

DESIGN AND DEVELOPMENT OF EFFECTIVE AND CUSTOMIZABLE SERIOUS  
GAME PLATFORM BASED ON LEARNING PROFILE

By

STAVROS CHARITAKIS

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Approved by:  
Associate Professor  
**Nikolaos Vidakis**

## **Statement of Originality**

The work contained in this thesis has not been previously submitted for a degree or diploma at any other higher education institution or any other purpose. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except as specified in references, acknowledgements or in footnotes. I certify that the intellectual content of this thesis is the product of my own work and all the assistance received in preparing this thesis and sources have been acknowledged.

Stavros Charitakis

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## Abstract

The robust growth of Information and Communication Technology (ICT) and its massive usage in every aspect of human life has made a tremendous impact on the learning procedure, leading to new concerns over the need to reform the educational system to embody such technologies. Therefore, a resurgence of interest has occurred in how to use serious games as assistance to pedagogical activities over the last years.

Serious games though must be designed for individuals to provide a personalized experience and increase perceived value for learners. However, creating such games is not an easy task, requiring an expertise from a wide variety of fields such as game and software developers, educational specialists, game testers and teachers. Platforms that enable collaboration for creating tailored-made third party serious games are now the top of the international research agenda and there are yet no significant exemplars available.

According to the above we have designed and developed the IOLAOS platform, which aims to facilitate the collaboration of user roles in order to (a) enable educational experts to codify learning styles and preferences into game creation, (b) share information and instructions with game developers to make their games adaptable (c) allow teachers to create their own virtual classes, monitoring game learning sessions and customizing their learner's game experience based on their profile, (d) offer learners a unique game educational experience and (e) permit game testers to constantly evaluate the whole procedure and provide feedback for the reliability of the platform.

This thesis describes the design and the development of IOLAOS platform, which will contribute to the educational domain by enhancing the effectiveness of serious games.

## Περίληψη

Η ραγδαία ανάπτυξη της Τεχνολογίας της Πληροφορίας και της Επικοινωνίας (ΤΠΕ) και η εκτεταμένη χρήση της σε όλες τις πτυχές της ανθρώπινης ζωής έχουν επιφέρει τεράστιο αντίκτυπο στην εκπαιδευτική διαδικασία, δημιουργώντας νέους προβληματισμούς σχετικά με την ανάγκη μεταρρύθμισης του εκπαιδευτικού συστήματος ώστε να ενσωματώσει τέτοιου είδους τεχνολογίες. Ως εκ τούτου, αναζωπυρώθηκε το ενδιαφέρον για τη χρήση εκπαιδευτικών παιχνιδιών ως αρωγός στις εκπαιδευτικές δραστηριότητες τα τελευταία χρόνια.

Εν τούτοις, τα παιχνίδια αυτά πρέπει να σχεδιάζονται με τέτοιο τρόπο ώστε οι ενδιαφερόμενοι να παρέχουν μια εξατομικευμένη εμπειρία και να αυξάνουν την αντιληπτή αξία για τους εκπαιδευόμενους. Ωστόσο, η δημιουργία τέτοιων παιχνιδιών δεν είναι εύκολη διαδικασία, καθώς απαιτεί εξειδίκευση από ένα ευρύ φάσμα επιστημονικών πεδίων, όπως προγραμματιστές λογισμικού και παιχνιδιών, εξειδικευμένους εκπαιδευτικούς ερευνητές, δασκάλους καθώς και δοκιμαστές παιχνιδιών. Οι πλατφόρμες που καθιστούν εφικτή τη σύμπραξη για τη δημιουργία εκπαιδευτικών παιχνιδιών αποτελούν πλέον την κορυφή της διεθνούς ερευνητικής ατζέντας χωρίς βέβαια να έχουν παρουσιαστεί σημαντικά υποδείγματα ακόμη.

Σύμφωνα με τα παραπάνω, προχωρήσαμε στη σχεδίαση και ανάπτυξη της πλατφόρμας IOLAOS, η οποία στοχεύει στη διευκόλυνση της συνεργασίας όλων των χρηστών προκειμένου να α) επιτρέπουν στους εξειδικευμένους εκπαιδευτικούς ερευνητές να κωδικοποιούν σε ψηφιακή μορφή τις θεωρίες και μορφές μάθησης για την δημιουργία παιχνιδιών, β) να μοιράζονται πληροφορίες και οδηγίες με τους προγραμματιστές παιχνιδιών έτσι ώστε τα παιχνίδια να υλοποιούνται με ευέλικτο τρόπο που θα ευδοκιμούν την παραμετροποίηση τους αναλόγως των πληροφοριών, γ) να επιτρέπουν στους εκπαιδευτικούς να δημιουργούν τις δικές τους εικονικές τάξεις, να μαγνητοσκοπούν τις εκπαιδευτικές συνεδρίες παιχνιδιών και να προσαρμόζουν την εμπειρία του εκάστοτε μαθητή βάσει του προφίλ του, δ) να προσφέρουν στους μαθητές μια μοναδική εμπειρία εκμάθησης μέσω της εξατομικεύσης των παιχνιδιών και τέλος ε) να επιτρέπουν στους δοκιμαστές παιχνιδιών να αξιολογούν συνεχώς την όλη διαδικασία και να αλληλοεπιδρούν με σκοπό την αξιοπιστία της πλατφόρμας.

Αυτή η πτυχιακή εργασία περιγράφει τον τρόπο σχεδιασμού και ανάπτυξης της πλατφόρμας IOLAOS, η οποία θα συνεισφέρει στον τομέα της εκπαίδευσης, με την ενίσχυση της αποδοτικότητας των εκπαιδευτικών παιχνιδιών.

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# Chapter 1: Introduction

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## Contents

**1.1 Scope and Objective**

**1.2 Thesis Volume Overview**

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**Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το Heading 1 στο κείμενο που θέλετε να εμφανίζεται εδώ.**

There has been a rapid and disruptive change in the landscape of education worldwide in the recent years due to the evolution of our technology-driven society. The robust growth of Information and Communication Technology (ICT) and its massive usage in every aspect of human life has made a tremendous impact on the learning procedure, leading to new concerns over the need to reform the educational system to embody such technologies.

Nowadays, education does not conclude with the completion of one of the levels of the European Qualifications Framework [1]. On the contrary, in the fast-paced information economy, lifelong earnings require lifelong learning. Consequently, education starts from our formative years and has a long journey to keep our skills sharp and maximize knowledge, income or employability.

To that end, classical education skills such as typical reading and writing are no longer adequate preparation for success in life. Everyone grows up with smartphones, tablets, and video games familiarizing with technology through daily interactions. It is evident that learning experience should go beyond its boundaries embracing the advent of new technologies and adapting learner assessment to the needs of a digital age. The Young Digital Planet team in their book of trends in education [2, pp. 64–104] claim that an efficient manner to dazzle today's lifelong learners is through fun, proposing seven different approaches along with case studies.

Therefore, a resurgence of interest has occurred in how to use serious games as assistance to pedagogical activities over the last years. A stark picture of the rapid rise of such games is revealed by the market research report [3], where results indicate that serious game market is forecast to exceed 5 billion dollars by 2020 at an annual growth rate of approximately 16% between 2015 and 2020.

Serious gaming is a subject undergoing a second youth and, as such, one might expect to face a diversity among earlier and later definitions and terms to rectify such a rejuvenation. Although most of the authors refer to the use of computer games in learning and instruction as serious games [4]–[7], others use the term interchangeably with other terminologies [8]. C. Girard et al. [9] use the term Computer Assisted Learning (CAL) while Connolly et al. [10] and Wouters et al. [11] the term Game-Based Learning (GBL). Erhtel & Jamet [12] add to the later the element of Digital and, instead of GBL use the term Digital Game-Based Learning (DGNL), while Young et al. [13] adopt the term Learning Games (LG).

Such a diversity of terminologies leads to a variety of definitions too. As Breuer & Bente point out, “...the definition of the term ‘serious game’ often varies depending on who uses it and in what context” [6]. Most of the authors state that the educational element,

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applied to the development of the game, should be the main goal [4], [5], [9], [2, pp. 84–86], while others [6], [10] are satisfied if the game is used for educational purposes. Although there has been a controversy about the precise definition, all the authors agree on the core meaning that serious games must share the characteristics of games in general, while distinguishing themselves as “serious” by introducing the educational element.

Gamification is becoming an increasingly growing topic among companies and educational specialists worldwide. In the rush, gamification is confused with the terminologies mentioned above. However, GBL and serious games are training tools themselves, defining learning outcomes, while gamification is not. The latter uses game mechanics to engage learners in their training efforts, such as competition, collaboration, stories, achievements, levels, and rewards. These techniques can certainly be used to increase motivation and improve completion rate. They can be considered as persuasive practices though, rather than educational games [2, pp. 72–73].

Serious game as a meaning is not a new trend, dating back in the fifteenth century where the oxymoron phrase “serio ludere” was used in literature, adding a sense of humor in learning [14]. However, the closest meaning as we know it today was first introduced in the 1970’s [2, p. 84], [14] as war games to train strategic skills and later on as war simulators for military purposes. Currently, they can be witnessed in many areas such as education, health, advertising and business [7], [14].

There is a common belief in the research community [4], [6], [10], [15] that gaming provokes intrinsic motivation and prolongs the engagement factor. Erhel and Jamet [16] identify two types of goals regarding students, mastery and performance goals. A serious game could attract students with both since it can provide the mastery goals with learning acquisition as the game proceeds and the performance goals with competition to claim the highest score, respectively.

Another possibility that comes out of serious games is feedback, which can be applied to users through the whole duration of the game to invigorate acquired knowledge, as well as help them to grab and absorb the relevant cognitive processes [10], [16]. In contradiction to obsolete learning, which has no easy way to gather information about student’s evaluation, GBL can use game logs in order to constantly monitor learner’s progress [4].

The main question as to whether serious games provide a better method for education is indeed addressed by most of the reviewers. Although all of them seem to have a positive opinion, they could not agree on whether there is adequate evidence to support it scientifically. The most widely cited review by Connolly et al. [10] concluded that there is

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indeed enough evidence to justify a positive answer, but there still exist areas for continuing researches. In addition, Bellotti et al. [4] provide many indications that serious games are beneficial for education, but they also point out that there is still not enough valid proof for that. A primary limitation lies in the inconsistency use of test subjects (groups) and the numerous confounding variables that hinder from distinguishing the advantages of serious games [4], [12].

As the term serious games has entered the mainstream lately, the research community continues conducting surveys to collect more empirical findings. More recent literature reviews [8], [17] confirm previous researchers' results and illustrate higher quality data about the positive outcomes of such games in education.

### **1.1 Scope and Objective**

The present thesis aims to contribute to the effectiveness of serious games in education. The main objective of this thesis is to design, and implement an open authorable and adaptive platform, namely "IOLAOS<sup>1</sup>" which allows third-party serious games developers to personalize and customize their games based on learning methods, learning styles, learning abilities & competencies and learner preferences, i.e. based on a learning process profiling. The key contribution of the present work relies on its ability to facilitate the collaboration of expertise of diverse professions, each one with his own role. The roles that are supported at the IOLAOS platform are: (a) Educational expert, (b) Game developer, (c) Learner, (d) Teacher, (e) Game tester and (f) Administrator.

In specific, educational experts are responsible for creating game preferences according to learning styles, learning theories and special needs that will be later used to adapt game experience accordingly. As a result, game developers' work is to get familiar with this information and design their games in a way that allows customizations at certain parameters. Learners, on the other hand, should register to the platform to create their own user and learning profile, as well as participating in learning game sessions. Teachers having in their possession an online book of user and learning profiles and game preferences based on educational criteria, can assign them to the learners so that they have their own personalized educational gaming experiences. Game testers are authorized to assign their own game preferences and play third-party games to constantly evaluate the whole procedure and provide feedback for the reliability of the platform. Finally, administrator is responsible for verifying roles and games, as well as respond to technical issues of the platform.

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<sup>1</sup>IOLAOS in Greek mythology was a Theban divine hero famed for helping with some of Heracles's labors.

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## 1.2 Thesis Volume Overview

The thesis is organized in four chapters as follows:

**Chapter 1:** This chapter includes a brief introduction, focusing on the necessity of serious games in education and highlights the scope and the main objectives of this work.

**Chapter 2:** It explains the correlation of pedagogy theories with games for eliminating the communication gap between education and game industry. Thus, it presents the state of the art of serious game platforms, suits, frameworks, protocols, gamification enabling software, and game based learning approaches.

**Chapter 3:** Presents a detailed description of IOLAOS. More specific, this chapter will elaborate on the architectural design, the system and user design along with its components and the connection between them.

**Chapter 4:** Describes technologies used for the implementation of the platform and analyzes the implemented system components. It also provides an overview of the platform's user roles.

**Chapter 5:** This chapter presents use cases based on third-party serious games collaborating with the IOLAOS platform.

**Chapter 6:** The last chapter of this thesis includes a brief discussion about the topic, along with findings and conclusions. Finally, presents possible directions for future work

## Chapter 2: Background

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### Contents

#### **2.1 Learning Theories and Learning Styles**

##### **2.1.1 Behaviorism**

##### **2.1.2 Cognitivism**

##### **2.1.3 Constructivism**

#### **2.2 Pedagogues and Games in Practice**

#### **2.3 Serious game platforms, suits and frameworks**

#### **2.4 Gamification Enabling Software**

#### **2.5 Requirements, Gaps, Limitations and Unique Assets**

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In this chapter, research on how to apply learning theories and styles in gaming is conducted in the interest of eliminating the gap between game industry and educational experts, as well as for adopting these techniques in our platform. Moreover, we provide an elaborate research on state of the art of serious game platforms, suits and frameworks to find gaps, limitations as well as unique assets that each one of them has.

## 2.1 Learning Theories and Learning Styles

One way to empower the use of serious games in education is through pedagogy; by correlating game design elements with widely accepted learning and instructional theories [18]. Educational specialists have long studied the individual learning preferences. Over the years, academics have proposed many theories to describe how these instructional methods can be tailored to cater to the different styles. An overview by Nielsen [19] identified three different theories that will be briefly referred over the next few paragraphs.

The information presented in **Table 1** is the outcome of our study of the three learning theories, namely Behaviorism, Cognitivism and Constructivism, and provide the reader with a comparison of these three different approaches illustrating how educational paradigm's features might be translated into practical applications in serious games for each theory.

