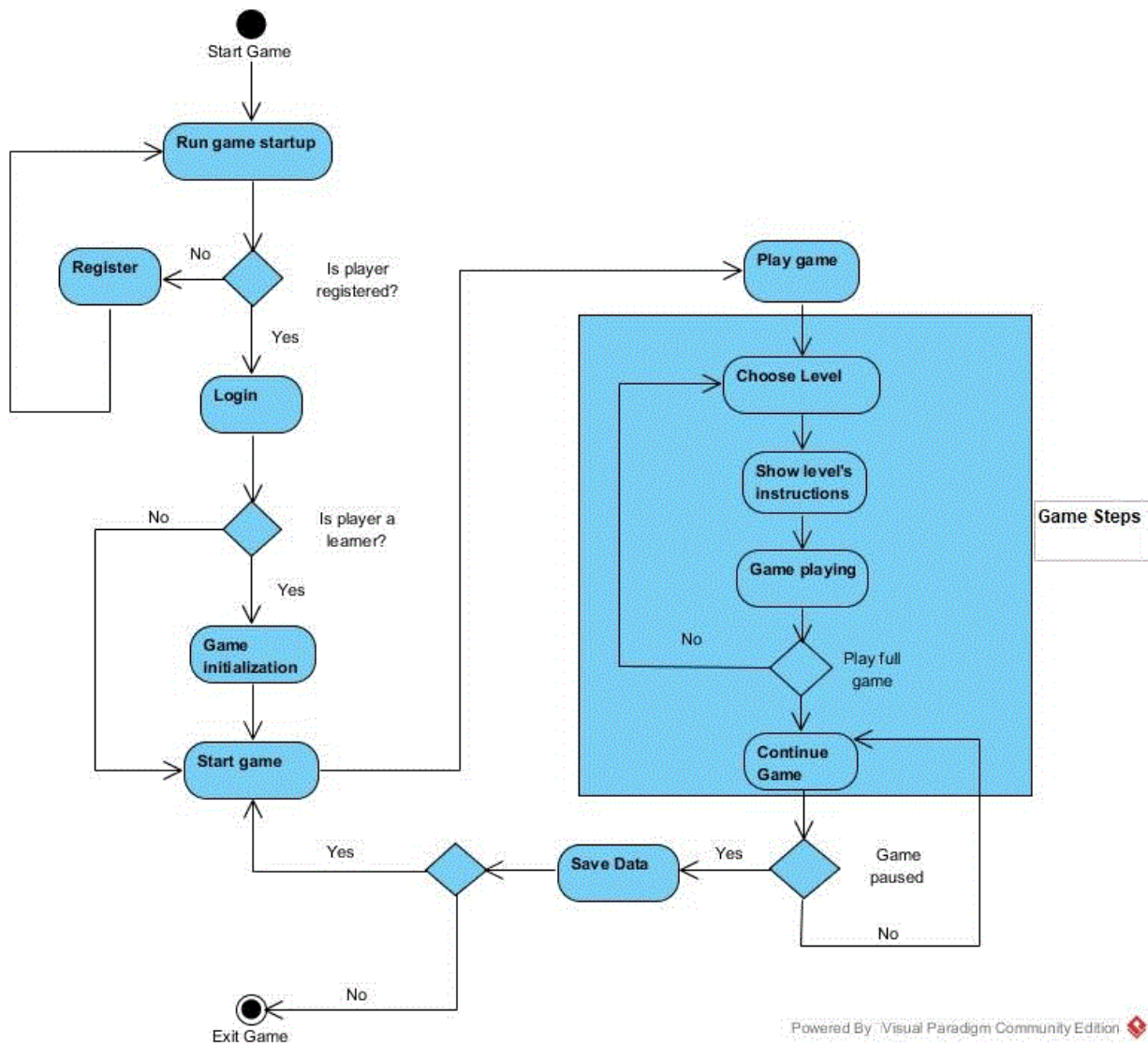


Figure 29 Game's activity diagram

From the activity diagram on Figure 29, occurs that first activity after the “Start Game” initial node is the “Run game startup”. The first decision has to do with the player’s login. If the decision is TRUE, which means that players profile exists, it continues with the login. If it is false it connects to the IOLAOS platform to create player his / her own profile and after that returns to game’s login. When login is done another decision comes up. In case of player’s role is a learner, the game initializes its characteristics according to players profile. In other roles, in the case that decision is FALSE, continues with the “Start game” activity. Next activity is the “Play game” and after that is the “Game Steps” object. Activities in “Game Step” simulate the main game use case workflow. This workflow contains the “Choose Level”, “Show level’s instructions” and “Game playing” activities. If the game runs for one level it returns to “Choose Level” activity. If the game continues, “Continue Game” activity, and “Game paused” decision is TRUE, the activity of “Save Data” comes next. Here is the final decision on the system. If the “Game Saved” is TRUE it returns to “Start game” activity and if it is FALSE, it leads to “Exit Game” final node.

#### 4.5 The “Power Grids EduGame” Component diagram

The architecture of Power Grids EduGame, as it emerges from software design, ended up in the



components diagram below.

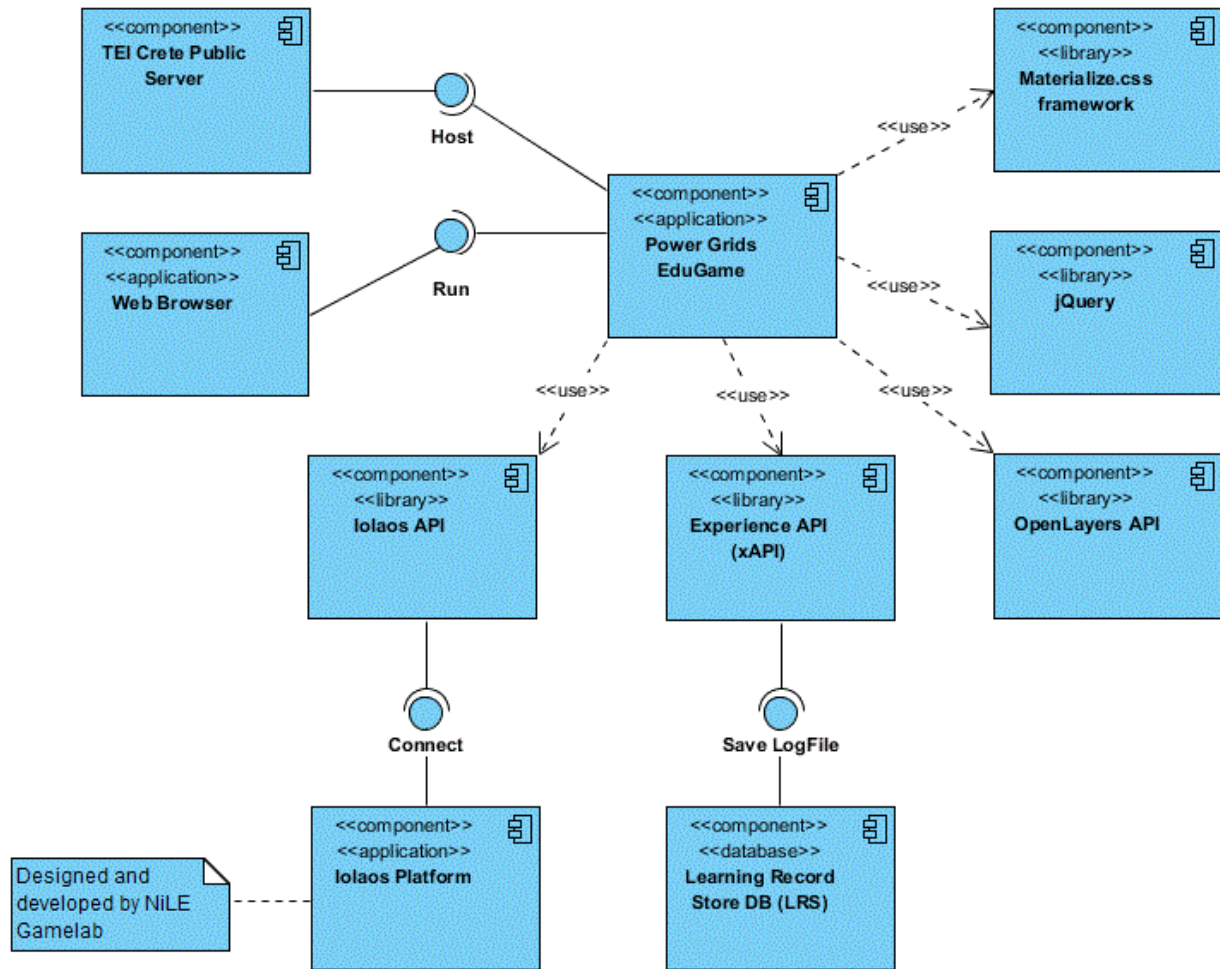


Figure 30 Game's component diagram

In the components diagram on the Figure 30 above, the Power Grid EduGame component as the core of the diagram is presented. On the upper left corner, the component “TEI Crete public server” hosts the game. Underneath is the “Web Browser” component, which is responsible for running and playing the game. The Rest of the components are APIs, libraries and frameworks that “Power Grids EduGame” implementation based on. Those components are: Materialize.css, jQuery, OpenLayers API, Experience API (xAPI) and Iolaos API. More details for the libraries are presented in Chapter 3: Technologies used, except IOLAOS which is presented in Chapter 4: The Power Grids EduGame, in 4.1 IOLAOS Platform paragraph.

## 5 Pilot implementation

According to Chapter 4 and more specifically the analysis and design of the game, in this chapter we implement the Use cases: “User authentication and game’s configuration” and “Level 1: Build the power grid”. Also, useful user – map interactions that have been implemented are presented in this chapter. The scenarios and actions of each use case are being presented with figures taken from the final implemented version of “Power Grids EduGame”.

### 5.1 Implementation of “User authentication and game’s configuration”

Figure 31 presents the implementation of the Login Graphical User Interface (GUI). As it is shown in the figure the Login GUI consists of a modal with two text fields, a checkbox, and two buttons.