*Table 1: Educational Paradigms' features from game point of view*

<b>Learning Theory</b> <b>Game feature</b>	<b>Behaviorism</b>	<b>Cognitivism</b>	<b>Constructivism</b>
User Profiling	✗	✓	✓
Scaled Rewarding	✓	✗	✓
Scaled Penalty	✓	✗	✗
Learner's Reviewable Progress	✗	✓	✓
User Level Adjusted Challenge	✗	✗	✓
Observation Live	✗	✓	✓
Observation Offline	✓	✓	✓
Examples or Tutorials	✓	✓	✓
Social Networking	✗	✓	✓

### 2.1.1 Behaviorism

Behaviorism is a learning approach based on the hypothesis that the learning procedure is a change in observable behavior triggered by external stimuli from the environment. A key feature of behaviorism is the reward or punishment of a new behavior.

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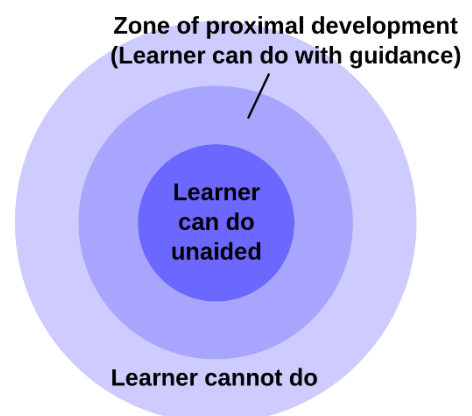
The theory provokes that rewarding someone for a particular behavior reinforces him to act in the same way in similar situations [19]–[21]. Conversely, punishment is used to decrease the frequency of unwanted actions [20], [21]. Another fundamental principle of the theory is the existence of repetition and feedback. Hence, learners are capable of repeating the learning process until they acquire knowledge, while appropriate feedback is provided according to their performance. All the above can easily be integrated and applied in video games, i.e., increase the game time if the player's answer is correct [19], and allow players to replay educational videos at their own pace [20].

### 2.1.2 Cognitivism

In the cognitivist approach, the learner becomes the center of attention acquiring knowledge through a variety of different modalities such as text, pictures, and sounds. The key to this paradigm is to enable learners to identify and analyze problems, as well as apply past learning. More broadly, cognitivism attempts to provide an intense learning experience similar to the limitations and potentials of the human mind. Cognitivism can be considered as an extension of the behaviorism learning theory rather than a replacement [19], [20]. Instances of how to apply this theory in games is presented in [20], where students learn English expressions while viewing familiar art pictures and in [19], where students absorb math knowledge by playing geometry puzzles.

### 2.1.2 Constructivism

Previous learning theories are nowadays considered deprecated in a manner where learning is handled as a procedure happening inside the learner and ignore the interaction with the learning environment and surrounding learners [20]. According to constructivist, learning is reinforced by having to explain it. Learners construct mental models to understand the world around them and take an active role in creating their own understanding rather than



receiving it from someone who knows. This theory is based on the philosophy that one learns through observation and interpretation (learn by doing) [19], [20]. Concurrently, the social interaction plays a crucial role, and it is linked to the Zone of Proximal Development (ZPD), which defines what a learner can do with or without help [20], [22, pp. 84–91] as shown in **Figure 1**. Simulations and microworlds are

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the key principles for the constructivist theory. The former provides a realistic situation where learners can explore in order to construct their own mental model of the environment while the latter facilitates the existence of immediacy of feedback as the learner creates models [19], [23]. A theoretical framework in [23] describes a list of techniques that can be adopted by games to define their level of constructivism.

## **2.2 Pedagogues and Games in Practice**

The resistance and negativity hindering experimentation and adoption of serious games today are based on the assumption that games fail to embody the fundamental elements of learning and instructional theories. Consequently, an agreed-upon common language is essential to minimize the gap between game developers and educational experts. Both Gagné and Gardner (as cited in Becker [18]) outlined that good games already embody the main components that can be used for instruction and learning.

Similarly, to many others, Gagné's theory [24] cover both learning and instructional principles. His theory presents five kinds of learning that can be well suited in most good games: (1) verbal information, the recall of information both oral and written that was taught in the past, (2) intellectual skills, involving the manipulation of information to solve problems, (3) cognitive strategies, refer to the creation of plans to win the game, (4) motor skills, the use of some sort of controllers in games to improve physical performance, and (5) attitudes, which are vital to role-playing, i.e., the consequences of player actions affect the external appearance of the game characters.

According to Gagné's theory [24] good instruction requires planning and there are nine steps of delivering instruction embodying the five categories mentioned above. A brief description of the Nine events of Instruction [18], [25] is presented below:

- (1) Gaining attention (reception):** At the beginning of the game, players are informed about the elements of the game. Its usage is to grab their attention and allure them to play.
- (2) Informing learners of the objective (expectancy):** Once gaining attention is achieved, information about the objectives of the game is presented including the story of the game and description of how to win.
- (3) Stimulating recall of prior learning (retrieval):** During the game, users are asked to make decisions based on prior learning. To that end, games should provide information acquired in previous levels.

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- (4) Presenting the stimulus (selective perception):** This includes all the necessary actions, prompts, tasks and interesting activities of the game to prolong player's engagement. The ZPD [22, pp. 84–91] is utilized to prevent boredom at first and avoid discouragement as the game difficulty increases.
- (5) Providing learning guidance (semantic encoding):** All the instructions and hint messages are displayed to guide the player through the game.
- (6) Eliciting performance (responding):** An important factor of the game, consisting of all the objects and non-player characters that interact with the player to enhance knowledge in a virtual environment.
- (7) Providing feedback (reinforcement):** Feedback to the game is provided in the form of communication messages, prompts, scores and character conversations. It is one of the imperative elements of the game to provide players with a sense of progress.
- (8) Assessing performance (retrieval):** Assessment is another essential part of the game to keep players motivated to succeed and continue. During the game scores are logged and evaluated.
- (9) Enhancing retention and transfer (generalization):** Skills, knowledge and strategies gained in one game are often transferable to the real world and to other games as well.

As Becker [18], [25] concludes, Gardner's Theory of Multiple Intelligence is one of the most important developments in learning theories and refers to intelligence as different modalities and types rather than a single general ability. Although Gagné and Gardner Theories share common assets, they differentiate in the fact that Gardner suggests an easy classification system based on social interaction and culture, while Gagné concentrates on cognitive constructs. The former proposes eight primary forms of intelligence: (1) linguistic, (2) musical, (3) logical-mathematical, (4) spatial, (5) kinesthetic, (6) intrapersonal, (7) interpersonal, and (8) naturalistic. The concept of this theory is that learning can be achieved through the development of instruction for these learning styles.

The existence of Gardner's learning styles can be seen and applied in a successful game. Although their connection with game design principles is apparent, we present the following table (**Table 2**), which highlights the application of the eight "intelligences" in GBL from our perspective.

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*Table 2: Theory of Multiple Intelligence and GBL*

<b>Intelligence</b>	<b>Skill</b>	<b>GBL</b>
Linguistic	Reading & Writing Learn new languages Tell stories	Verbal and written cues to guide through the game play
Musical	Interpret sounds, rhythms, tones and pitches	Music and sounds to entertain and provide feedback and reinforcement
Logical-mathematical	Logic Organization Critical thinking Patterns and experiments	The flow of the game story underlying concepts and the immediate response to the player's action
Spatial	Understanding of space Ability to visualize	Provide rich and colorful 2d or 3d environments, multiple views
Kinesthetic	Good at physical performance Control physical motion e.g. dancers, actors, sports athletes	Movement in games is either enabled with game controllers such as gamepads or by paralleling player's actual movements through devices such as Kinect.
Intrapersonal	Self-understanding Self-consciousness Self-motivated Self-reflection	Interaction with virtual characters that their understanding is crucial for determining the outcome of the game
Interpersonal	Understanding other people's emotions Socializing Cooperation Leadership	Enable collaboration with other players in the same virtual environment for common or opposite goals. Exchanging information
Naturalistic	Ecosystem awareness Recognize staff in the real world, e.g. flowers and animals	Provide a simulation of an ecosystem populated by flora and fauna in which the player must use its mechanics to survive, win and explore

### **2.3 Serious game platforms, suits and frameworks**

Since the arousal of video games in learning environments, early efforts were made to introduce several frameworks for their exploitation in the serious game industry. De Freitas and Oliver [26], suggested a four-dimensional theoretical framework for evaluating games for educational purposes, while Linehan et al. [27] proposed Applied Behavioral Analysis, an empirically validated method of teaching, as a framework satisfying the requirements for constructing successful educational games.

#### **UniGame**

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UniGame: Social Skills and Knowledge Training [28], [29], on the other hand, is a web-based framework, where teachers use GBL in their classes by editing a predefined game to their own needs and topics, thus fostering collaboration inside a constructivist learning environment.

### eAdventure

eAdventure [30] is a platform developed by the research group at the Complutense University for creating computer learning games. Specifically, it is an open code authoring environment to produce *point-and-click* first and third-person adventure games. eAdventure enables the participation of teachers in the development process without requiring advanced computer skills. This is achieved by providing them with easy to use tools to create scenes, characters and all other required assets for composing games. Moreover, teachers have at their disposal a repository of games that can be used and tailored to their own preferences, instead of creating new ones from scratch.

This platform also simplifies the integration of games in the pre-existing learning infrastructure, allowing the exportation of such games as Learning Objects (LO). The latter are compliant with Learning Management Systems (LMS) such as Moodle, enabling reusability. All these features satisfy the primary goal of the platform which is to ease the development of serious games by overcoming the barriers that hinder their adoption, such as reduction of high development costs of serious games.

### uAdventure

The software of the platform was built with Java technology to accomplish cross-platform desktop compatibility. However, the rapid progress of mobile technology made eAdventure unavailable to tablets and mobiles due to ineffective platform support. For this reason, the same research group launched a new platform recently, namely uAdventure [31], which is an update of the previous one, eliminating the technical problems and adapting to new technologies. uAdventure is built upon the game engine Unity, which supports the majority of desktop as well as mobile platforms. Furthermore, the new platform takes advantage of the eXperience API (xAPI), which will be later discussed, in order to include game records and develop analytic tools for customizing the gameplay.

### Semi-automated serious component

Another attempt to reduce the time and cost of the development of serious games is the semi-automated serious component based on engineering approach proposed by [32]. This approach consists of three layers. The upper layer, called Interactive Wizard User Interface is responsible for collecting all the information from a game developer, which is

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necessary for the edit and preview of the game. The middle layer enables the user to create components based on serious educational game engine including four modules: element selection, object creation, game composition and game script output. Finally, the last layer is made of a repository filled with game assets, game components and game scripts. However, the game components are deficient in reusability to be applied in many different games.

### ARLearn

ARLearn is a web-based tool suite for creating mobile serious games. Its main usage is to reenact real-world simulations, like field trips. Educators develop games through an authoring environment containing a set of predefined media items, which can be attached to maps, progress and scoring rules. The platform supports two kinds of games, one through StreetLearn, a google streetView mashup providing an augmented reality experience and another with a map view in real environments using the GPS technology.

ARLearn's open adaptable architecture allows communication with third-party applications through a real-time messaging protocol, Extensible Messaging and Presence Protocol (XMPP). Therefore, an event trigger, i.e., player score update, could broadcast XMPP messages, which can be seen by the educator in real-time [33], [34].

The framework can support a variety of scenarios other than field trips, such as role-playing games and classroom response systems. A case study of how the application can be utilized in such scenarios is presented in [35], where the United Nations Refugee Agency (UNHCR) simulate a hostage taking scenario. ARLearn enabled participants to easily make the connection between physical and virtual world and capture the importance of such emergency drills.

A general consensus that narrative architecture and ludic design are two important approaches to serious game theory does exist. They both play a significant role in teaching and learning. Lester et al. [36] described the design issues and the empirical finding of motivation in narrative-centered learning environments and found a strong connection between narrative and educational games while claiming that a narrative-centered learning environment is a promising approach for fostering positive learning gains, as well as for promoting student's motivation. In that respect, Padilla et al. [37] come to agree that narrative elements and ludic tasks are unquestionably affecting learner's motivation, interest, and immersion.

### StoryTec

For that, storyTec is another serious game platform implemented by the Digital Storytelling group, introducing an authoring environment for the creation of interactive

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multimedia games. It facilitates a structured collaboration between a different group of people (game designers, domain experts, technicians, and pedagogics) to produce educational content, which is adapted to the gameplay [38], [39]. Following the same philosophy, as storyTec, which is based on the collaboration between different groups of people, other Open Authorable Frameworks [40], [41] have been designed to add a more educational value to games by codifying learning theories, learning styles and pedagogical methods to adjust gameplay according to the specific target group of players.

### **Emergo project**

Emergo project [42], [43] released a scenario based platform with the capability of allowing a variety of roles in the game. More precisely, the system can accommodate administrators, who manage the platform in general, teachers, who create or edit games in a user-friendly environment using common reusable and adaptable components, and students who play the games. Last but not least, programmers are also engaged to provide proper extensions when it is needed.

### **Dynamus**

Serious games for cultural heritage are lately used to enhance visitor's experience through virtual reality which is a fast-evolving topic enticing many tourists [44]. Visual representation of text and 3D objects is now facilitated by the robust game engines. DynaMus is a web-based platform which exploited this technology to deliver a fully dynamic interactive virtual environment for the composition of virtual museums, which adds educational value to the users of the platform. The latter communicates with open web-based repositories, Google images, and Europeana, through JSON data-interchange format for achieving interoperability. More efforts are currently made to include Artificial Intelligence (AI) concept in the platform to provide personalized touring experience [45].

### **GOALS**

A learning system considering user's profiling, called GOALS, an acronym for Generator of Adaptive Learning Scenarios is introduced in [46]. Its principle is to adapt the learning experience according to the physical and cognitive abilities, as well as competencies and skills of the user. Its design consists of three layers representing knowledge about concepts involved in learning domain, pedagogical and serious game resources. All the above along with user profiling information interact with each other to produce adaptive learning scenarios, which will be used for inputs in serious games.

### **FitForAll**



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In the context of games for sports and health, FitForAll (FFA) [47] is a web-based platform containing games specifically designed for the promotion of physical activity of elderly people. The FFA exergaming platform is based on a multilayer architecture and utilizes the Controller Application Communication (CAC) framework, which allows the integration of diverse controllers such as Wii remote and balance board. This is the hardware layer which gathers all the information about user's movements and transmits the data to multiple software components [48]. The game list type is limited and compliant with the guidelines and recommendations for exergaming designs for elderly. Additionally, the logic of the games is event-based triggered providing real-time communication in order to adapt gameplay according to user profiling, goals achieved, etc.

### **webFitForAll**

The positive outcomes of using FitForAll lead the same research team to release a new version of the platform, namely webFitForAll (wFFA) [49]. The updated release was based on the advent of new technologies such as HTML5, websockets and Javascript libraries for eliminating restrictions in platforms compatibility, in contradiction with the previous version which was built on on.NET framework and Microsoft XNA Game Studio, allowing its deployment only in Windows PCs. wFFA provides a unified serious games web-platform supporting agile development since it uses web services to keep the framework light weighted and facilitates the collaboration with game developers.

## **2.4 Gamification enabling software**

In the context of gamification, the real challenge is how to embed persuasive techniques and game mechanics in education to reduce negative behaviors and increase positive emotion regarding learning.

A relevant case can be illustrated in [50], where a programming course, called JFDI Academy was created with applications of such techniques. These involved live feedback (auto grading-system), resulted in an active discussion of the assignments and experienced points, simulating the levels and competition characteristics of a game. Moreover, the course provided a storyline using "missions" as assignments and other multimedia techniques to enrich the content.

Class Dojo is as classroom management web 2.0 tool for behavior modification used to give learners positive as well as negative reinforcement based on the behaviorism theory [51]. The system exploits a set of proper game mechanics listed in [52] to encourage classroom participation and school values.

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Another gamification framework is presented in [53], which collaborates with a pre-existing social learning environment. It focuses on assisting teachers to integrate game elements in learning activities that are validated in real scenarios. Still, there is no empirical proof of the effectiveness of this platform, but it is worth noting that it uses personalized activities according to profiles for improving student's motivation and learning outcomes.

### xAPI

Currently, research is interested in analyzing player's interaction with educational content in order to improve the learning process. This can be applied by taking advantage of the serious game analytics. However, the lack of a standard format upon which educational games should agree for representing player's interaction still remains challenging. To that matter, a review was conducted [54] to collect serious in-game interactions and propose a model containing the most commonly tracked interplays using xAPI specification. The heart of the latter is the Learning Record Store (LRS), which is a storage area for recorded learning experiences. Learning events are stored and retrieved in the xAPI format, making LRS interchangeable [54], [55]. In the past, SCORM was used for that purpose. Its limitation, though, lies in its design goal to capture only results and its indissolubly link to conventional LMS [54].

## **2.5 Requirements, Gaps, Limitations and Unique Assets**

Serious game area is offering high potentials in learning. However, designing such a game is not an easy task, requiring an expertise from a variety of fields such as game and software developers, educators, psychologists, etc. [6], [32]. B. Kim et al. [56] advocate: "*The more entertaining a game is, the less effective it is as a learning tool*" and vice versa while adding that bridging the gap between game and educational design is proved to be a challenging job.

Consequently, educational games should consider two inversely proportional variables, fun and educational efficiency. Most educational platforms mentioned above adopt certain mechanisms such as the virtual representation of objects accompanied by text [45] story graphs [38] and storylines [30], [31] to illustrate educational content. In the view of learning theories and styles, though, the platforms are restricted to the models that the game itself as type provides due to the lack of design flexibility. Thus, the majority of platforms [28], [30], [31], as shown in **Table 3**, inherit their natural constructivism concept, without deepening the fundamentals of the theory. In the case of Storytec [39], pedagogues are capable of defining the educational design of the game, but they also have to repeat this

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process for every single one they create. ARLearn [33], on the other hand, is based on the Kolb's learning cycle, where players acquire knowledge by actively participating in frameworks and social context with a certain social engagement structure.

A major problem that appears when it comes to adoption of serious games is the engagement factor of teachers. Although learners are more willing to learn through gaming, teachers seem to have a skeptical view. The findings from a review in [57] indicated that a significant percentage of teachers hesitate to use such games in classrooms mainly due to the lack of personal experience, time, technical problems and adverse effects of gaming. Yet, the majority of them seem to be willing to adopt serious games as complementary or rewarding material, while they actively believe that learning games will play a crucial role in education in the future. As an outcome of the literature, all serious games platforms, other than [47], [49] provide authoring environments, allowing teachers and instructors to become the tailor of their own games. Despite that, these platforms fail to enable communication and collaboration between teachers and game developers in order to embody and enrich learning objects and goals in games. As a result, teachers have a limited repository of game objects at their disposal for the composition of games, while they are restricted to apply specific educational theories relying on the platforms' design. Concurrently teachers assessment is vital regarding evaluation [4]. Systems like [28], [30], [38] are limited to display game results, while others [31], [47], [49] provide a greater range of results and analytics assisting teachers to better evaluation and enabling real-time observation [33].

**Table 3** below confirms that each one of the platform is designed especially for its own needs and it is unable to provide guidance for the development of a wide range of serious games. Besides, no such well-developed framework exists that can be versatile to the learning theories and pedagogies in respect to the user learning profile, independent to the game creation.

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Table 3: Comparison of serious games platforms' features

Platform Feature	UniGame	eAdventure	uAdventure	ARLearn	StoryTec	Emergo	Dynamus	GOALS	FFA	wFFA
Supported Roles	Teacher Player Trainer	Storywriter Programmer Artist Instructor	Storywriter Programmer Artist Instructor	Teacher Player	Game designers Domain experts Technicians Pedagogics	Tutor Student Administrator Developer Run manager	Visitor Exhibitor- administrator	Serious game designer Learner Domain expert	Player Game developer Healthcare professional	Player Game developer Healthcare professional
Educational Theories	Constructivism	Constructivism Scaffolded learning	Constructivism Scaffolded learning	Situated learning Immersive learning Kolb's learning cycle	Defined by pedagogics	No	Task-based	Domain concepts defined by learner profile and learning objectives	No	No
Environment	Web	Desktop	Desktop	Web	Desktop	Desktop	Web	Desktop	Web	Web
Game type	Social	Point-and-click	Point-and-click	Simulation Role-playing			Simulation		Exergaming Simulation	Exergaming Simulation
Player customization	No	No	Yes	No	Yes	No	No	Yes	Yes	Yes
Player Evaluation	Game results	Game results	Big data and game analytics	Real time game observation	Game results	Student's actions	No	System evaluation to select scenario based on learner profile	Data layer for evaluation In game evaluation	Analytic data records In game evaluation
LMS compatibility	No	Yes	Yes	No	No	No	No	No	No	No
Cross-platform	No	No	Yes	Yes	Yes	No	Yes	No	No	Yes
Active	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Special Traits	Collaboration Teamwork Forums Video conferencing		xAPI enabled	Virtual reality experience		Adjusted player environment according to emotions (future)	AI for personalized experience (future)		Use of wii remote and balance board	CAC HTML5

# Chapter 3: IOLAOS Platform

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As stated in the introduction, educational video games seem to have a beneficial effect on the learning procedure, but there are still few well-developed frameworks that indicate adequate standards and guidelines for empirical proofs. During our state of the art research in the field of serious games, we observed that the majority of the platforms assign the game development to teachers, providing them with user-friendly authoring tools. We strongly advocate though that the outcome of such games is insufficient to involve learning theories and pedagogic methods, which are essential for the learning process, as well as to produce attractive games that prolong engagement factor and increase motivation.

Therefore, we proceeded to the design and implementation of the IOLAOS platform that enables the accommodation and collaboration of different groups of people, each one adhered to its own user role and specialty in order to generate third-party serious games, customized and tailored according to player's user and learning profile. More broadly, the platform is focused on establishing the operational model for the codification of learning theories, pedagogic methodologies and special needs that will be later attached to learners, providing them with unique effective learning experiences through games.

Our approach is not only concerned with serious games, but instead, it seeks to provide a guided learning environment, both for teachers and learners, allowing the existence and evaluation of inclusive learning sessions. Consequently, the objective of the platform is to propose a generic online free technological framework that will contribute to the enhancement of the effectiveness of serious games in education.

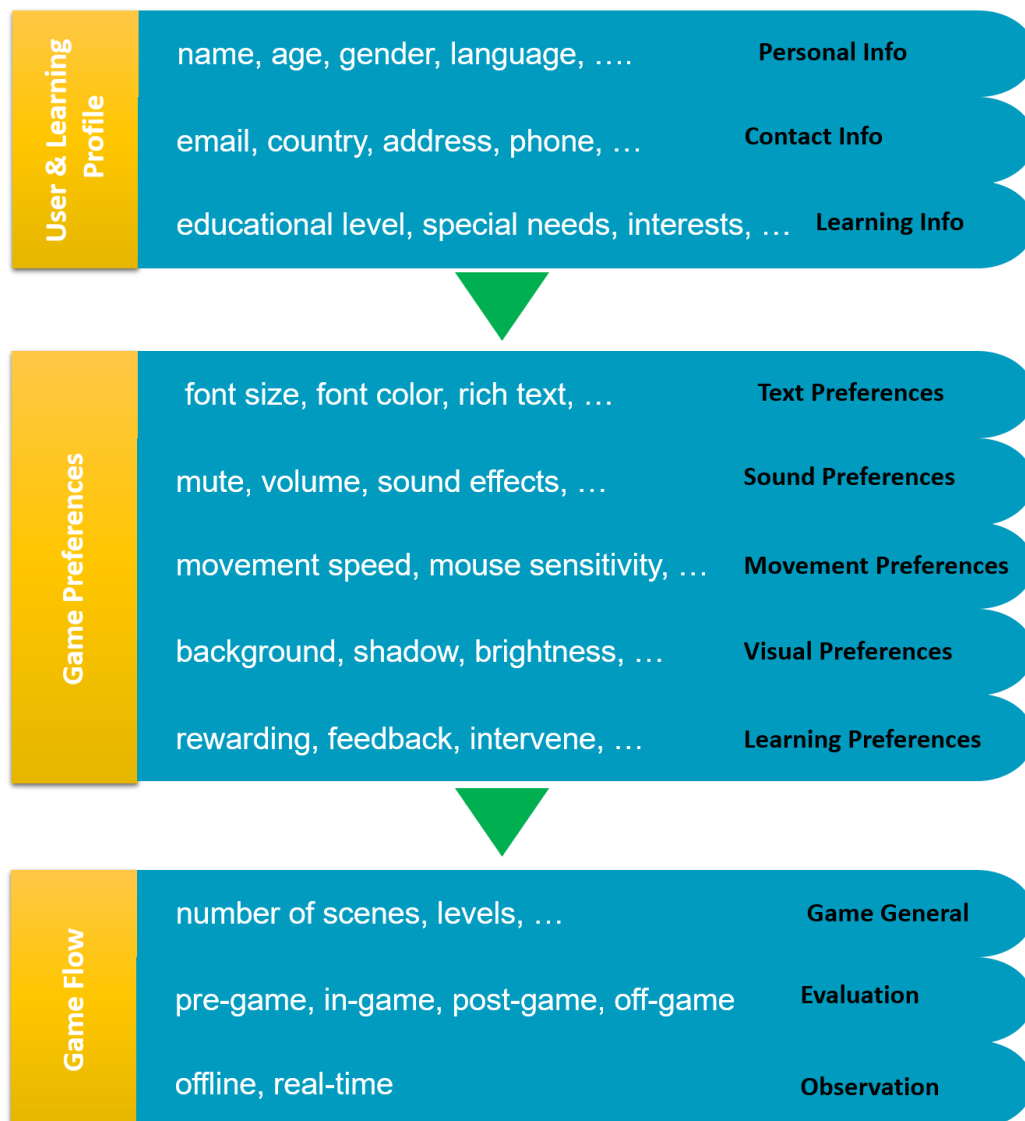
### **3.1 Architecture**

IOLAOS is based on a lightweight, stateless, web-friendly architecture and features predictable and minimal resource consumption. It includes tools and 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.

Intended user roles of the platform are the administrator, educational experts, teachers, game developers, learners and game testers, where all of them are an integral part of the system and play a crucial role for defining the Abstract Educational Game Model Protocol (AEGMP). The latter is based on the common space (learning techniques) between psychology, pedagogy and games, such as theories of Gardner and Gagne. It includes

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structured data about the flow of the game in means of material design, i.e., which text, sound, visual, movement, and learning preferences are allowed for a specific type of learning groups. This information is used as a guide to deliver game prototypes that are following specific educational theories and pedagogic methods. As illustrated in **Figure 2**, the user & learning profile is used to determine the game preference package that will be applied to the game resulting in unique game experience. The game evaluation has two-folded significance; one is that games can be reviewed and rated in order to help teachers to select appropriate serious games for their own needs, while the other one is that game session evaluation is achieved throughout the game, using feedback from in game produced analytics.



*Figure 2: AEGMP structure*

The general architecture of IOLAOS is comprised of several main modules that are related with each other, while concurrently they are independent in the sense that the software

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architecture has been developed to support a flexible and reconfigurable modular system. This means that system extensions can easily be imported without affecting the platform's functionality.

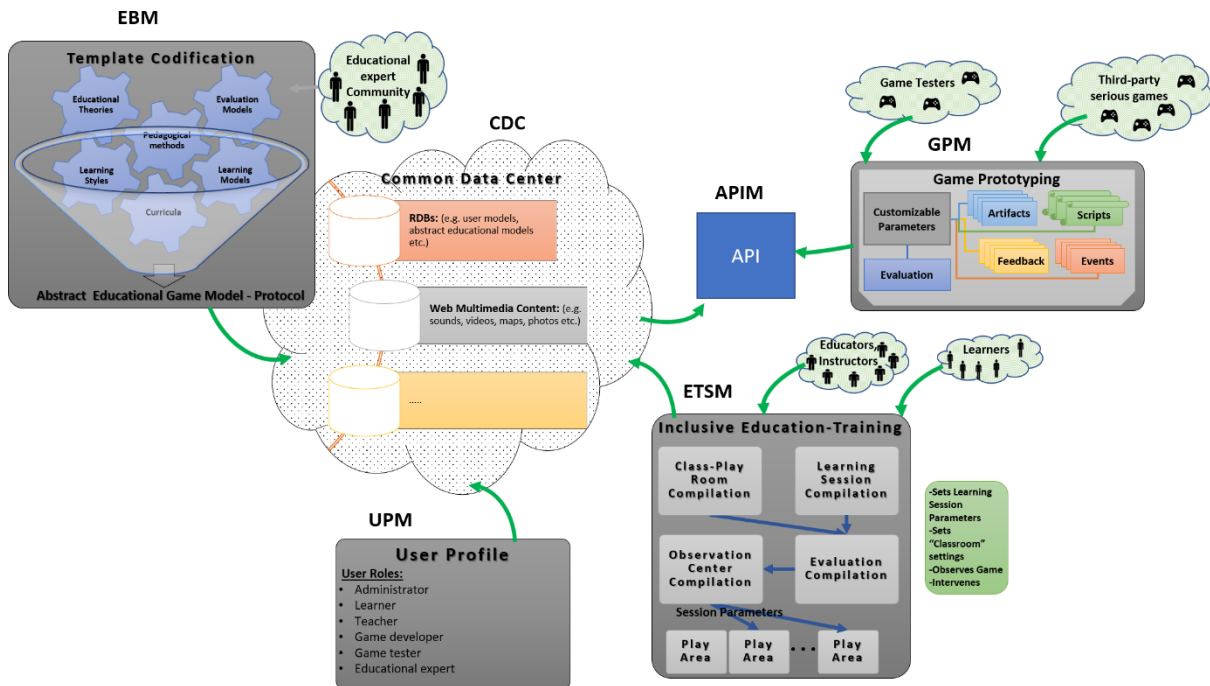


Figure 3: IOLAOS Modular Architecture

### 3.2 Component Design

The component-based architectural style of IOLAOS, as presented in **Figure 3** is focused on the decomposition of the design into six individual functional components that expose well-structured communication interfaces. The core module of the platform is the Common Data Center (CDC), which is surrounded by the rest of the modules, namely, Educational Base Module (EBM), User Profile Module (UPM), Education Training Session Module (ETSM), API Module (APIM) and Game Prototyping Module (GPM).