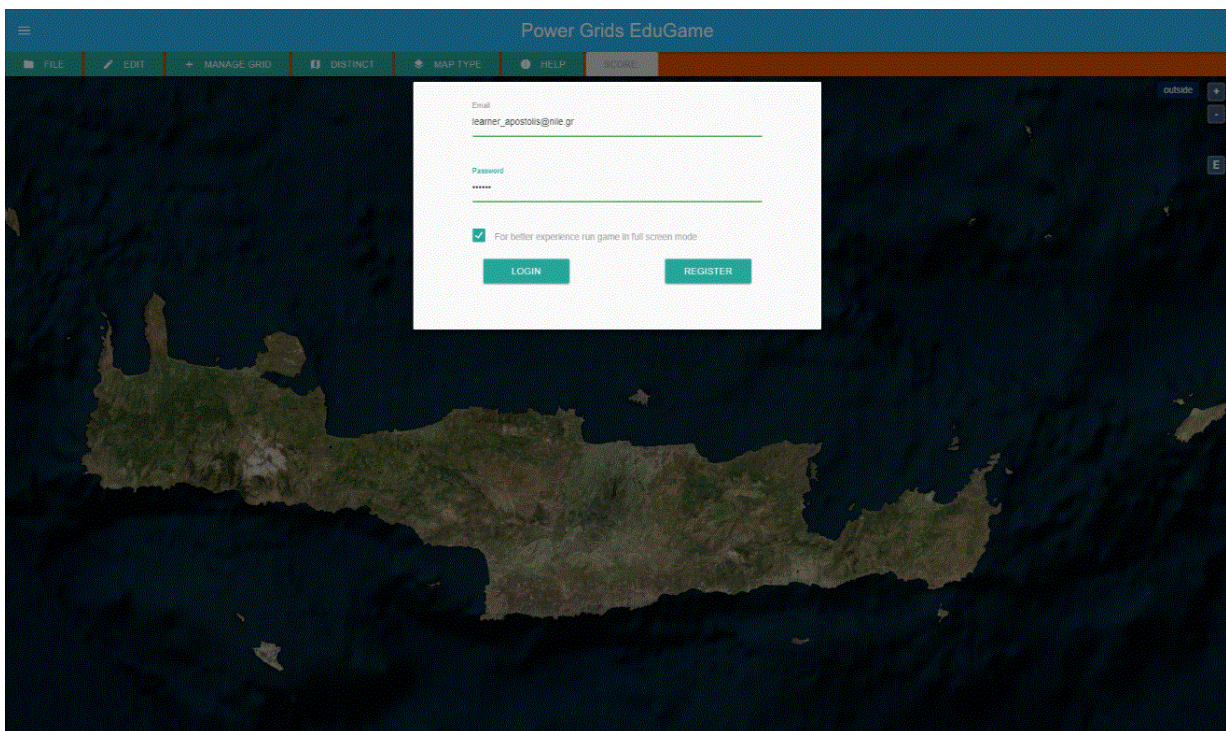


Figure 31 Login implementation

In order to access the game a user inserts his email in the first text field and his password in the second one. For better game experience user can click the checkbox under the password field to run the application in full screen mode. By pressing the login button, a HTTP request to IOLAOS platform for user authentication is sent. For the authentication, “Power Grids EduGame” makes use of authenticate service from IOLAOS platform API. The platform responds with a JSON file. An example of this file is presented in the Figure 32 below.

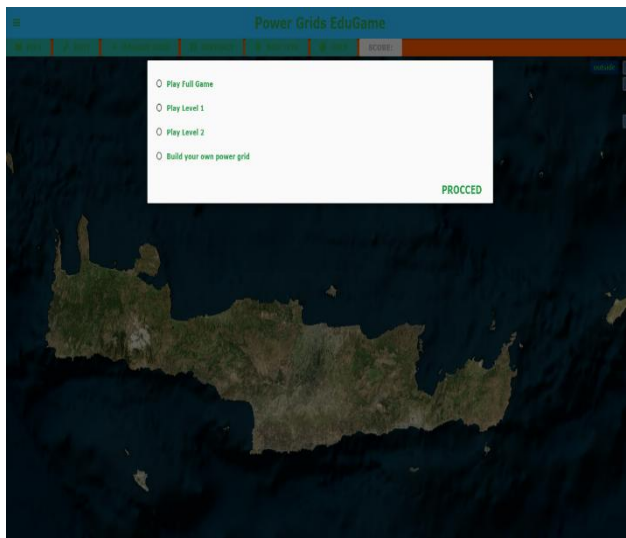
```
age: 24
birthday: "1993-03-06"
email: "learner_apostolis@nile.gr"
first_name: "Apostolis"
language: "en"
last_name: "Trampas"
message: "authenticated"
profile_pic: "http://seriousgame.teicrete.gr/images/profile_pics/293.jpg"
school_type: 1
user_id: 293
username: "learner_apostolis"
```

Figure 32 Response JSON file from IOLAOS

Authentication response file contains user’s profile data. These data are listed in an array containing name, user\_id, age, email, first name, last name, username, birthday, school type, language and profile picture url. If the user is authenticated message has the value “authenticated”.

Configuration of the game is succeeded by using the game\_preference service from IOLAOS API. After the user authentication, game sends a request through the service. Platform responds with an array of game preferences, including font\_size, line\_space, font\_color, font\_background, font\_family, volume, background, brightness, backward\_speed, vibration and other parameters. An example of different figures presenting game’s configuration according to different user game preferences are presented on this table:

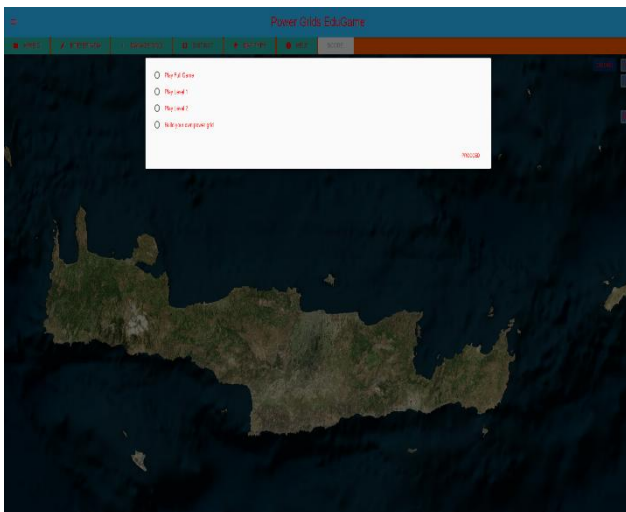
Table 11 Examples of different game's visual configurations



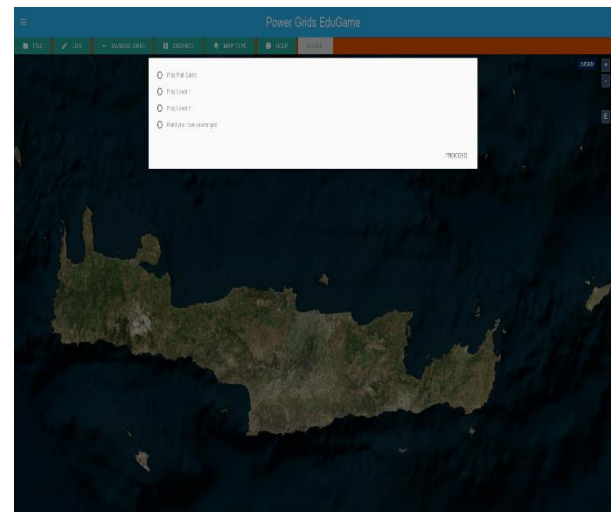
(a)



(b)



(c)



(d)

The examples present visual configuration of “Power Grids EduGame”. On the first and the last figure, (a) and (d), the game’s GUI font\_size, line\_space, font\_color, font\_background, font\_family are configured and audio volume is set in zero value. Second cell same parameters have been set, as well as background value is set to zero. This means that application runs in grayscale mode. In addition, on

cell (b) audio volume is set in maximum value. Last cell, (d), has no game preferences set and the game runs in default mode.

Game configuration action follows on the level choice. Through a modal with bullet options and a button user can choose which level to play. The user's options are: to play full game, only first level, only second level, only third level or create his own power grid are visualized with bullets. By choosing an option and clicking on proceed button user chooses which level to play and level's instruction modal opens. Instructions are shown on the next Figure 33.

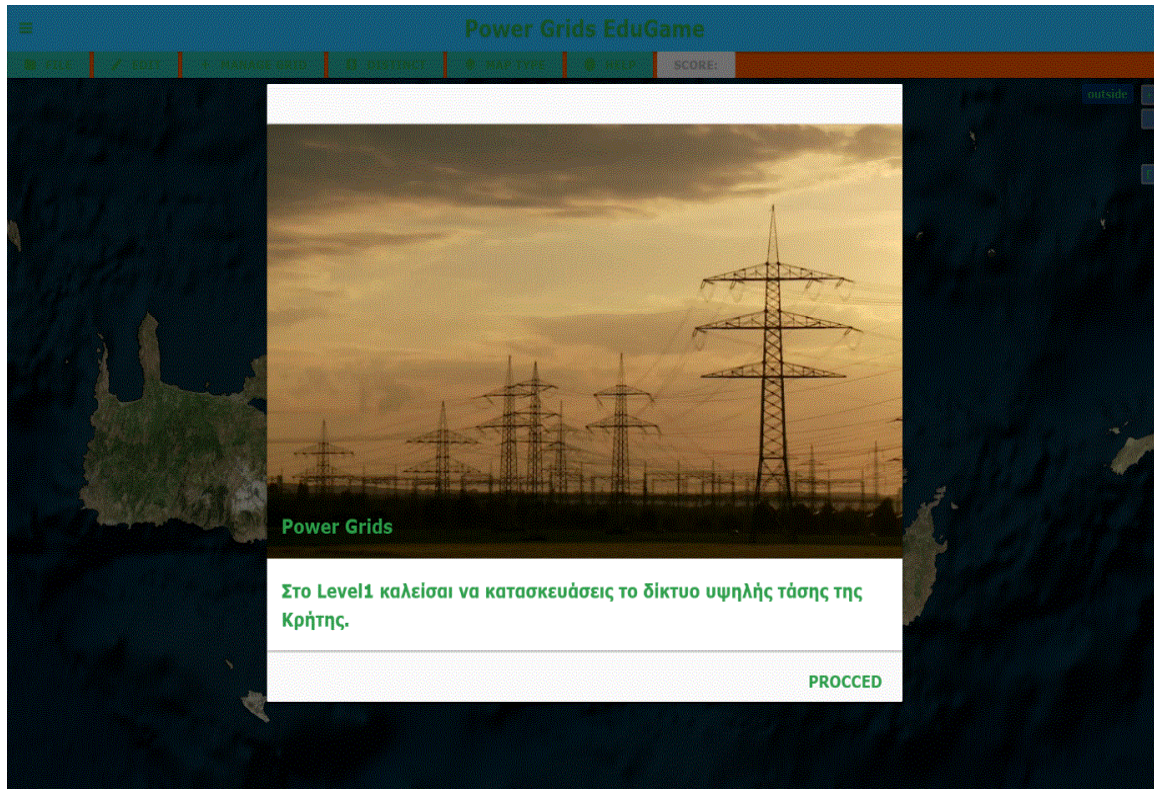


Figure 33 Level 1 instructions

By pressing the proceed button on instructions modal, user gets on “Power Grids EduGame” main GUI. As shown in the Figure 34 below, main GUI is composed of a navigation bar, a real – world map and a toolbar between them. World map uses the most space of the game's screen. Toolbar contains buttons for user – game interactions. Each button on toolbar, except distinct, has a dropdown menu. File button has the options of save power grid in JSON file and load a power grid's saved file. The use of the edit button can clear the map or delete a specific artifact on map. Through “manage grid” user chooses components to add on the map. User has the capability to choose between wind turbine, solar, pillar and create high voltage lines. Distinct button is used for navigation through different places on map and map type has options for changing the type of map's base layer. Toolbar's components are described on next paragraphs, as well as the interactions accomplished by their usage.