#### 3.2.1 Common Data Center (CDC)

The fundamental module of the platform is the CDC, which is a repository that houses all different types of data needed in the platform. The key role of this component is to deploy and manage relational (RDB) non-relational (DB) or Object Oriented (OO) databases, structured data files such as JSON, XML or ASCII, as well as multimedia content such as images, videos, etc. for the distribution of the data within the system.

The database modeling utilizes MySQL, which is one of the most widely used open-source database management systems. The entity-relationship diagram, i.e. the database schema is represented in **Figure 4**, and has been created using the design tool Visual



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Paradigm. As it is apparent, there are multiple types of relationships in our relational database, which are constructed in a way to support ACID transactions (Atomicity, Consistency, Isolation, and Durability). Moreover, proper foreign key constraints have been applied to each table of the database to enforce referential integrity at the database level.

For instance, when a user assigned with the learner role is deleted, the corresponding field of the table *classroom\_user* is also destroyed so that it is not displayed in the classroom layout, preventing undefined variable errors. Additionally, when a user erases all his address information, the *address\_id* field of the *user* table is set to null.

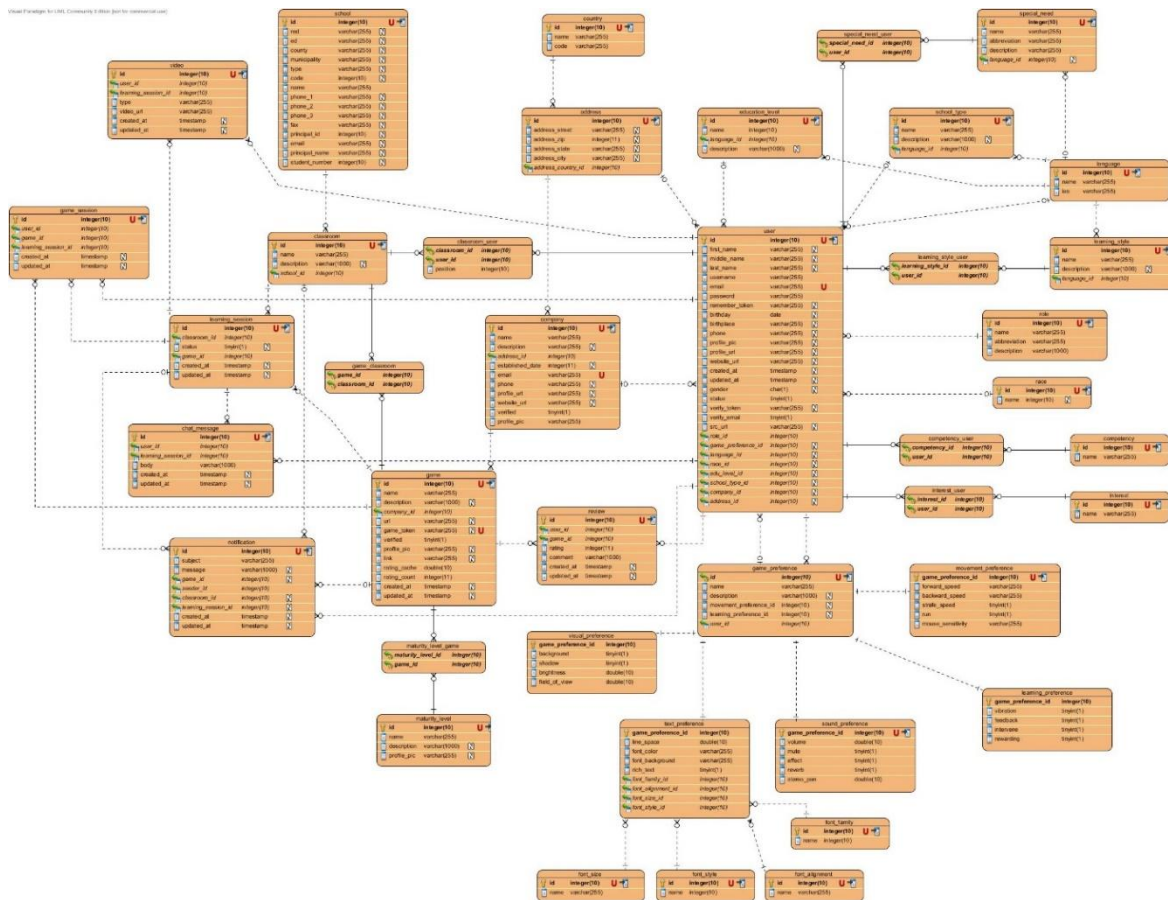


Figure 4: IOLAOS's CDC - Relational Database schema

### 3.2.2 Educational Base Module (EBM)

The EBM enables educational experts such as psychologists and pedagogues to digitalize either already existing or new game preferences based on learning theories, methods and special needs in order to be used into the AEGMP for customizing gameplay. The GUI of this module is constructed in the common space between pedagogy and games to explicitly map known and accepted learning and instructional design theories and models, such as Behaviorist approach, Gagne's and Gardner's theory, etc., to the design of serious games.

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Hence, educational experts can fully describe game preferences targeting specific groups of players, according to their learning profile, which are stored in our platform as compact autonomous entities so that they can be easily used and reused by game developers to customize specific parameters of their games. The addition of new features, as well as the modification of already existing ones is of significant importance for the future deployment of IOLAOS. To that end, the AEGMP is designed in such a way to easily support extensions and configurations.

The following use case diagram represents the capabilities of a user with the role “Educational expert” when interacting with the EBM. The Game Preference Controller is responsible for presenting the game preference list, while it also checks the validity of data before it is stored in database, as well as whether the user is authorized to proceed to certain actions such as delete and edit game preferences.

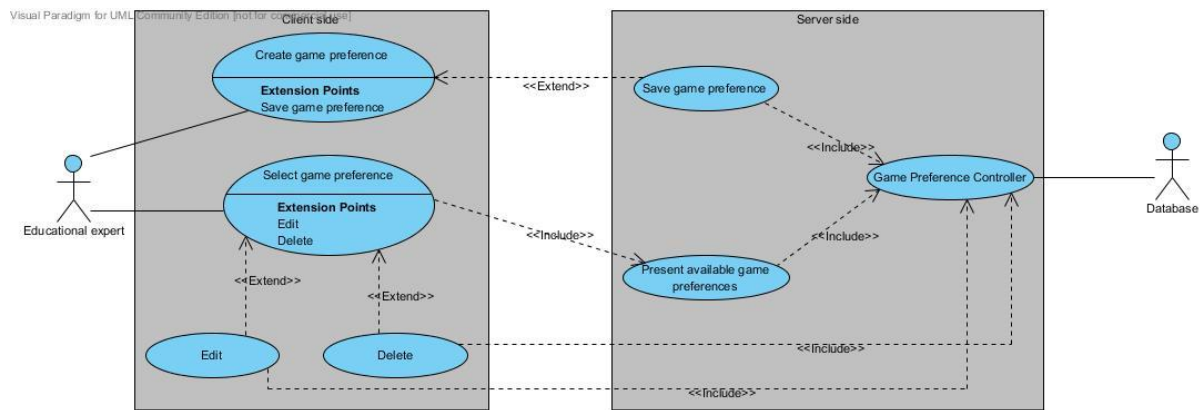


Figure 5: Role “Educational Expert” Use Case Diagram

### 3.2.3 User Profile Module (UPM)

The UPM allows users to share information about themselves with the use of registration and profile forms. The content information of the user profile depends on the roles that the platform supports. All user roles of the system are restricted to personal and contact information, while users assigned with the learner role can import additional information to provide a complete picture of their learning preferences for better learning profile evaluation.

The UPM is critical to our system since it is used to manage user roles and permissions, while at the same time contributes to the main goal of IOLAOS, which is to deliver personalized and customized game experiences. Furthermore, the user profile can be enriched with performance assessment and feedbacks that are attached to the learner while playing serious games. As a result, building a profile of a typical learner enables adaptivity

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and personalization to meet individual needs in numerous aspects, by correlating profiles with the appropriate game preferences.

However, the UPM is still in its “infancy” i.e. very early development stage, meaning that extensions and modifications are required to depict a complete user profile. To that end, the collaboration of educational experts and teachers is essential to propose new user profile features. All features that will be acquired from requirements analysis performed with the educational experts will be imported to the system with no effort due to the system’s flexible architecture.

The procedure of creating a user profile in our system is illustrated in the following sequence diagram, which differentiates according to the user role. Learners can automatically register to the system, while the other user roles require IOLAOS administrator verification to proceed to registration.

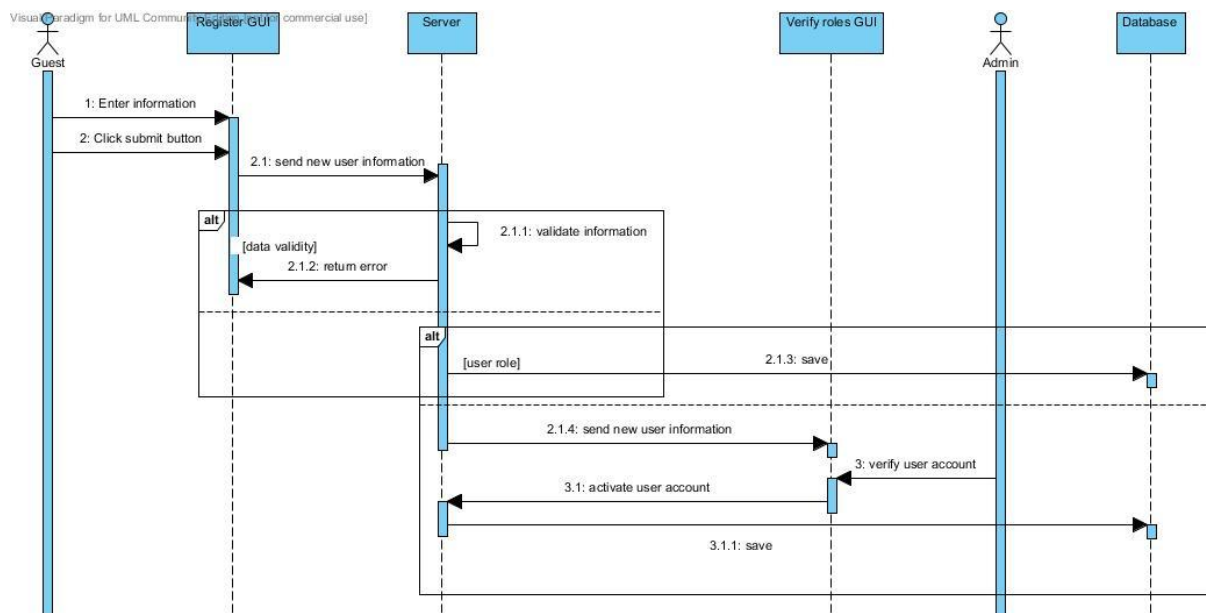


Figure 6: User Registration Sequence Diagram

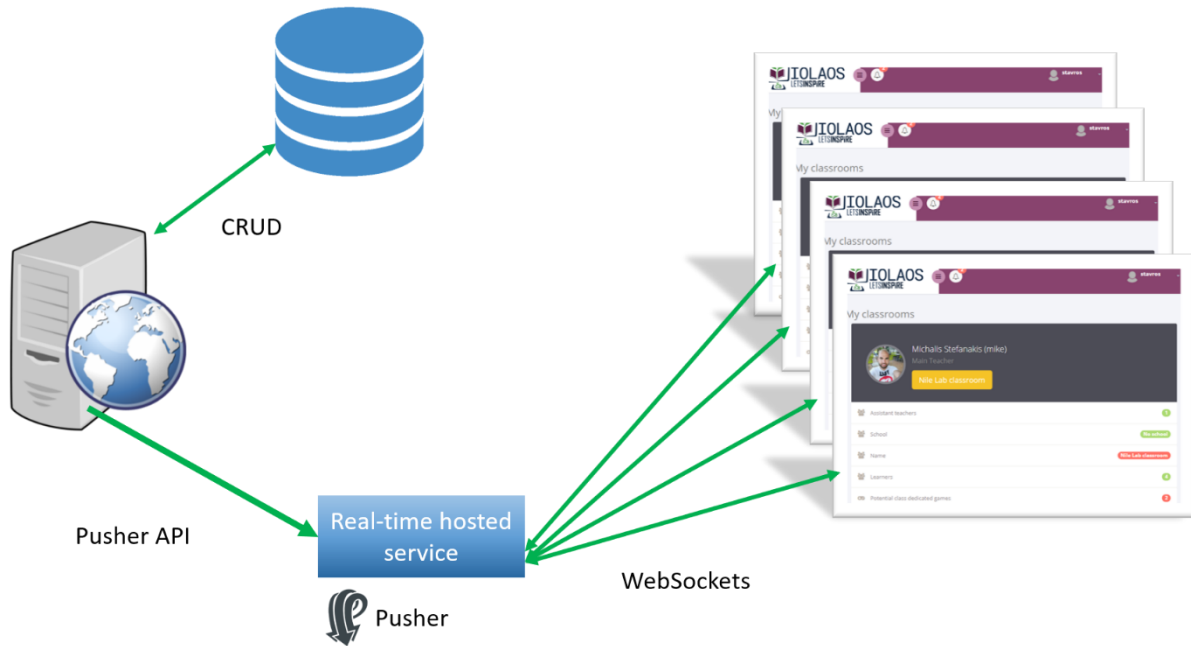
### 3.2.4 Education Training Session Module (ETSM)

Within this module, our platform provides the teacher with the ability to enact classroom simulations. Firstly, the teacher creates a classroom, selecting the learners and assistant teachers and then sends them invitations to participate in the learning session, which includes the play of an educational game. During the learning session, educators are fully aware of who is present at the session and can interact with their students, either using the chat application or by setting up a video conference.