Figure 34 Main GUI

Last table of figures on this paragraph shows the side navigation panel (Sidenav). User has access in sidenav by clicking the upper left corner button on the game’s main GUI. In this panel only user’s profile picture, name and email are listed when application runs through a device with large screen, like computer or laptop, (a). Also, it is used as a toolbar on small screen devices, like smartphone or tablet, (b).

Table 12 Different usage of GUI's side navigation panel



## 5.2 Create energy plant

First level of “Power Grids EduGame” has to do with the creation of a real power grid. From use cases paragraph occurs that level 1 has three scenarios, the insert components in power plant scenario, connect components in power plants scenario and create high voltage lines scenario. In this paragraph the creation of an energy plant is analyzed at length, as it generates from the game’s workflow. This analysis refers to the first two scenarios of level 1 use case.

As mentioned above, when the user is logged in the game, he sees the main game’s GUI. First of all,

the user must zoom in the area of interest and click on the map. By clicking on the map game parses, a JSON file with regions and according to the point's coordinates that user clicked, cities and power plants of this region are loaded on the map. The examples on this chapter are based on Crete's region. Game is implemented for all regions of Greece too and workflow is the same. As it is presented on Figure 35, Figure 36 below the power plants and substations are loaded on game's map.

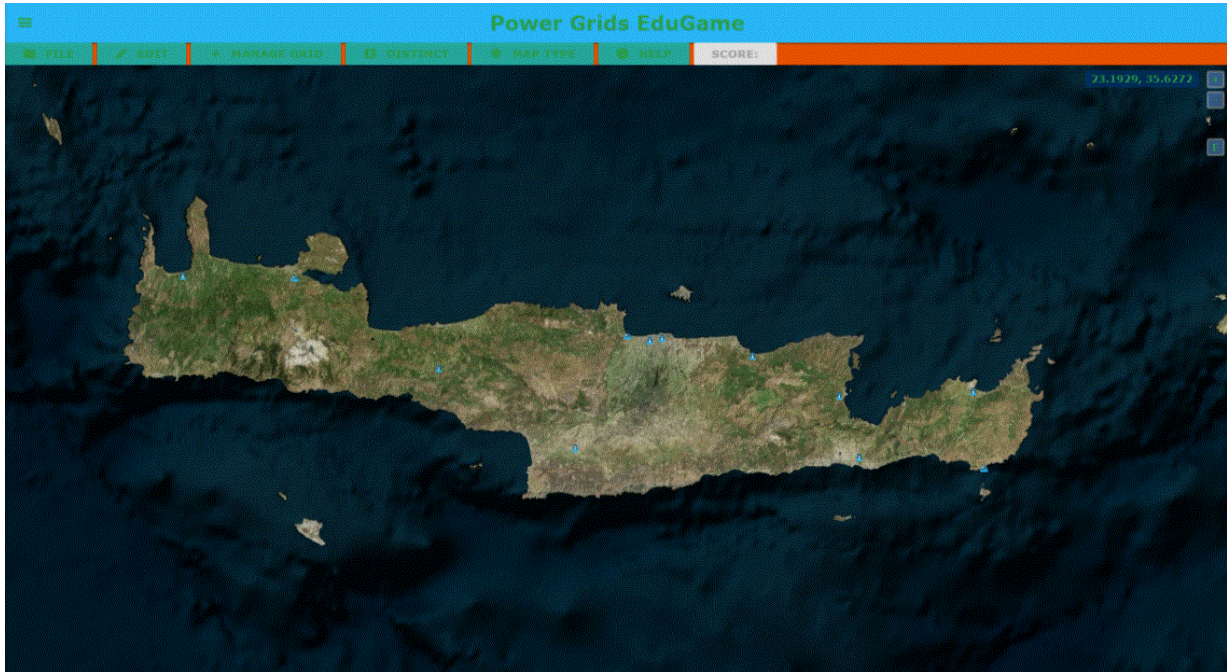


Figure 35 Power plants on map (1)

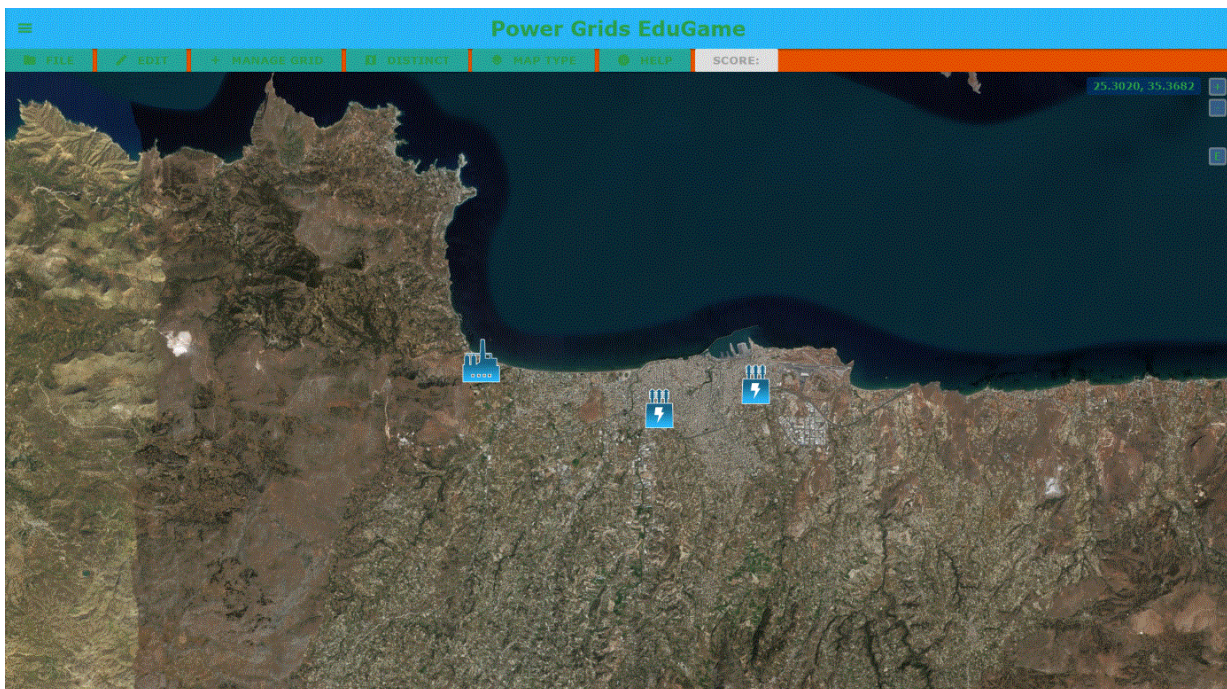


Figure 36 Power plants on map (2)

By clicking on a power plant (factory icon) a mini map of each plants area opens (Figure 37) Mini map is a real - world map appended in a modal. It is centered on each power plant's coordinates and works with same interactions as the game's main map. The mini map modal contains a real world – map, a toolbar and a button. Toolbar contains buttons with dropdown menu. Dropdown menu opens with hover on each button.

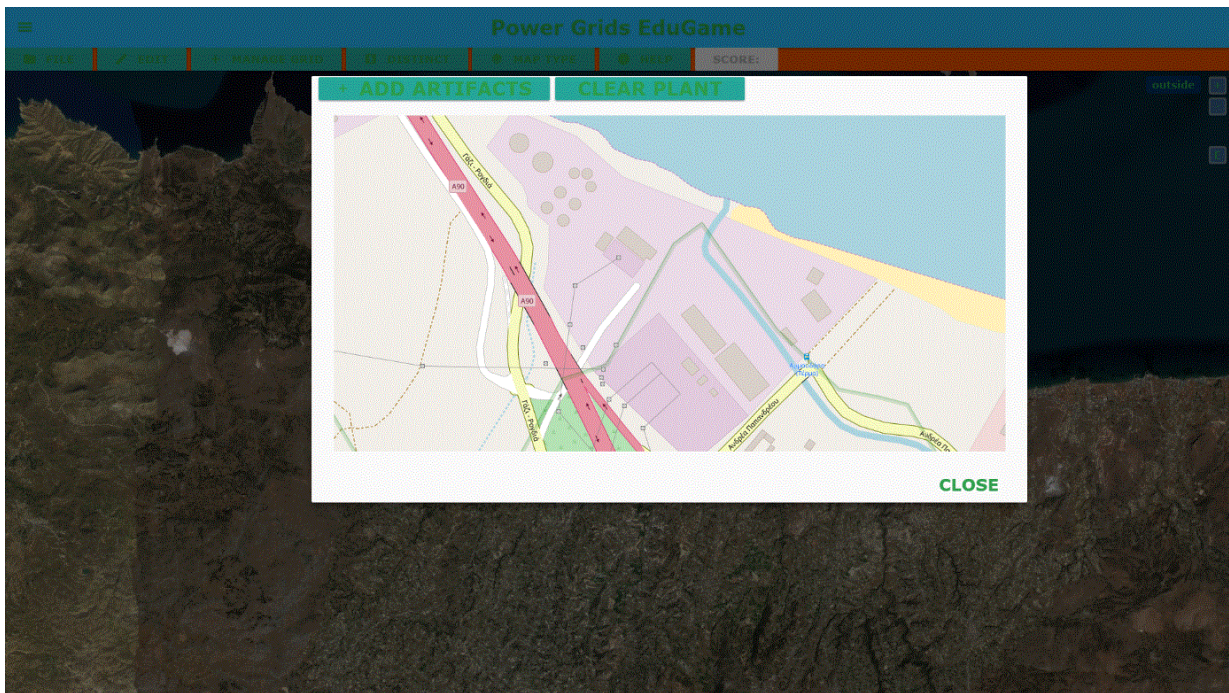


Figure 37 Power plant's mini - map

First dropdown is the “Add artifacts”, as it shows on Figure 38. User can choose from “Add artifacts” components to add on power plants mini map. Each power plant is consisted of diesel generators, hybrid generators and transformers. The interaction is the same with game’s main GUI toolbar dropdown menu, “Manage grid”.

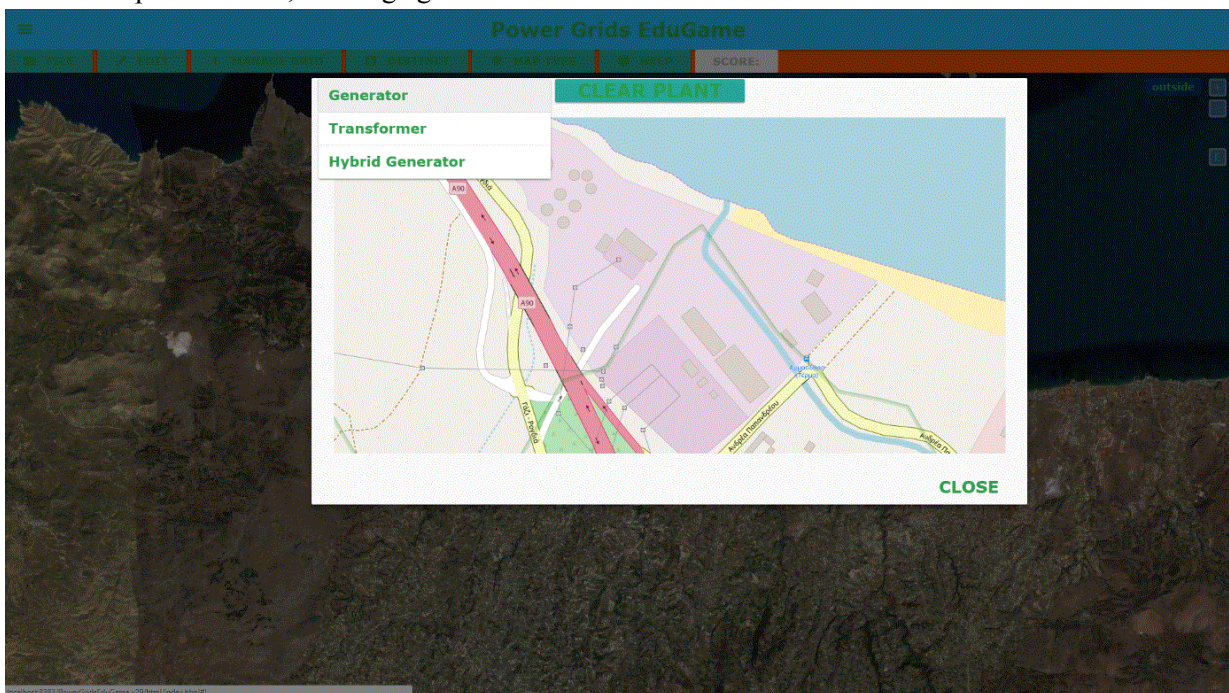


Figure 38 Select artifact on mini - map's toolbar

After the user selects an option, clicks on a point on mini map to add the component chosen. Components on each power plant are describing only this specific plant and are visible only on this plant’s mini map (Figure 39).

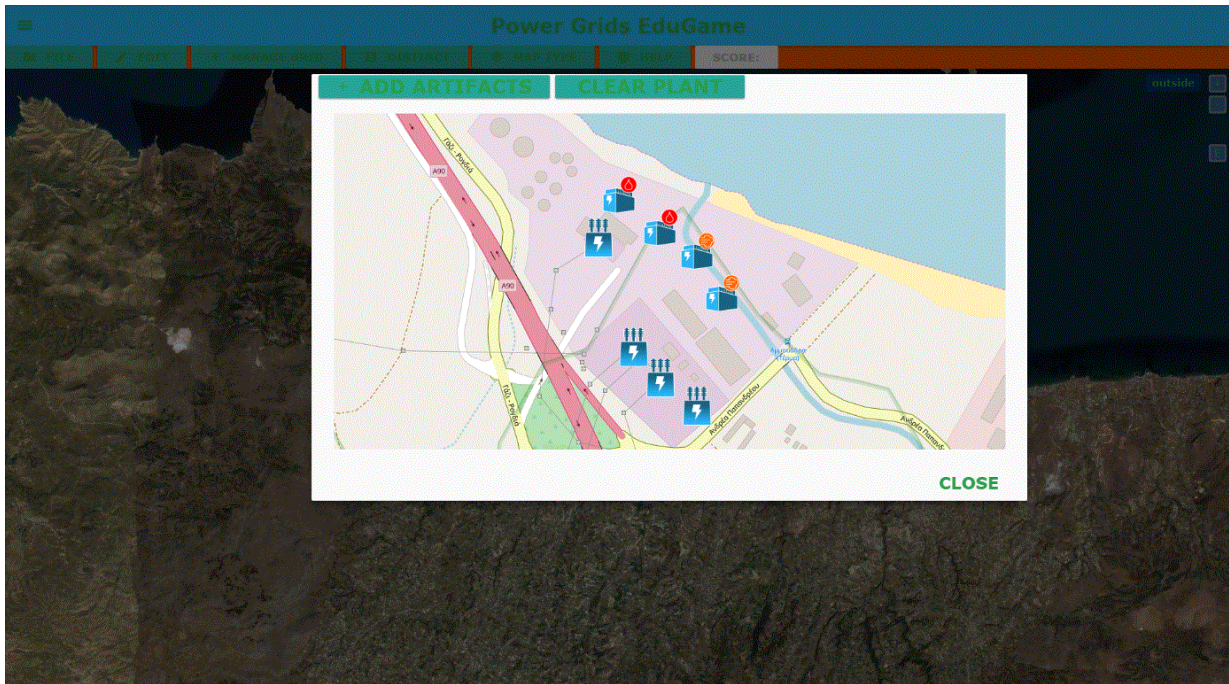


Figure 39 Artifacts on power plant's mini - map

Last action of user in order to complete the creation of a power plant, is to connect the components inside it. The connection can be only between generators, diesel or hybrid, to transformers. The relation is many to many. This means that many generators can be connected to many transformers. If the user right - click on a generator, a popup menu opens (Figure 40). This popup contains a list with all transformers in power plant and two buttons, “connect” button and “delete” button. The list is loaded dynamically with each plant’s transformers. User is able to choose many transformers from the list at the same time. Connect button is responsible for establishing the connection between generators and transformers. Delete button enables the user to delete a component from the power plant. Delete is also available on transformers right click popup menu. By clicking delete button system deletes the component and all connections form this, if it is a type of generator, or to this, it is a transformer.

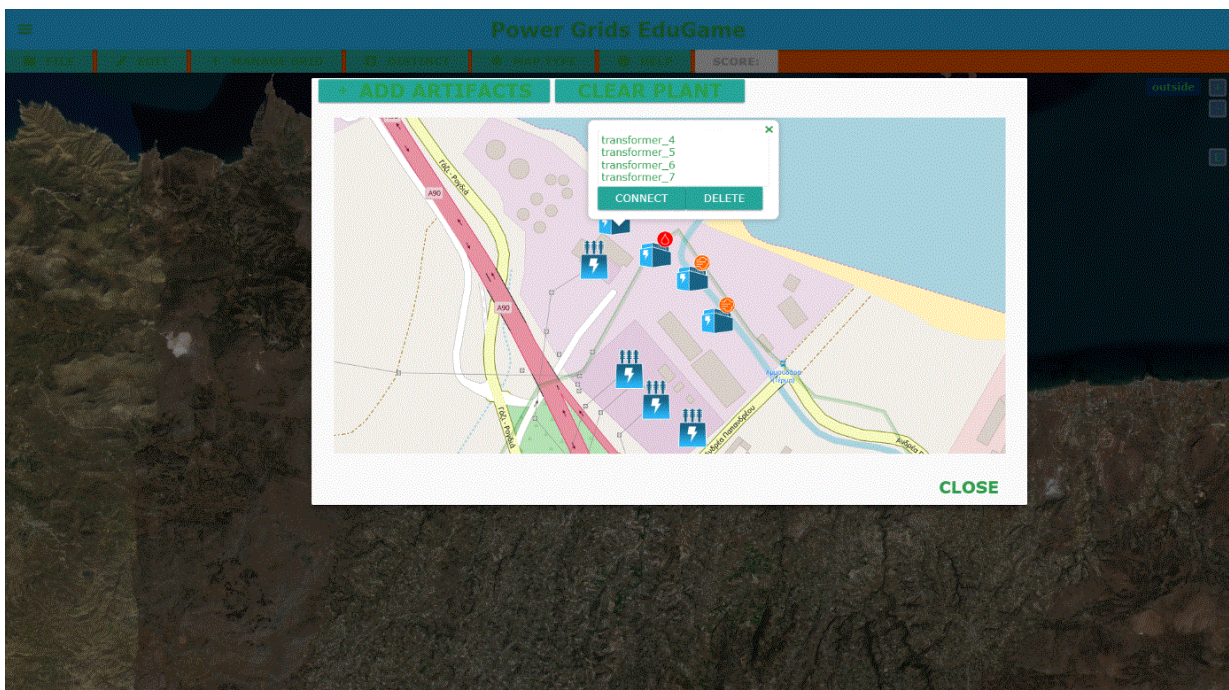


Figure 40 Artifacts popup menu



A visualization of connections between power plant's components is presented on Figure 41 below. Each connection is implemented with a simple line, with red color and an arrow at the end. The arrow depicts on which transformer connection ends.

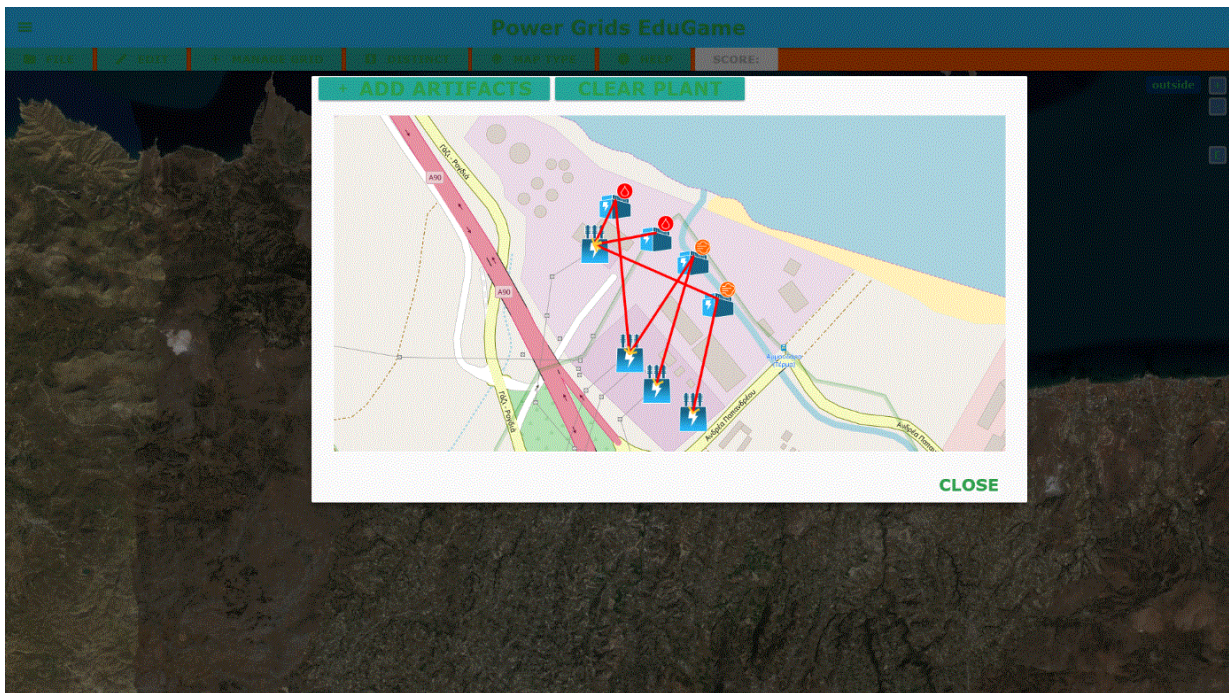


Figure 41 Connected artifacts

When user finishes inserting components on each power plant and establishing the connections between them, can close the mini map. As results from Figure 42, when a power plant has each own components and connections the power plant's icon has a green tick. In order to finish the creation of a whole power grid on a specific region user has to accomplish the same workflow on each power plant shown on the map.