For the chat application and the participant status (online/offline), our platform provides a broadcast event system, which is utilized over a WebSocket connection. The latter

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is achieved through Pusher, which is a hosted service and acts as a real-time intermediate layer between server and client. Pusher is responsible for securing persistent connections to the clients over WebSockets, in order to instantly transmit data to them when new events are detected in the server side. For instance, when a participant sends a chat message, an instance of it is created in the server and stored in the database. Immediately, the server broadcasts the event to the pusher, which in return distributes it to all the connected browsers over WebSockets (**Figure 7**).



*Figure 7: Real-time events with Pusher*

The inclusive learning environment of the platform also supports online video conference, as mentioned above, enabling educators to evaluate learners' performance through live observation and intervene when it is necessary. Camera and screen records are also available for future use, offering better guidelines either for the teacher (monitor progress and assign different game preferences to the players), or for the learners (watch their progress). This service is implemented by taking advantage of HTML5 and WebRTC technologies and its architecture is described in sub-chapter 4.1.6 WebRTC.

Nonetheless, WebRTC alone is not enough to implement a many-to-many video conference. For this reason, we needed a middle server and a signaling infrastructure, like PubNub in order to establish direct connection and coordinate communication and metadata between peers. In other words, the centralized media server takes all the streams, mixes it all together and sends it back to clients (see **Figure 17**).

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### 3.2.5 API Module (APIM)

This module is considered as a concrete way of establishing communication between our system and third-party serious games. The main component of this module is the REST API, which stands for the Representational State Transfer Application Programming Interface. The latter allows one piece of software to contact with another, by defining a set of functions that are used to perform requests and receive responses via HTTP protocols. In fact, it is a web service that is mainly defined by (1) an Uniform Resource Identifier (URI), which is used to address resources, like <http://seriousgame.teicrete.gr/api/countries>, (2) the media type of data, referring to the interpretation of data to the client; in our case we use JSON format so that all modern programming languages can translate the responses and (3) HTTP methods that correspond to create, retrieve, update, and delete (CRUD) operations as shown in **Table 4**.

*Table 4: CRUD to HTTP method mapping*

Method	CRUD	Description
GET	Retrieve	Retrieves/Reads a representation
POST	Create	Creates a new resource
PUT	Update	Updates an existing resource
DELETE	Delete	Deletes a resource

API serves as a middle-layer between the CDC and third-party applications. Due to the usage of HTTP, our system can interact through this module with any software regardless the programming language used, which is vital for IOLAOS in order to establish collaboration with all kinds of games. The purpose of the APIM is to allow third-party games to retrieve information about the player's game preference during the login stage in order to adapt the game play accordingly.

The procedure is presented in **Figure 8**, where a player enters the game using IOLAOS credentials and the login is achieved through the REST API and our implemented authentication system. The response is a JSON containing player's information, which can be exploited by the game. Subsequently, the game makes another API GET call, with the unique *game\_token* and the *user\_id* as parameters, requesting the user's game preference. The system ensures that the user still exists, as well as that the *game\_token* is valid. Afterwards, following the MVC pattern (see subchapter 4.1.1), a JSON including the game preferences for the player is fetched and sent to the client (game) through the REST API.

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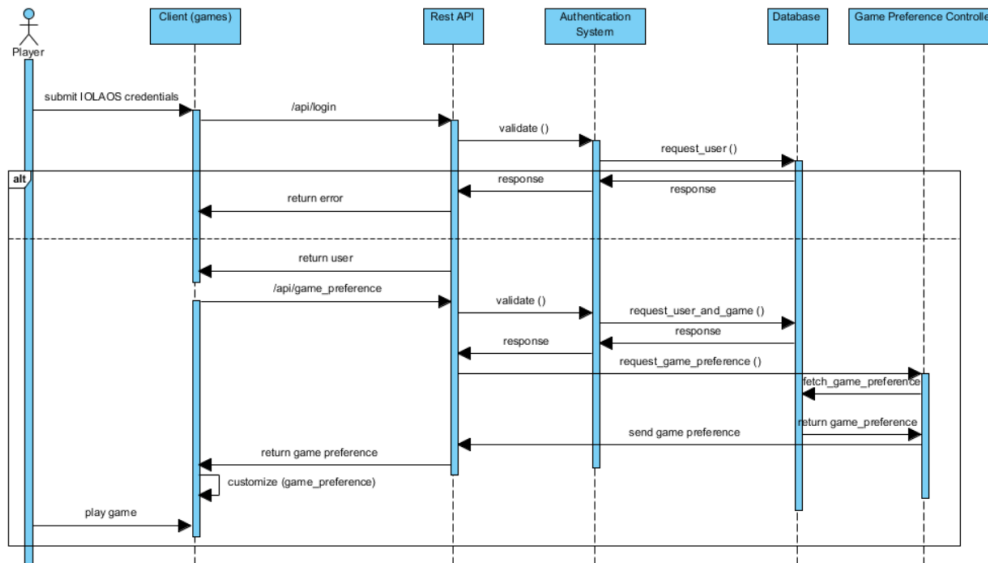


Figure 8: REST API login and game customization procedure

### 3.2.6 Game Prototyping Module (GPM)

The last component of IOLAOS architecture is the GPM, which refers to all the necessary additional features that third-party games should adopt in order to be under the umbrella of IOLAOS platform, i.e. the IOLAOS AEGMP. The first step is to include tools and services to establish a proper connection with the REST API of our system. As mentioned above, this kind of communication is possible and independent of game engines and programming languages used for the creation of the game. Furthermore, scripts and functions are required for personalizing the game prototypes to fit educational and player needs.

To this end, custom and adaptable design is necessary for the development of the game, where the response of standard HTTP requests results in the manipulation of various game parameters. As shown in **Figure 9**, the game should be designed to be flexible to accept player's game preferences as input and modify certain game elements.

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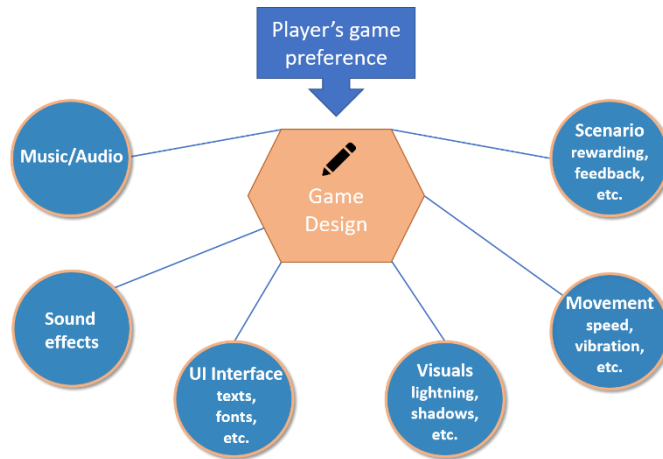


Figure 9: Game design customization

This module also involves the “Game tester” roles, in the sense that testers are playing the games in order to check and verify that the game complies with the IOLAOS protocol and define the maturity level that the game resides. When the verification and validation of the game has been completed, a report is generated according to which the platform’s administrator provide the game with IOLAOS privileges. The latter refers to the ability of third-party games to satisfy some key principles required for becoming part of IOLAOS community. All games should at least acquire the IOLAOS basic maturity level, which is related to their ability to apply customizations at certain game elements’ parameters. **Figure 10** illustrates the procedure of how a third-party game is evaluated to become part of IOLAOS platform.

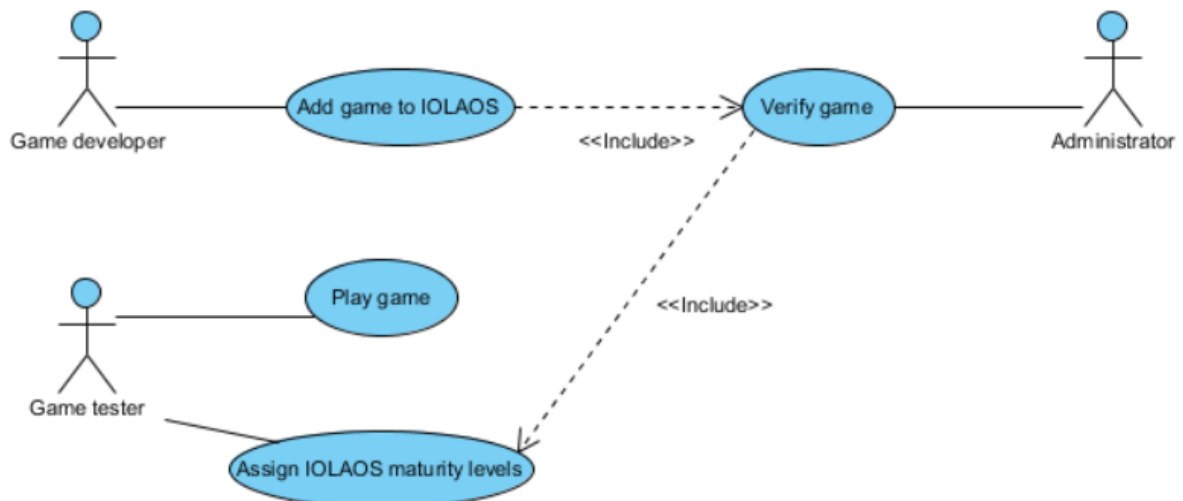


Figure 10: Procedure for game Approval

# Chapter 4: System Implementation

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#### 4.1.4 Vuejs

#### 4.1.5 HTML5

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### 4.2 Implemented IOLAOS Components

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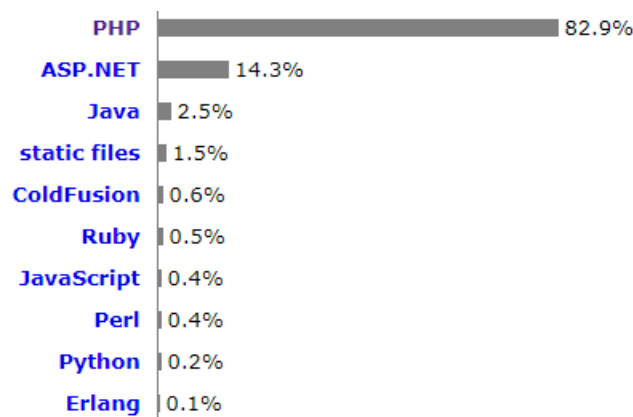
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## 4.1 Technologies used

IOLAOS is a platform geared toward continuous deployment, interoperability, maintenance, and long-term operability and performance. To achieve this, we leverage a wide range of existing open source technologies, which guarantee platform independence in the context that can be easily extended or replaced with the advent of new better technologies. This chapter presents a brief description of the main technologies used for the implementation of this platform, analyzes the implemented system components as well as provides an overview of the platform's user roles.

### 4.1.1 Laravel Framework

The server-side-scripting of IOLAOS is written in PHP. The latter is an acronym for Hypertext Preprocessor and it is a server-side programming language mainly used and tailored for dynamic web development. As illustrated in **Figure 11** [58], PHP is the most widely used language on the web, long prevailing among others.



*Figure 11: Percentage usage of server-side programming languages for websites [58]*

IOLAOS though, is an open adaptable authorable framework, meaning that coding in straight PHP would cause a series of problems such as spaghetti code, redundant work, lack of maintenance and abstraction, security leaks, difficulties in teamwork collaboration etc. [59, p. 2]. Consequently, it was vital to our purposes to use a PHP framework, as a layer upon PHP, which covers architectural patterns and principles to overcome such difficulties. Based on [60]–[62] and influenced by **Figure 12** [63] we concluded to use the Laravel framework for the needs of our project.

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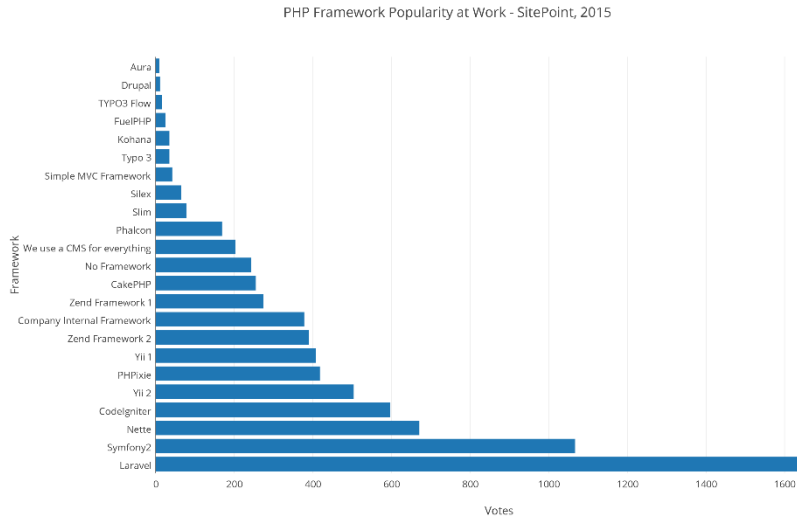


Figure 12: PHP Framework popularity in 2015 [63]

Laravel is a free open source PHP web application framework, following the Model View Controller (MVC) [59, pp. 8–10] design pattern. The latter is used to provide a solid structure in web applications and it is comprised of three dependent structural elements as it is indicated by its name. The Model in Laravel is a class related to a database table, responsible for accepting requests and fetching information from database in order to transmit it back to the Controller. The View corresponds to the representation of the response of the Controller in a proper format, like HTML. In Laravel, Views are built using the blade engine, which is a lightweight template language for creating hierarchical layouts accommodating dynamic content. The last component is the Controller which is the bridge between Model and View. When a request is sent to the server the Controller receives the request, process the data according to the type of the request (GET, POST, PUT, DELETE), handles the server-side logic, communicates with the Model and sends the response back to the View. MVC in terms of how it works in framework is similar to the structure and flow of a website as shown in **Figure 13**.

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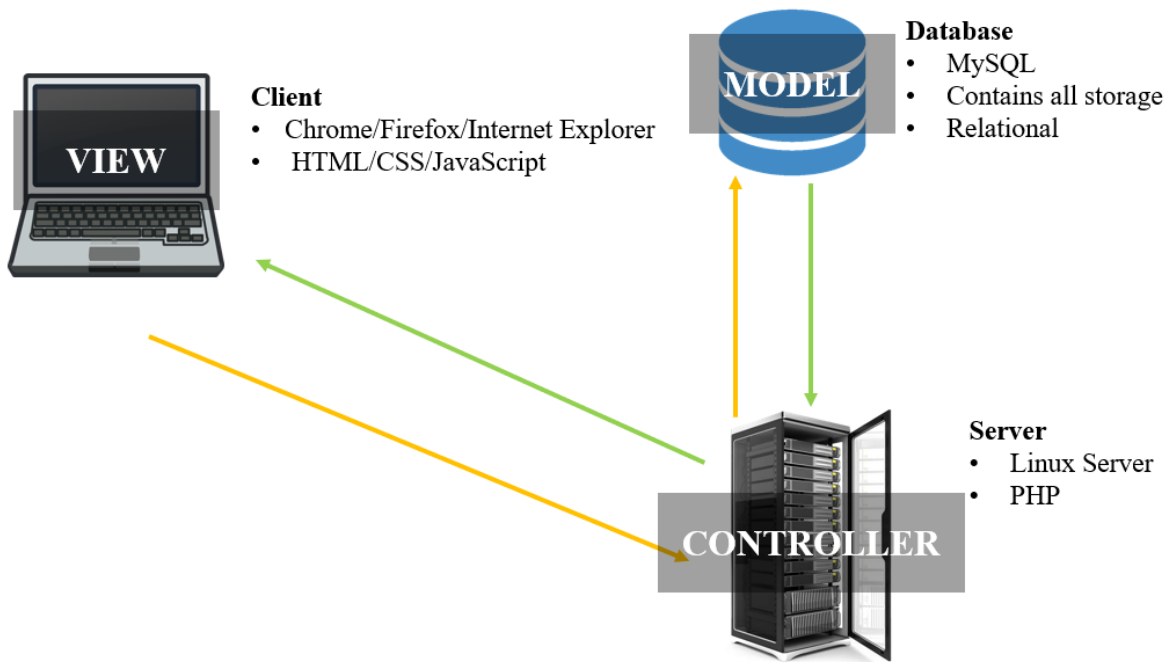


Figure 13: MVC functionality

Laravel also includes the Eloquent Object Relational Mapper (ORM) [59, Ch. 4], which provides internal methods for applying relationships between database tables through Models. Eloquent is equipped with a query builder, which is much cleaner and faster than writing raw SQL queries. In our case, the eloquent model enabled our platform to use the four basic operations (CRUD) without writing complicated queries due to our relational database concept resulting in better performance. **Figure 14** and **Figure 15** illustrate how easy it is to set up relationships between Models and exploit them for database interaction.

```
class User extends Model
{
    public function role(){
        return $this->belongsTo('App\Role');
    }
}

class Role extends Model
{
    public function user(){
        return $this->hasMany('App\User');
    }
}
```

Figure 14: One-to-many Eloquent Relationship

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```
class User extends Model
{
    public function classroom(){
        return $this->belongsToMany('App\Classroom', 'class_user', 'user_id', 'class_id')->withPivot('position');
    }
}