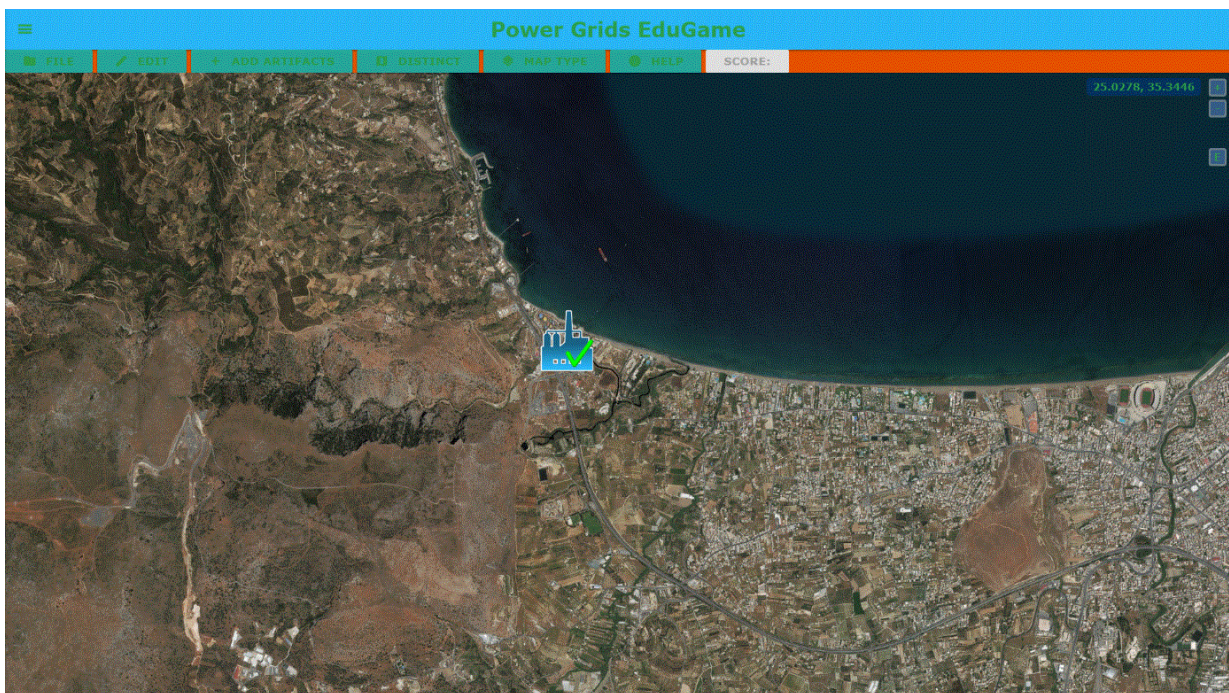


Figure 42 Power plant's changed icon

### 5.3 Inter connection of power plants

In order to finish the design of the real electrical power grid, the user has to create the high voltage lines. When the user finishes developing each power plant on the region of interest, he returns on game's main world map. The main toolbar provides an option with title "Manage Grid". Last option on this menu, is the "Create lines". On Figure 43 below, some transformers are placed on specific positions on the main map. Transformers reflect the substations on the electrical power grid. A substation is responsible for transforming the electricity through a power grid. High voltage lines are listed on the region's JSON file. Each region has its own high voltage lines for its power grid.

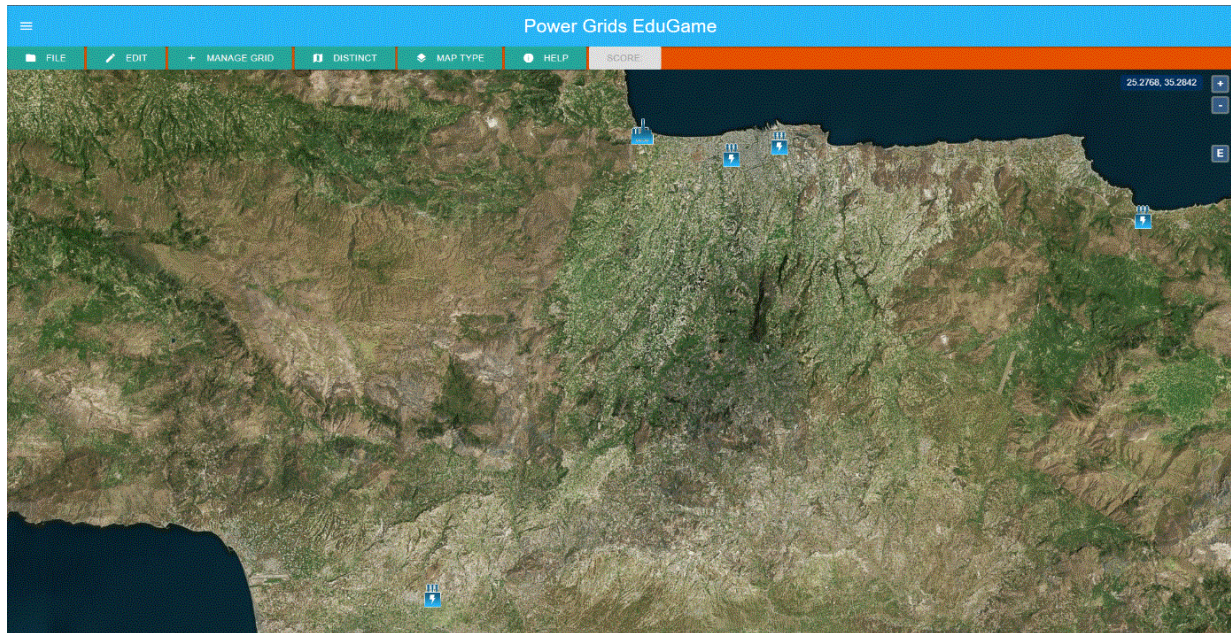


Figure 43 Substations on map

"Create lines" option is shown on Figure 44 below inside the red circle. By clicking on "Choose lines", lines are taken from JSON file and they are visualized on the screen. The visualization of high voltage lines is the same with connections inside power plants.

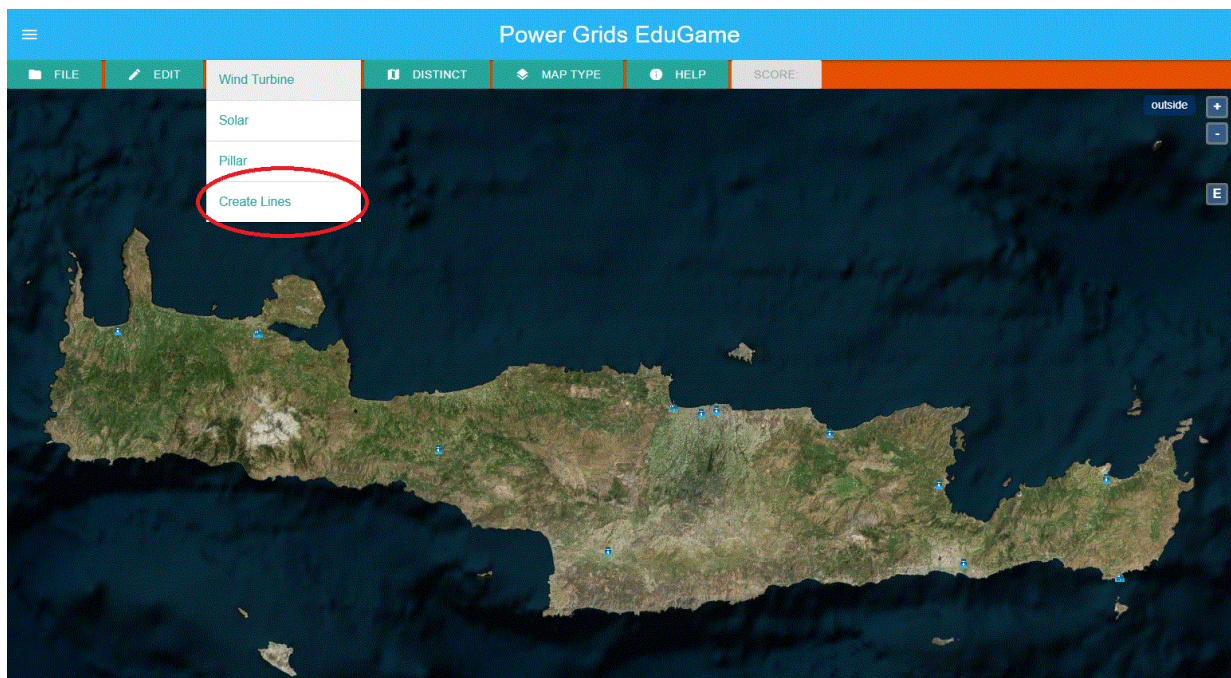


Figure 44 Create lines option

The real power grid's high voltage lines and inner connection between power plants are shown on Figure 45 below.

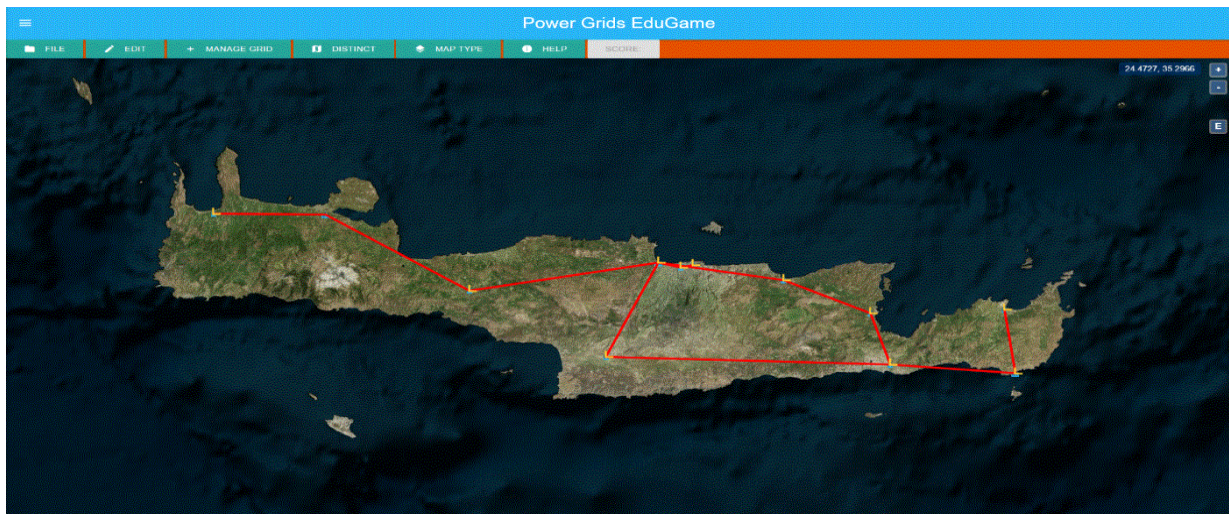


Figure 45 High voltage lines

On the last Figure 46 of this paragraph the map is zoomed, and different high voltage lines of the power grid are shown.

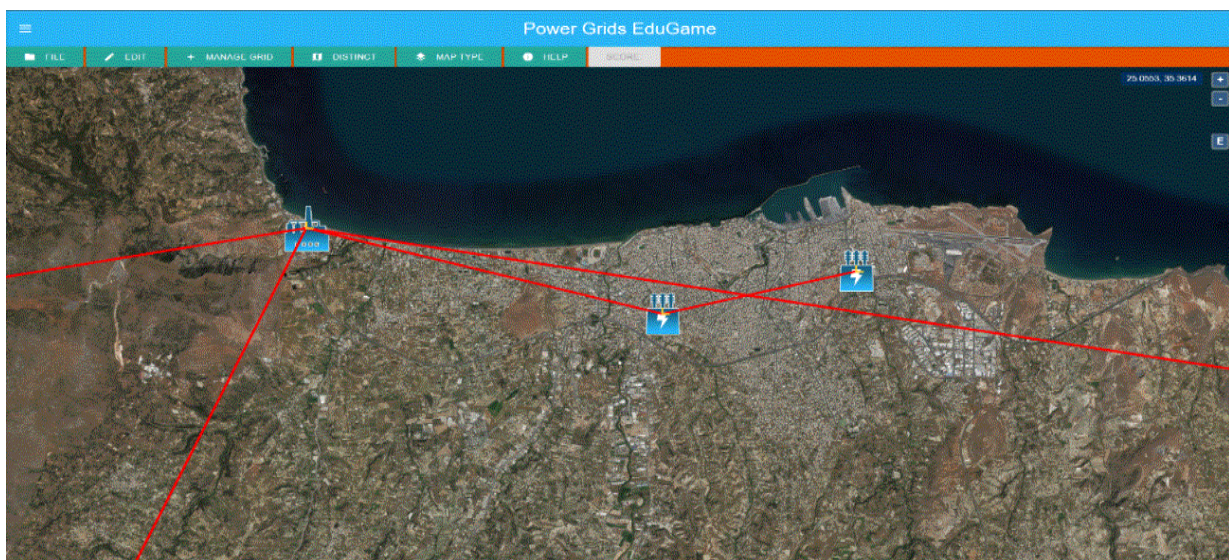


Figure 46 High voltage lines on zoom

## 5.4 Useful user – map interactions

Last paragraph of “Pilot implantation” chapter documents the useful user – map interactions workflow. The interactions implemented for better navigation through map, are “Fly to” interaction, “Change map type” interaction and “Extend map to default view” interaction.

“Fly to” interaction enables the user to travel to a specific power plant without cursor dragging on the map. As stated above, “Power Grids EduGame” loads regions dynamically according to user’s click on map. For this interaction the user has to press “Distinct” button on game’s main GUI (circle on Figure 47).

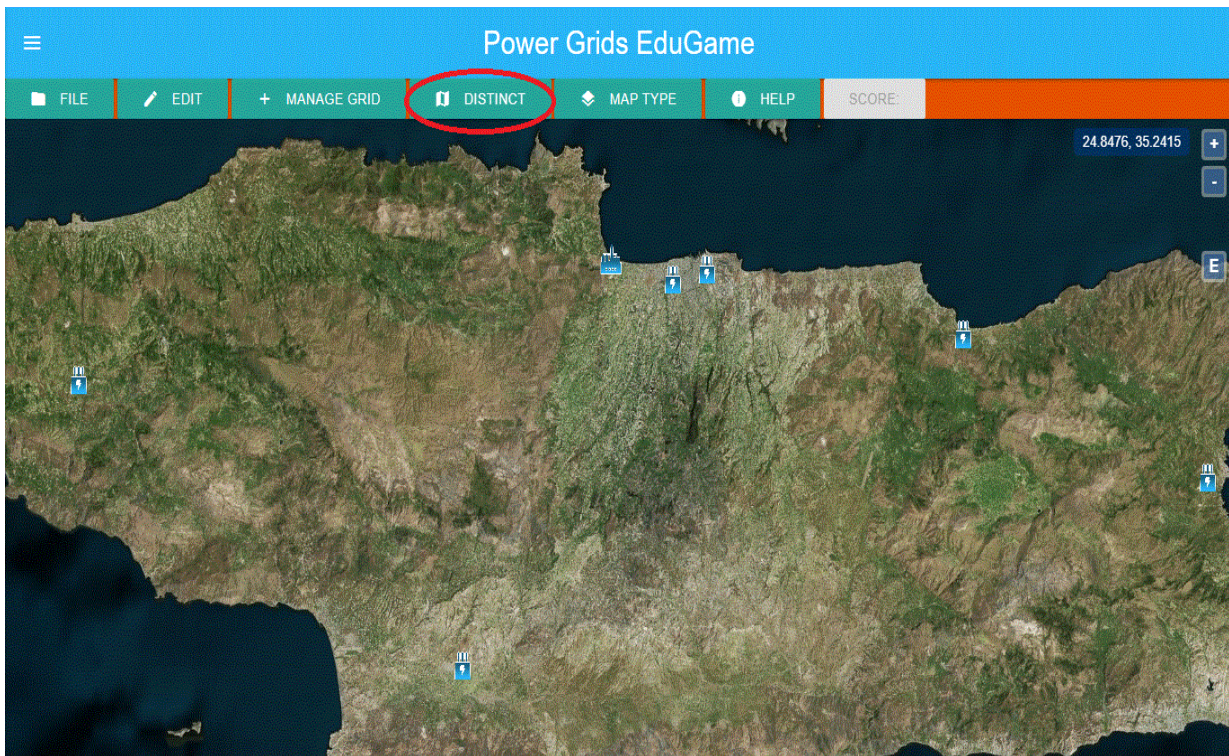


Figure 47 Distinct button on main toolbar

Once “Distinct” button is pressed, modal opens. This modal contains only a dropdown menu (Figure 48). The dropdown menu is loaded with the cities on the region that user is on the map. Regions and cities on each region are official data and have been taken from official source.

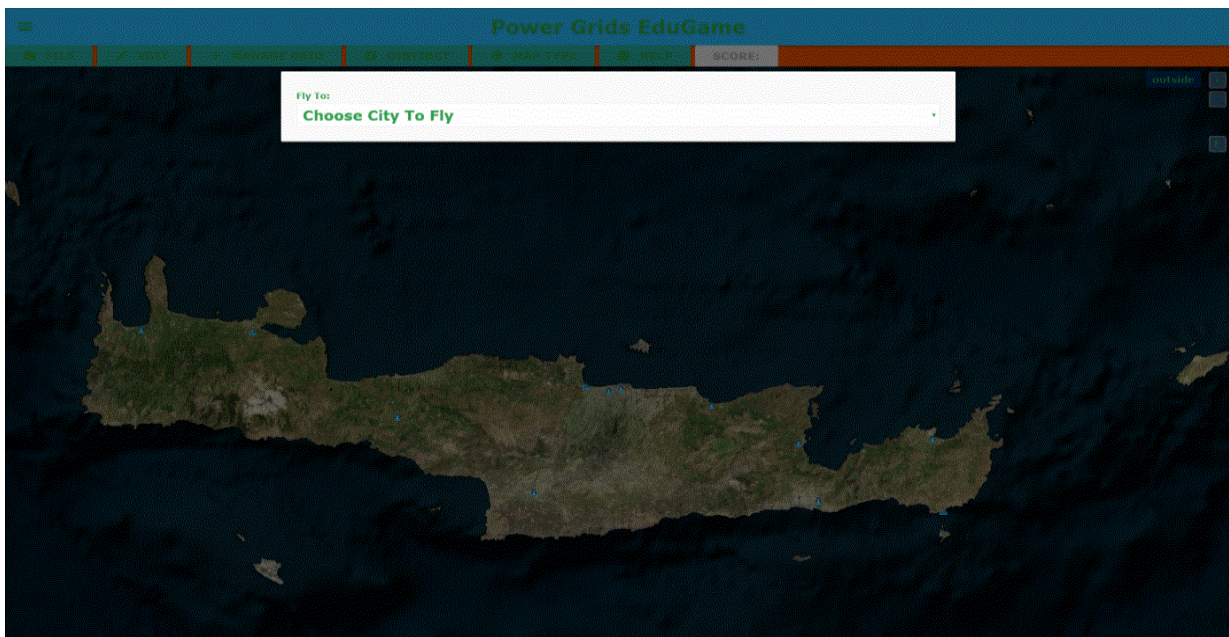
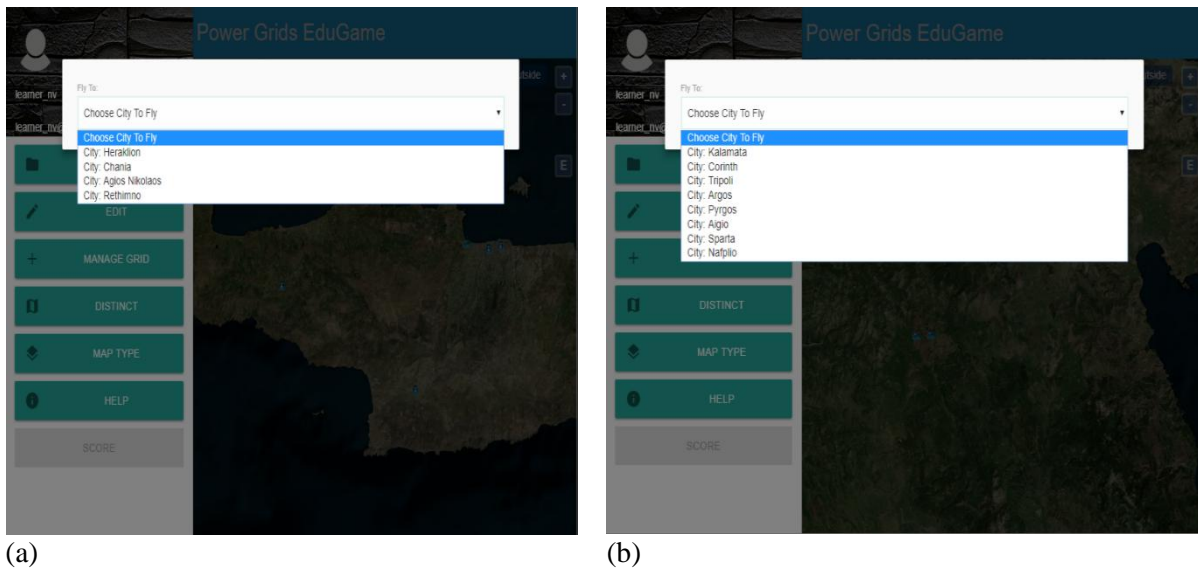