class Classroom extends Model
{
    public function classroom(){
        return $this->belongsToMany('App\Classroom', 'class_user', 'user_id', 'class_id')->withPivot('position');
    }
}
```

*Figure 15: Many-to-many Eloquent Relationship*

Another possibility that comes with the Laravel package is the built-in authentication [59, Ch. 7], which was used with a few modifications to accommodate the user roles of our system, enabling login and register functionalities, while concurrently ensuring protection from common attacks. Furthermore, this kind of routing facilitates the adoption of a REST API, which is critical in IOLAOS platform for the communication with the third-party serious games. In such APIs, a URL and a http method are required to send and receive responds to/from server. **Table 5** presents examples of how a REST API is utilized in our system. This in combination with the middleware, which is a mechanism for filtering HTTP requests, provided by Laravel, is a powerful asset to our platform. REST API and middleware permit us to manipulate and control who is allowed to perform certain actions. For instance, the game list of our platform can be requested and seen by anyone (authenticated or not), while the deletion of a user can be done by the user itself when authenticated in the platform, or by the administrator of the platform.

Our platform exploited a lot of conveniences that Laravel provides. Broadcast Service Provider is such a convenience, which transmits events over a WebSocket connection to provide IOLAOS with real-time, live-updating Graphical User Interface (GUI) [64]. Using this provider, we implemented the notification system, as well as the learning session chat messaging. Finally, Laravel includes artisan which is a command line tool used for multiple tasks such as generating controllers, models, and run database migrations.

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Table 5: Rest API IOLAOS's service examples

Method	Route	Description
GET	/ game_list	Overview game list page
GET	/games/:id	Overview specific game page
GET	/api/education_levels	Returns a collection of education levels in JSON format
GET	/api/game_preference/:user_id	Returns game preference for specific user
POST	/api/register	Creates a user if data is correct
DELETE	/user/:id	Deletes a user with the id specified

### 4.1.2 Bootstrap

Bootstrap is a free and open-source library for building responsive websites and web applications. It aims to ease the development of dynamic websites and web applications, and it contains HTML and CSS based design templates. For instance, typography, forms, buttons, navigation and other interface components can be easily created by bootstrap. Furthermore, bootstrap is the most-starred project on GitHub, with over 90K stars [65], [66].

There is a variety of reasons we used bootstrap and specifically bootstrap version 3.0.0. Firstly, it is the latest trend of designing responsive websites since it provides a great easy to use grid system. It also includes styling for most of the HTML elements and an extensive list of components. In addition, there is a package of JavaScript plugins in Bootstrap which interacts correctly with the CSS components, such as menus, dropdown lists, etc. From our technical experience with other similar frameworks such as materialize design, bootstrap was preferred due to its high compatibility with most browsers (especially old browsers) and its huge community for documentation and online support.

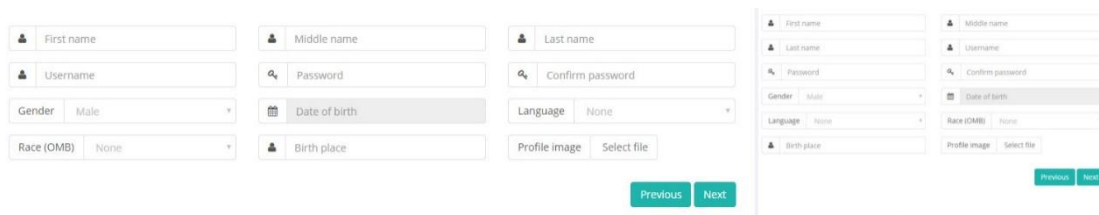


Figure 16: Responsive Grid System applied in IOLAOS

### 4.1.3 JQuery

JQuery [67] is a rich-content JavaScript library, designed to simplify scripting on the client-side of HTML and it is supported by the majority of web browsers. Its primary goal is to achieve smooth manipulation of Document Object Model (DOM), event handling as well

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as enhanced animation. It also facilitates the communication between client and server using the Asynchronous JavaScript and XML (AJAX) and including JSON parsing. In our platform JQuery was used for DOM handling, client form validation as well as for asynchronous requests to the server to create dynamic data tables.

#### **4.1.4 VueJS**

VueJS [68] is defined as a progressive JavaScript framework that focuses on building GUI. It is independent of the model or database of the applications in order to be incrementally adoptable and easily integrated into existing libraries, while concurrently it is powerful enough to create advanced single page applications. We use VueJS into the learning session view for real-time event handling. For instance, when a user enters/leaves the session, all participants are informed about its action by the online, offline icon attached to the user respectively.

#### **4.1.5 HTML5**

Hypertext Markup Language (HTML) is the language that web pages are written in. Like a computer program executes code written in Java or some other programming language, a web browser takes HTML and translates it resulting in a web page. The last major revision of HTML, version 4 was released in 1997, when most web pages had much simpler layouts consisted mainly of static images, gifs and text. Interactive elements required plugins such as sockwave or Java, while high quality streaming video or audio was a real challenge. But since then the annual internet traffic has dramatically increased. Consequently, an update to the language that is the backbone of the web is essential to include native supports that today we take for granted. To that end, HTML5 was introduced in 2014 by the World Wide Web Consortium (W3C) and became a milestone in the development of HTML.

HTML5 became a powerful platform, comprised of HTML, CSS and JavaScript APIs to provide web with rich capabilities. Its primary goal is to provide interoperability and consistent functionality across all browsers and devices [69, Ch. 22]. Another innovation is the support for media, since video and audio tags allow HTML5 supporting browsers to play common video formats natively without requiring any extra plugins. Along with other improvements such as security and privacy, ability to interact with device's hardware, HTML5 enabled Real Time Communication between browsers using audio, video or peer-to-peer data [69, Ch. 24].

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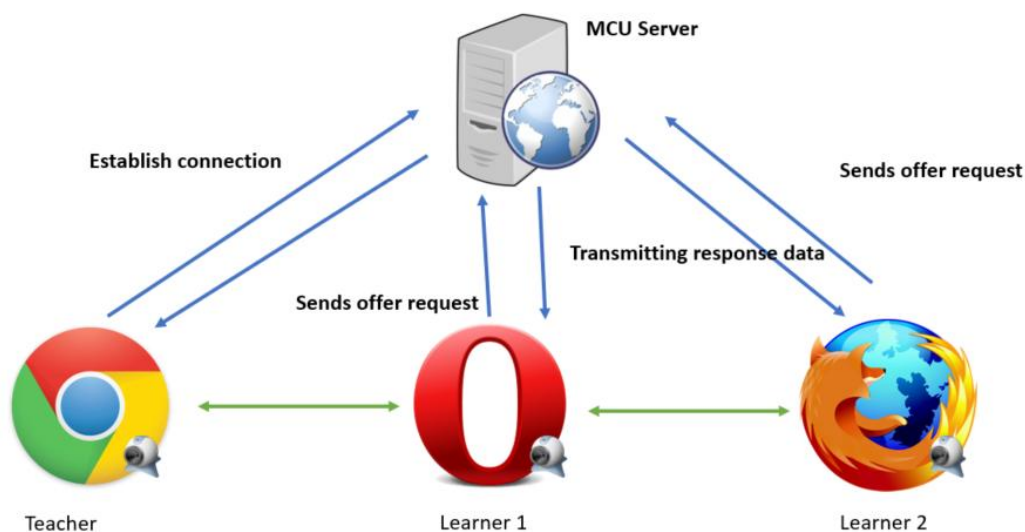
HTML5 enabled our system to request a surge of access to device hardware such as cameras and microphones through the `getUserMedia ()` API, while the canvas element was used for real-time video processing and rendering.

#### 4.1.6 WebRTC

IOLAOS platform supports video conferencing solution in the concept of virtual classrooms. Nowadays, this is applicable due to better internet connections and the increasing computation power. However, the rejection of plugins that do not provide interoperability and cross-platform compatibility is essential, while the need for standard communication protocols emerged.

Hence, the enabling technology behind that is Web Real Time Communication (WebRTC) [70], which was introduced by the W3C and the Internet Engineering Task Force (IETF). WebRTC enables human communication via voice and video in real-time through browsers, without requiring third-party plugins.

The whole process of how we used the WebRTC technology in the IOLAOS platform is illustrated in **Figure 17**. The teacher instantiates the connection and sends a request to the media server waiting for response. When a learner enters the video conference and the connection is already established, a message is sent to the server requesting the streaming of the participants. Then the server receives the offer and transmits the data to the connected users of the video session. Due to the multiple peer connection, the server is a Multiple Unit or Multipoint Conference Unit (MCU), which is used as a bridge to distribute media content to a big number of participants.



*Figure 17: Process for multi-user video conferencing*

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WebRTC consists of three main API blocks:

- The first one is the **getUserMedia**, which permits the access from browser, using JavaScript, to the hardware devices such as camera, microphone, or the screen itself for screen capturing. This API collects all the multimedia streams coming from local devices, but it does not relate to communication at all.
- **RTCPeerConnection** is the component of WebRTC that encodes and decodes media and transmits it over the network. It also deals with Network Address Translation (NAT) traversal.
- The last API is the **RTCDataChannel**, which simply allows the transfer of arbitrary data between browsers, without going through any server along the way.

Once the platform sets up a video conference communication, it also takes advantage other JavaScript libraries such as RecordRTC, making feasible the camera as well as the screen recording, which are stored on the server for further manipulation.

WebRTC approach ensures data integrity and security through HTTPS protocol. The latter is required for accessing camera, microphone or screen sharing. However, in this phase of our project we still lack an HTTPS protocol. For demonstration purposes though, we overpass the security limitations by disabling the web security of browsers.

## **4.2 Implemented IOLAOS Components**

Our previous platform design along with the database deployment and the embodiment of the framework with a variety of technologies gave birth to the innovative system environment of IOLAOS, integrating the visual representation layers with real-time consuming layer among users. To illustrate some of the concepts described above and highlight the capabilities and strengths of IOLAOS we will proceed and describe the implemented platform components. As mentioned before, IOLAOS is focused on facilitating the collaboration between different groups of people. Hence, we provide an overview of each user role of the platform, emphasizing on the workflow of each one individually.

### **User Role: "Guest"**

Apparently, a guest of IOLAOS has limited access to the platform services since its main usage is to become a member of the community claiming a role. An overview of the platform is available, informing the guest about its goal as well as provide an appealing GUI in order to entice visitors to register, by presenting all the user roles of the system along with their functionalities as shown in **Figure 18**.



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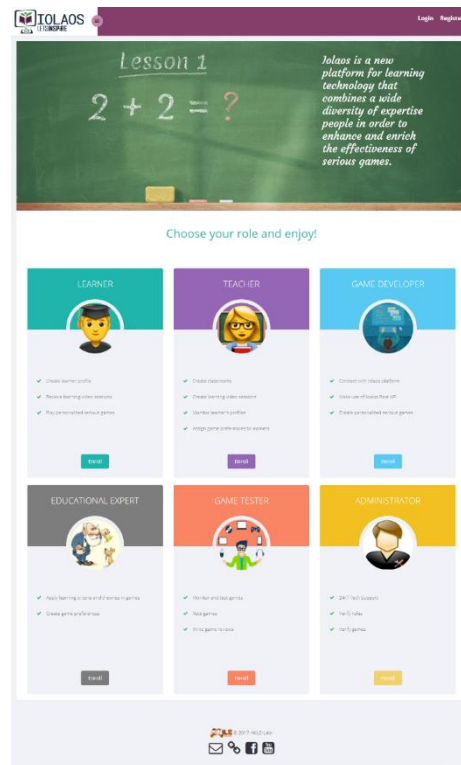


Figure 18: Homepage of IOLAOS

Furthermore, guests can browse through a list of games that are approved by IOLAOS as shown in **Figure 19**, where the latest imports of the platform are visually presented with a carousel slider, while the full game list is available below, sorted by rating.

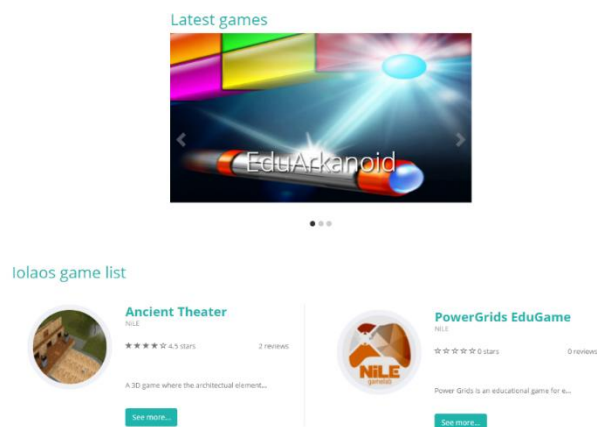
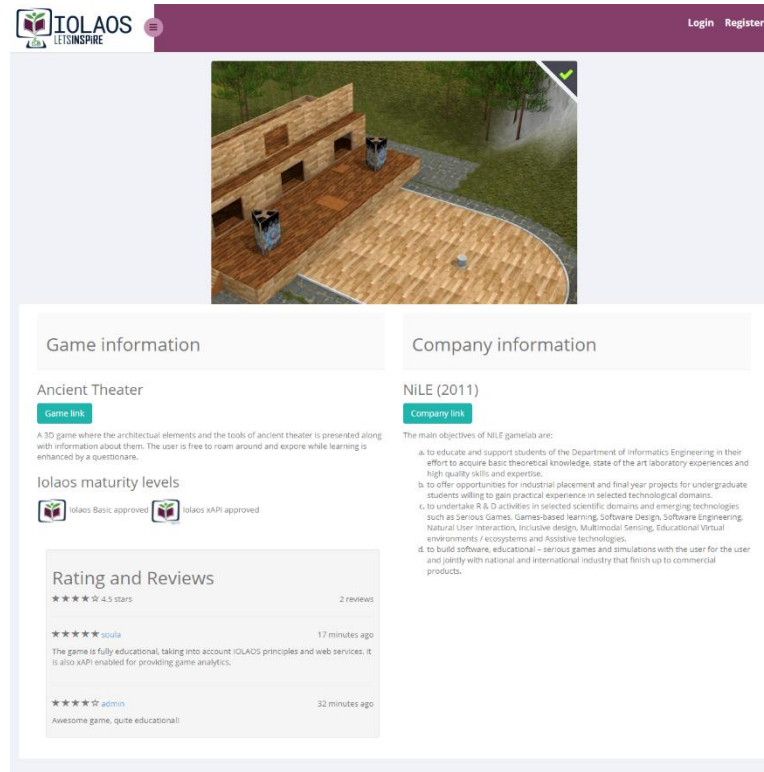


Figure 19: IOLAOS game list

More information about each game individually is provided, where other than game description, links, and company information, a rating and review section is available. Unauthenticated users, though have no permission for rating and writing reviews. IOLAOS maturity levels reveal how well the game is integrated within the platform and what principles adopts. In **Figure 20**, the game Ancient Theater is equipped with two maturity levels. The first one is the basic IOLAOS approved maturity level, which indicates that it

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exploits our system's web services in order to affect the flow of the game according to the player's preferences. The other maturity level refers to the ability of the game to apply the xAPI specification for game analytics that can be later analyzed by our platform.



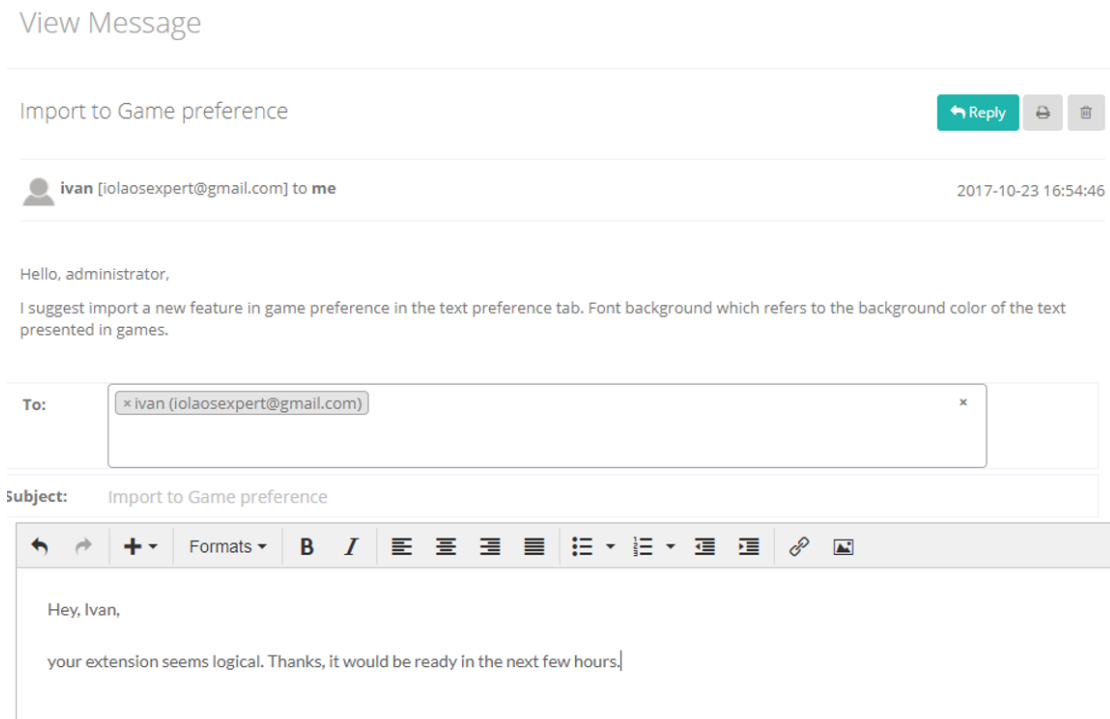
*Figure 20: IOLAOS Game Information*

To prevent unauthorized users from accessing other functionalities of the system, a Restrict Access to Page server behavior is applied, where the server redirects the user to the login page if he attempts to bypass the authentication procedure.

**User Role: “Administrator”**

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Administrator of IOLAOS fulfills a twofold role. Firstly, he is the intermediate link between the system and its user roles. He is responsible for responding to messages, providing proper instructions and technical support, as well as proceed to system



*Figure 21: IOLAOS Message Application*

modifications and extensions when it is necessary. The communication between the involved participants is achieved inside the system itself through the message application, the platform provides. For instance, an educational expert could ask the administrator to enrich the game preference options, as displayed in **Figure 21**.

The administrator is also involved in the registration process of the user roles. Direct registration for learners is applied in the platform. However, the rest of the user roles require the administrator's verification to participate in IOLAOS actively. Therefore, the administrator is accountable for checking user's registration details in order to contact them and finally decide whether to verify them or not. To that, a GUI is provided containing all the pending user requests for registration (**Figure 22**), enabling the administrator to either grant platform access with the corresponding role permissions or deny access and delete the request of the user if it is necessary.

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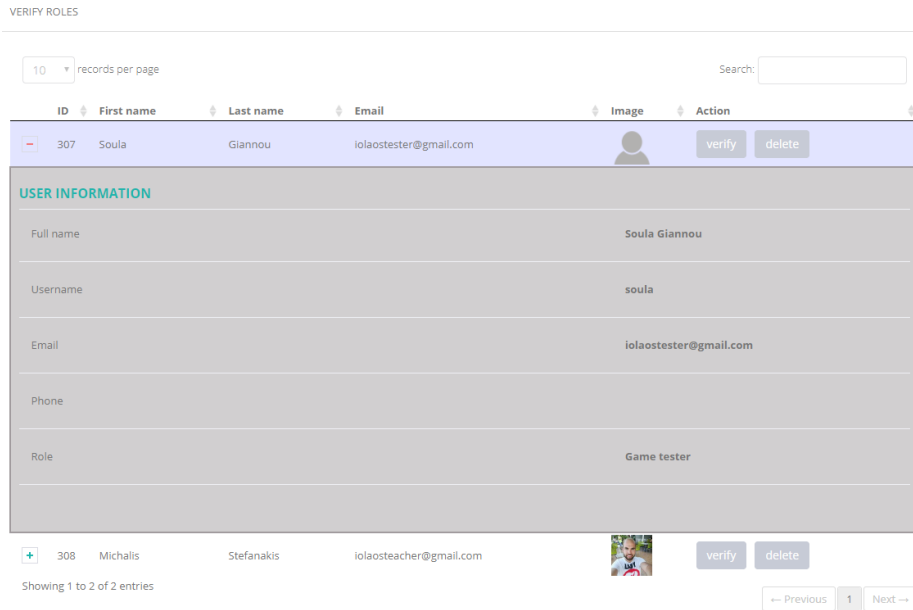


Figure 22: User Role verification GUI

In case that access is granted, the registration process is completed after an automatic verification email is sent to the user, who is prompted to activate his account by clicking the link, as shown in **Figure 23** and **Figure 24**.

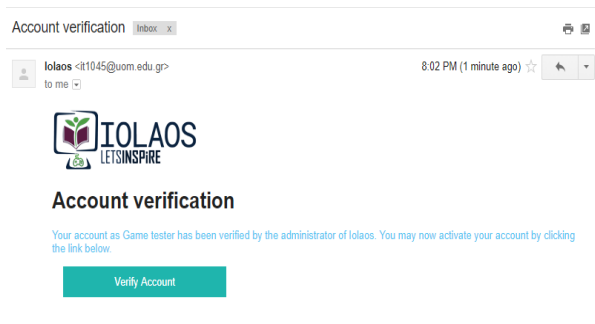


Figure 23: Email Verification

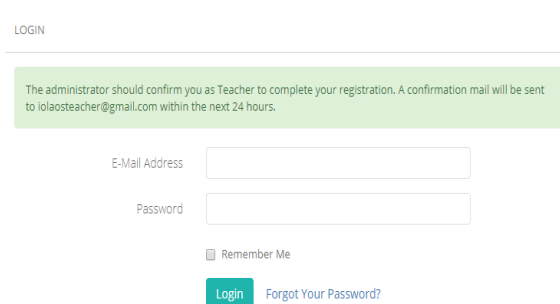


Figure 24: Account Activation

The same process is followed to import games to IOLAOS game list. The advent of a new game must be validated by the administrator who takes feedback from game testers regarding the game in order to proceed to verification. Once the game is included to IOLAOS list, a unique game token is distributed to the developers of the game, required for the usage of platform's web services.

### User Role: "Educational Expert"

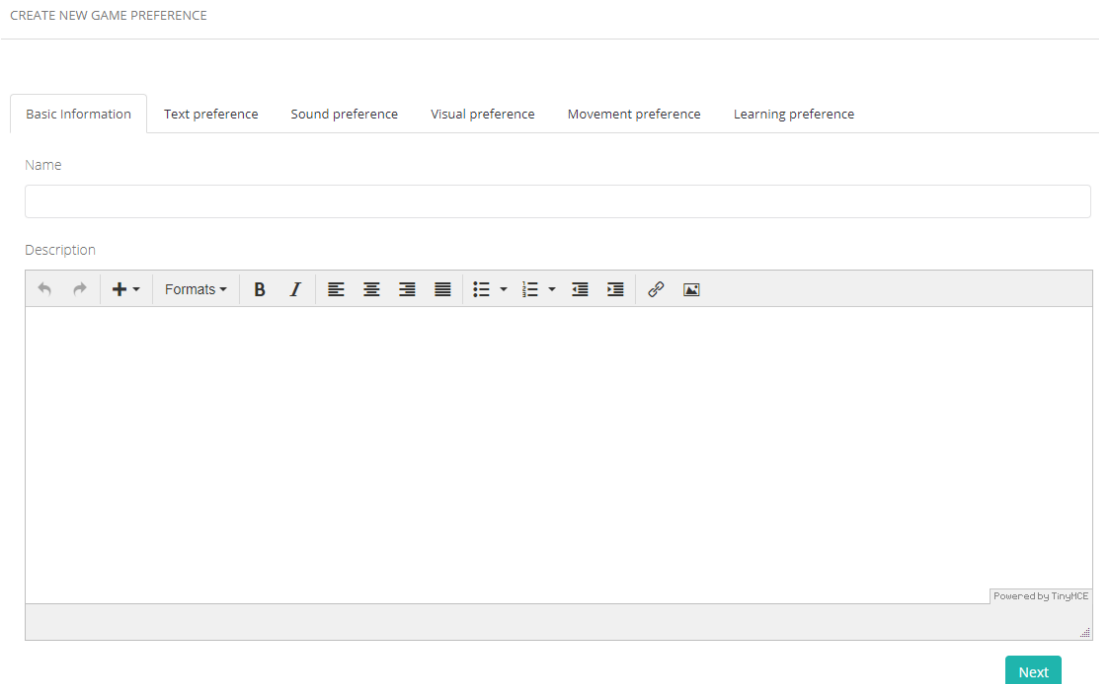
Educational expert is someone with a prolonged experience through practice and studying in the education field. The existence of people who are in charge of researching and producing intuitive works that show the impact of learning methods and styles on learner

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achievements is essential in our platform. Their expertise is used to codify game preferences, based on learning theories, methods, and approaches, as well as special learning needs.

The platform provides them with a GUI for the digitalization of game preference. Educational experts are encouraged to create game preferences for a specific target of learners using the existing options, while their suggestions for modifications and extensions of the platform is crucial for the effectiveness of the whole system.

The first step for the creation of game preferences is the completion of basic information such as name (usually based on learning theories) and description, which may refer to the target group specified, age, etc. (**Figure 25**).



CREATE NEW GAME PREFERENCE

Basic Information | Text preference | Sound preference | Visual preference | Movement preference | Learning preference

Name

Description

Powered by TinyMCE

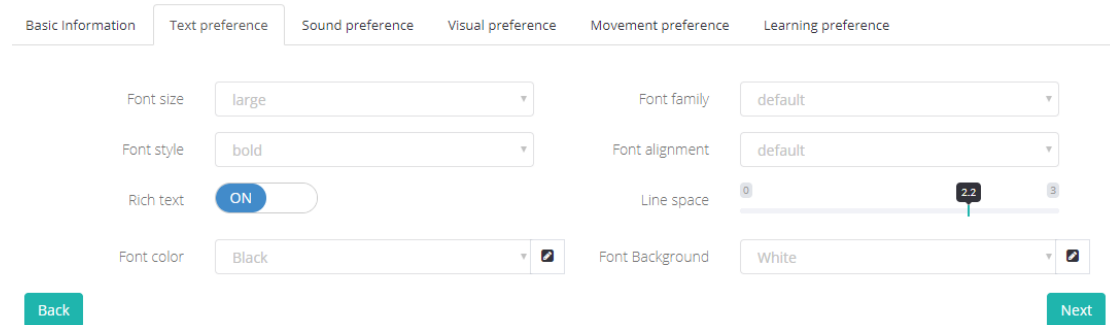
Next

*Figure 25: Game preference tab 1*

The second step refers to the text preferences of the game, which are connected with the Linguistic skill of Gardner's theory of Multiple Intelligence. One feature of the text preferences is the font size, which must be optimized in the game accordingly taking into account the allowed values (default, small, medium, and large). The reason we do not provide hard coded values such as 12px is due to the variety of font size formats and headings that exist in games. As a result, game developers are responsible for customizing the font size of different types of text according to the given value. For instance, large font size for one game may result in the increase of normal text by 2px and headings by 1px, while for another game the analogy could be 4 inches and 3 inches respectively. Other features such as font family of

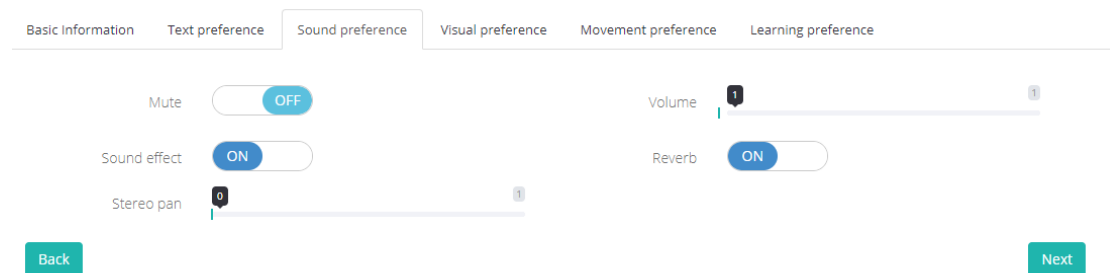
**Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το Heading 1 στο κείμενο που θέλετε να εμφανίζεται εδώ.**

text may be of great importance, especially when the game preference requires distinct texts without effects.



*Figure 26: Game preference tab 2*

In the third step, educational experts customize the sound preference, where their association with Gardner’s musical skill is apparent. A mute option is provided, in situations where learner’s attention is easily distracted by sounds, hindering the learning process. Other sound effects could be activated or deactivated while the volume of the sound is also controlled. Stereo pan can also be adjusted according to hearing problems, i.e. loss of hearing in the right ear.



*Figure 27: Game preference tab 3*

Visual preferences which correspond to the spatial Gardner’s intelligence are configured in step four. These options can be useful especially for visually impaired people. Background option is used to specify whether the game should be grayscale or not. Brightness level can also be adjusted using a percentage, while the field of view is useful for first person games defining the extent of the observable game world that is displayed on the screen.

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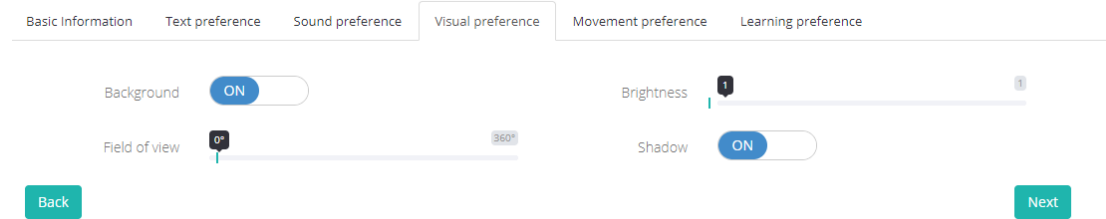


Figure 28: Game preference tab 4

Movement preference are mostly related to 3D games, where the speed of the avatars is controlled. Like the font size in text preference, forward and backward speed do not include hard coded values due to the variety types of games. For instance, specifying the forward speed of a character to 3km/s seems natural. Yet, following the same forward speed preference in a racing game results in ruining the concept of the game. This type of preference could be associated with the kinesthetic intelligence, when new features are assimilated regarding motion sensing input devices.

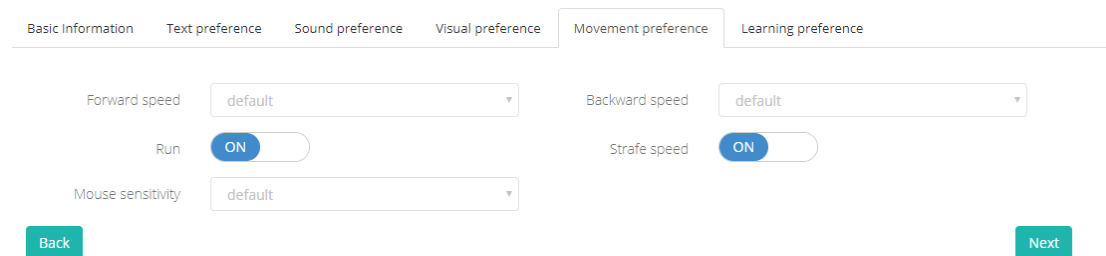


Figure 29: Game preference tab 5

The last step of the game preferences creation involves learning preferences that are related to learning theories. The empowerment of a behavioristic game could be achieved by enabling game mechanics such as constant feedback, rewarding and penalties.

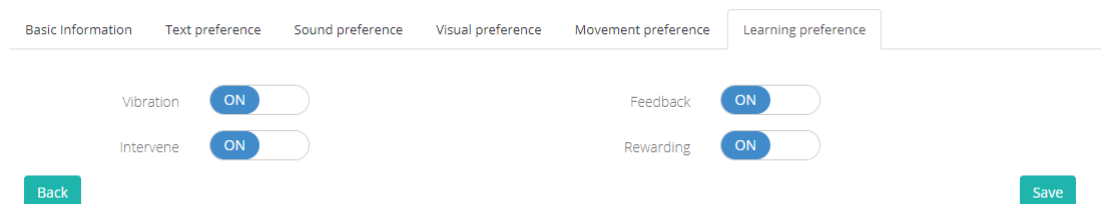
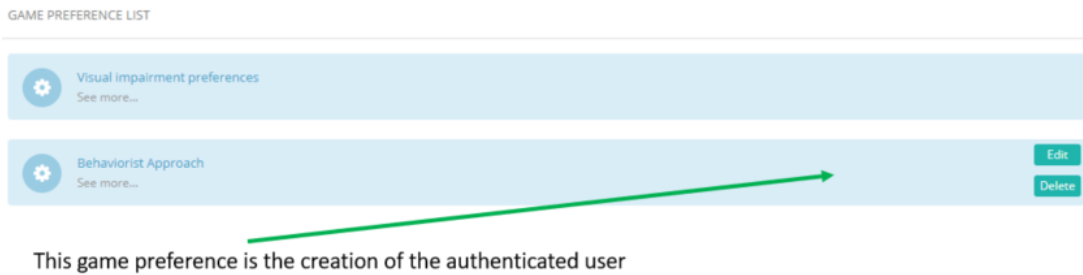


Figure 30: Game preference tab 6

Educational experts can have access to game preferences created by others, while they can modify or delete only their own game preferences, as indicated in **Figure 31**. Further work is needed at the game preferences level in order to accommodate all aspects of learning methodologies, methods, and styles.

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*Figure 31: Game preferences list*

### User Role: “Game Tester”

The role of the game tester is to reserve the quality of serious games that are affiliated with IOLAOS. Consequently, game testers are tasked to constantly check whether games apply the basic principles of IOLAOS, which are to be educational and appropriately structured to accept customizations in the gameplay through the information transmitted via IOLAOS API. These two aspects are essential for every game in order to be platform approved, acquiring the first IOLAOS maturity level. To gain more IOLAOS maturity levels, games should adopt other key principles, specified by the system, i.e. being xAPI enabled.

To achieve this, game testers should be familiar with the game preferences that are created by the educational experts, so as to relate each game preference to the game itself and how it is applied. Practically, they simulate the role of a learner, playing serious games and provide feedback. From their account settings, apart from the common functionalities that all user roles share, they are granted to assign themselves game preferences, as well as school type (mainstream or special school), which are the factors that define the game customization.

#### GAME CUSTOMIZATIONS

School type	Special schools
Game preference	None
	None
	Visual impairment preferences
	Behaviorist Approach

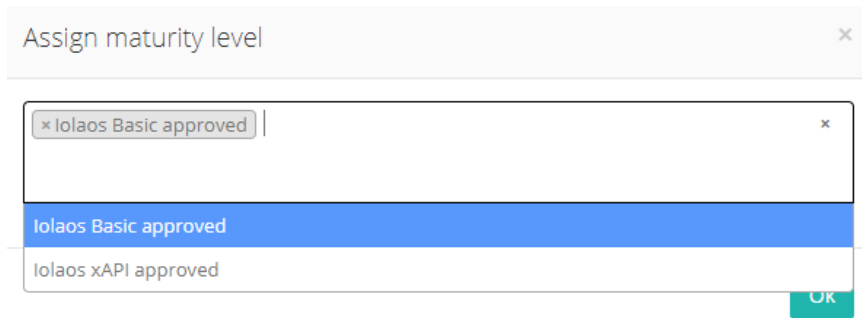
*Figure 32: Auto-assign Game Customizations*

Finally, game testers are authorized to add/remove IOLAOS maturity levels (**Figure 33**) to/from games respectively, according to their game experience. The existence of the IOLAOS maturity levels determines whether the game is approved by our platform. If no



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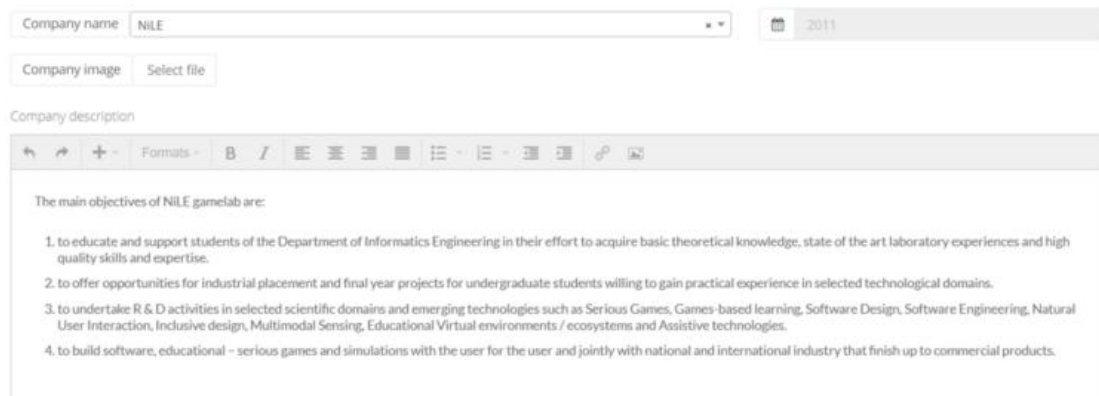
maturity levels are defined, games are not displayed on the platform while the usage of our API is not forbidden. Game testers are also encouraged to rate games, as well as write reviews in order to contribute to the IOLAOS community.



*Figure 33: Selection of IOLAOS maturity levels*

### **User Role: “Game Developer”**

Game developers registering to IOLAOS, apart from personal information they are asked to fill out the company information they are attached to, as well as game information. They can select an existing company, in order to achieve collaboration with other developers of the same company. If the user selects a pre-existing one, all the information of the company is automatically retrieved and appended to the proper inputs, where no modifications are possible (**Figure 34**).



*Figure 34: Game developer registration - Select existing company*

As mentioned before, successful registration for game developers requires verification from the administrator. When the registration is complete, the game developer acquires a unique game token for the game they registered at the platform. The latter is required to send requests to the API endpoints. Developers are encouraged to read the API documentation, which is a technical content deliverable, containing instructions about how to effectively use and integrate third-party games with IOLAOS platform. It is a concise reference manual carrying all the necessary information for the proper communication with the API, including

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details about the functions, arguments, return types, etc., supported by examples and tutorials. A fragment of the API documentation is illustrated below, referring to the use of the register service.

Register user