Figure 48 Choose city modal

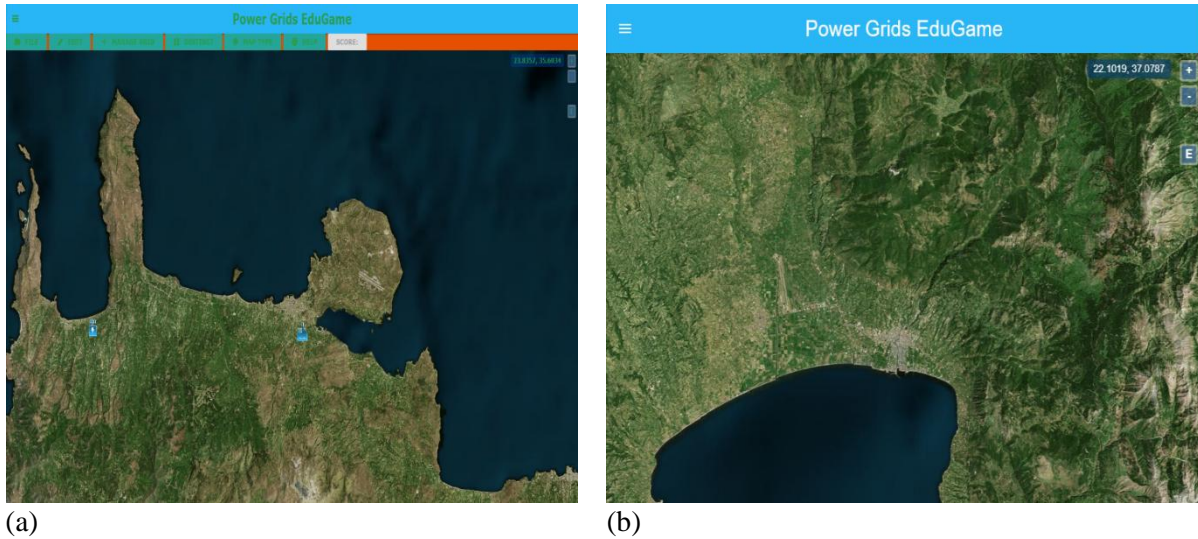
As next figures show, options on each dropdown menu, have the “City: city name” format. For instance, menu on (a) figure in Table 13, the cities of Crete region are loaded and on (b) figure the cities of Peloponnese region are loaded. Value of each option is the real city’s coordinates. By choosing an option modal closes automatically and after an animation the user “travels” to the chosen city.

Table 13 Two examples of cities lists options



From examples above, occurs that if the user on (a) figure chooses the “City: Chania” option, modal closes and travel to Chania city. This is presented in Table14 (a) figure below. Likewise, if user choose on “City: Kalamata option”, travels on Kalamata city.

Table 14 Results of "Fly to" interaction.



Another useful user – map interaction is the extend map to default view. In case of user through navigation on map reaches at some point an unwanted and unknown area, through a button resets the map’s field of view on default position. The red arrow on Figure 49 shows this button. The letter “E” is the first letter of the word “extend”.

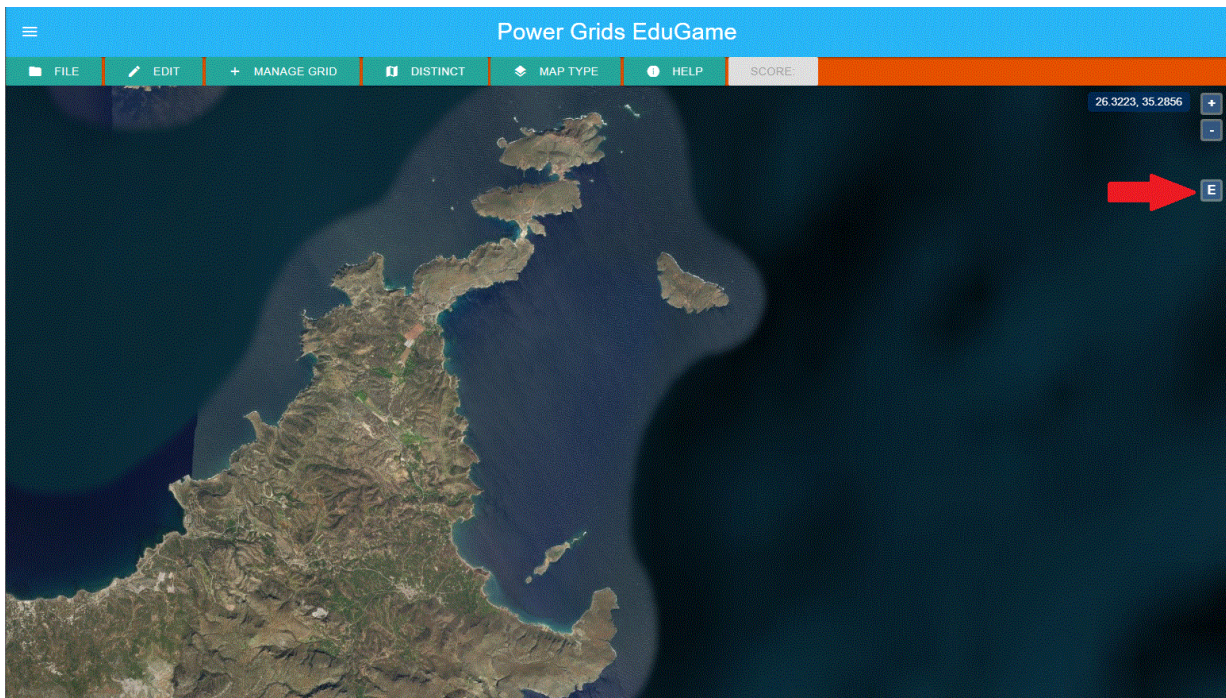


Figure 49 Extend button on map and map is centered in unknown place

Clicking on “E” button, map’s view resets on default position. Figure 50 shows the outcome of extend to default position interaction. At this state, as game’s main objective is the design and management of Crete’s electrical power grid, default filed view focuses on Crete region.

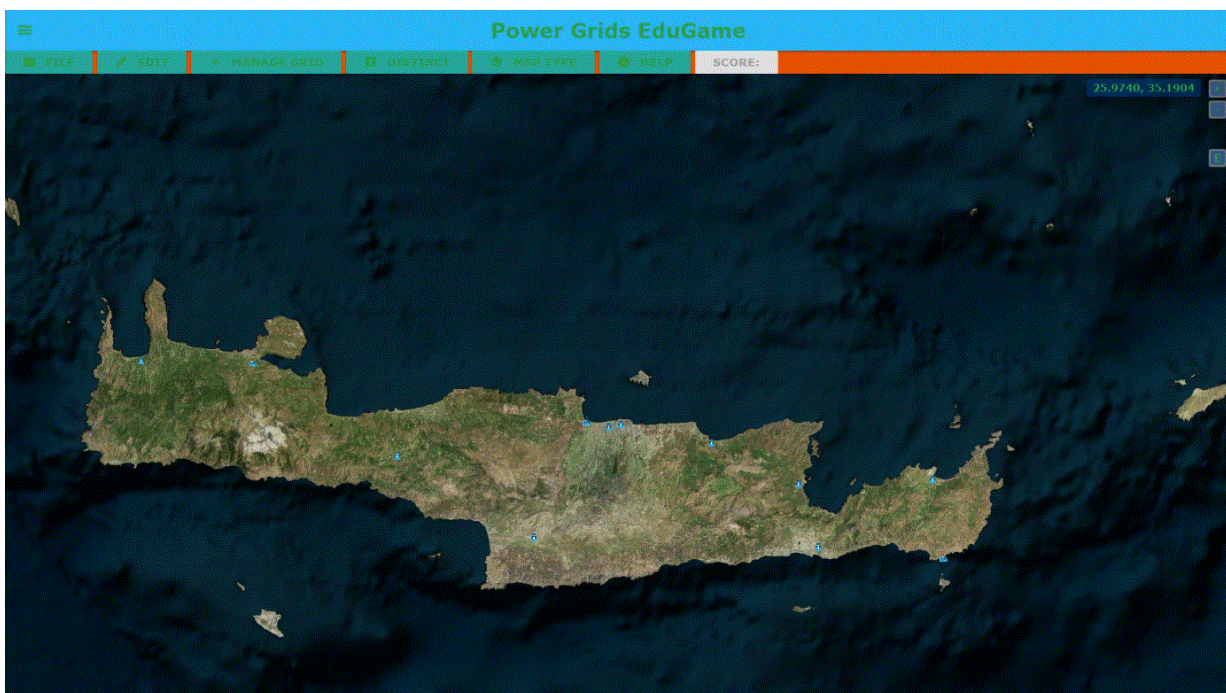


Figure 50 Map is extended in default view

Last interaction, is the “Change map type interaction”. User can decide the layer of main game’s map. The options are an aerial layer and an aerial with labels layer. “Power Grids EduGame” uses Bing maps layers for game’s main map and mini - map. Both layers offer worldwide orthographic aerial and satellite imagery. The difference between them, is that “Aerial with labels” layer provides political

boundaries and place names on map. In order user to swap between layers a dropdown menu with menu items (options) “Aerial” and “Aerial with labels” is provided on game’s main toolbar (Figure 51).



Figure 51 Change map's layer options on main toolbar

Figure 52 below shows the main game’s map with an aerial label. This change is accomplished by clicking on “Aerial” menu item on dropdown.

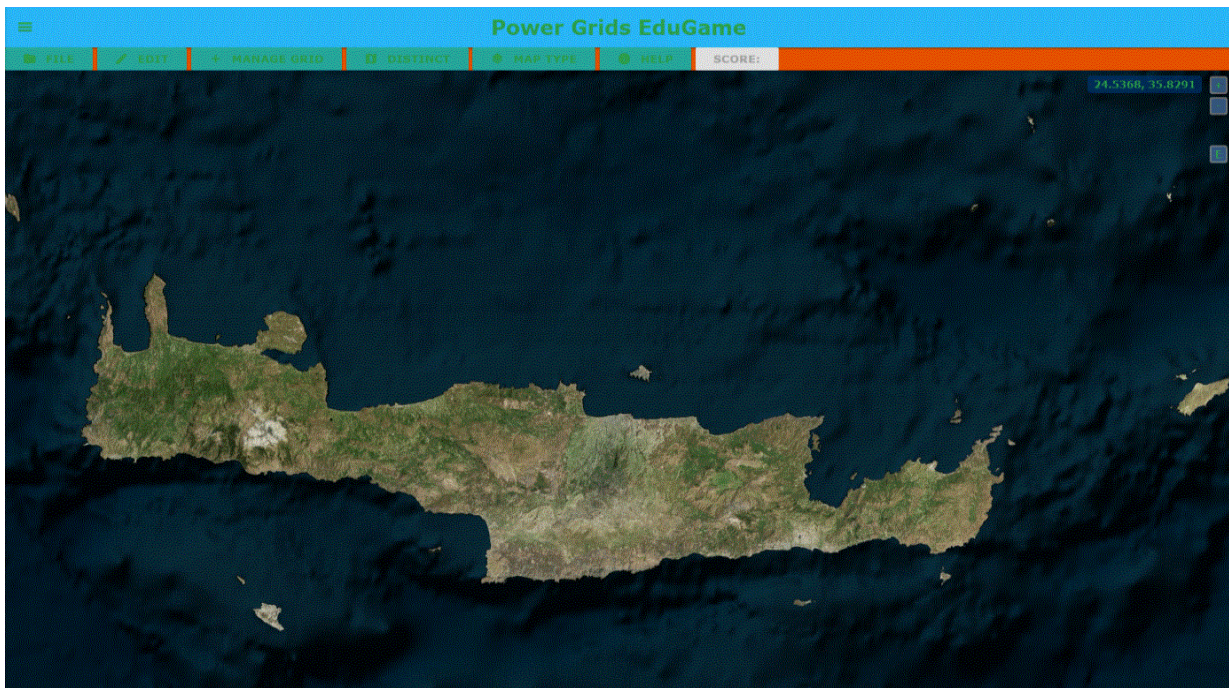


Figure 52 Map with aerial layer

The aerial with labels layer is shown on map by clicking “Aerial with labels” menu item (Figure 53).

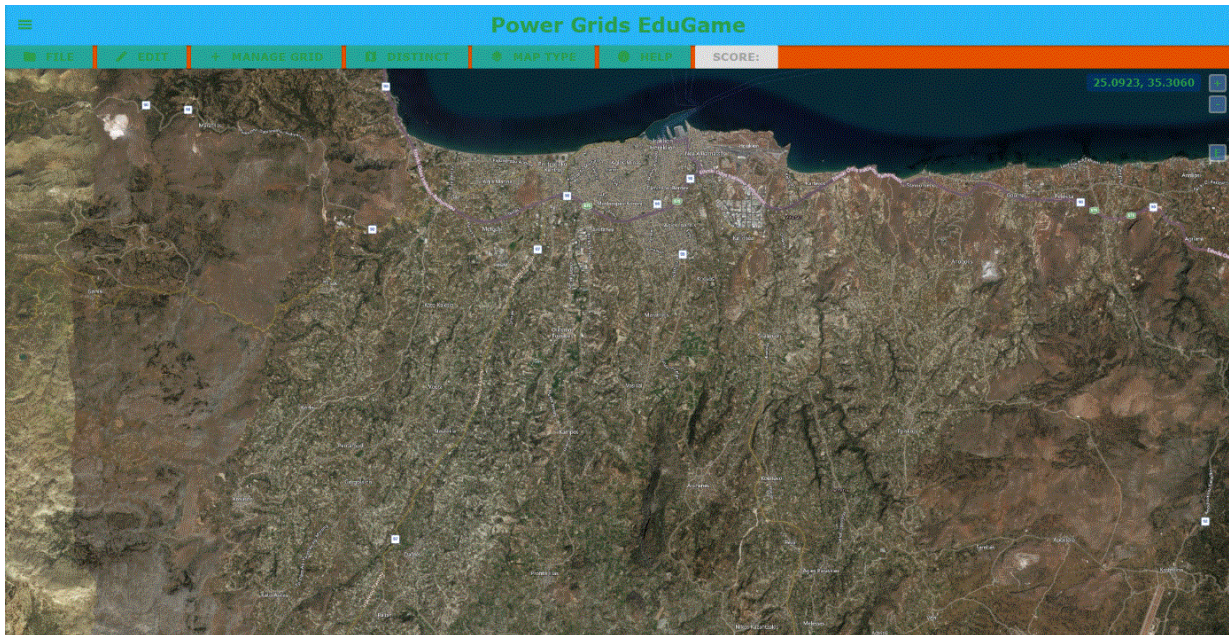


Figure 53 Map with aerial with labels layer

Combining “Change map type” interaction with “Fly to” interaction offers to the user the ability to find details of the city that “travelled”. Those details can be names from roads, city areas or borders between areas or countries.

## 5.5 Insert additional power grid’s components

On “Power Grids EduGame” main toolbar, the “Add artifacts” dropdown menu contains the options “Wind turbine”, “Solar”, “Pillar”. Each option is a type of power grid component. By choosing an option the user adds a component on game’s main map. The workflow is the same on “Insert components to power plant” scenario. These components are used for the implementation of game’s level 3 and level 4, which bear future work of the game. Figure 54 is an example of those components added on map.

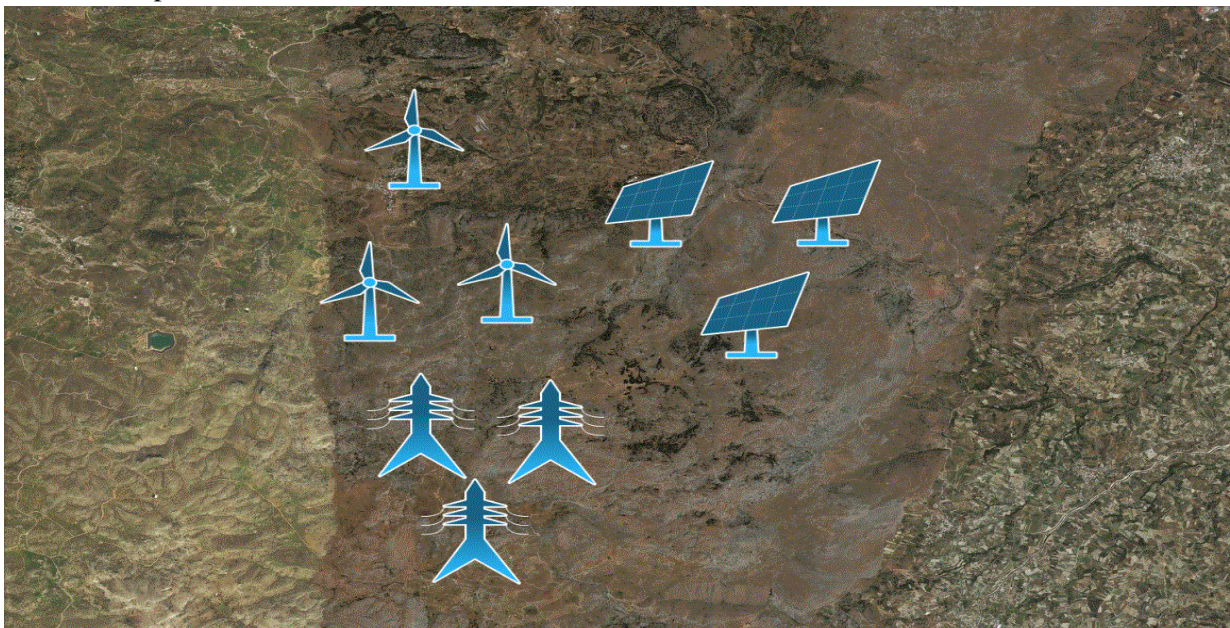


Figure 54 Additional artifacts added on map



## 6 Conclusion & future work

### 6.1 Conclusion

In this thesis an educational game is presented and the way that it can improve the learning process which can be succeeded by various learning ways as analyzed in Chapter 2. Nevertheless, serious games can be an evolving form of learning, by providing the learner with the proper guidance. Moreover, serious games keep learners alerted and can arouse their interest for the ongoing expansion of their knowledge. When the learning process is combined with the use of an educational game, essential elements and findings around the learning process are reinforced. According to these, learners can extend key competences, such as decision – making, and maybe later implement them in real life.

Serious games ensure continuous contribution and collaborations among learners. The learners' coexistence while involved in learning via games has direct benefit in both their sort and long term educational evolution. Serious games have many advantages and can be turned into powerful teaching tools. These advantages are:

- Strengthening knowledge and its degree of durability.
- Support group creation
- Support the development of various skills, such as strategic thinking, planning, communication, collaboration, team decisions and negotiation skills.
- Adaption of the learning experience according to the student's characteristics, style and degree of learning.
- Facilitate learning in order to take place in a context that makes sense for the game.

“Power Grids Edu Game” is an educational game. It focuses on designing and managing electrical networks and power grids, as long as in transmitting electrical power within and out of them. The design is based on real – world data and takes place in a real – world map. It is developed with web technologies, frameworks and libraries. The game follows the patterns of learning theories and it is customizable based on them. This is achieved by the continuous communication with IOLAOS platform. Finally, “Power Grids EduGame” provides simulation and modeling services, as well as data visualization.

### 6.2 Future work

Future work is based on improving the “Power Grids EduGame” scenario and play levels, as well as improving the educational aspects of the game.

More specific, chapter's 4 use case paragraph introduces the Use Case Level 2: Manage crisis situations and the Use Case: Level 3: Exchange amount of electricity through different power grids. Future work is focused on the implementation of these two use cases. This implies the addition of two more levels on the game.

Moreover, by the implementation of Level 2 and Level 3 the design and management of different power grids, is planned. A collection of real data for other power grids will be carried out. Game's main map and mini – maps, will be expanded to other regions of Greece. Also, for Level 3 financial information about electric power will be studied and collected.

Finally, the creation of user's log file will be implemented. By the use of Experience API (see Chapter 3), the game will be able to collect data and information about user's actions and activities through the gameplay. The Data will be statements in JSON files and will be recorded in a Learning record store (LRS). User's log file will be retrieved from the LRS and analyzed by educational experts in IOLAOS platform.

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