```
http://seriousgame.teicrete.gr/api/register
```

The /api/register endpoint returns a user if the registration is successful.

The response contains an array of user information containing the name, user\_id, age, email, first name, last name, username, birthday, school type, language and profile picture url.

Example

Request	Response
<pre>\$.ajax({   type: 'post',   url: 'http://seriousgame.teicrete.gr/api/register',   dataType: "json",   data: { 'race': 1, 'first_name': 'Stavros', 'last_name': 'Haritakis', 'username': 'api_register', 'password': '123456', 'gender': 'm', 'language': 2, 'email': 'nomail4@windowslive.com', 'school_type': 1, 'current_occupation': [1,23], 'learning_style': [3], 'special_ability': [2,5], 'interest': [26,35], 'competency': [17], },   success: function(data){     \$('body').html(JSON.stringify(data));   }, });</pre>	<pre>{   "message": "authenticated",   "user_id": 244,   "email": "wishmaster_thess2@windowslive.com",   "username": "wishmaster",   "first_name": "Stavros",   "last_name": "Haritakis",   "birthday": "1991-01-18",   "age": 26,   "school_type": null,   "language": "el",   "profile_pic": "http://seriousgame.teicrete.gr/images/profile_pics/244.jpeg" }</pre>

Figure 35: API documentation - Register service

The game becomes available to the public, as soon as it is tested by game testers and at least the basic IOLAOS maturity level is granted. Moreover, developers can add new games, following the same procedure that is to wait the administrator approval, while they can assign developers of the same company to their games in a sense of collaboration. As shown in **Figure 36**, a list of all the game developers of the company the authenticated user is attached is displayed for possible invitation for collaboration.

Game developers of game

✕

Kostas Tzanakis (frikalization)

Γιώργος Μαθιουδάκης (mathiew)

Figure 36: Multiple game developers for the game

### User Role: “Learner”

In the conceptual environment of IOLAOS, the learner is at the center of attention, providing him an enhanced learning experience through gaming. The key to accomplish this is the composition of a learning profile which refers to a variety of preferences that different learners adopt to deal with the educational content. This kind of profile is based on learning styles, gender, cultures, and intelligences, as outlined before, referencing to the theory of Gardner.

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To that end, we attempt to provide a partly panorama snapshot regarding the learning profile in the registration process. **Figure 37** highlights some inputs that can be accumulated to contribute to the fulfillment of a learning profile. The educational level based on [1] is used as a guideline to describe achievements of learners in the educational field, while the type of school (mainstream school, special school) addresses individual learner's unique needs. Learning styles in combination with interests and competences provide a better perspective on how individual learners better assemble knowledge. For now, the learning profile is comprised of these inputs, but as stated before, IOLAOS platform is capable of assimilating new features for the formation of a complete learning profile since the already imported ones are not sufficient enough.

Learner

Education level	<input type="text" value="None"/>	School type	<input type="text" value="None"/>	Current occupation	<input type="text"/>
Past occupation	<input type="text"/>	Learning style	<input type="text"/>	Special ability	<input type="text"/>
Interests	<input type="text"/>	Competencies	<input type="text"/>		

*Figure 37: Registration process of learner*

After the registration, user profiling becomes available to teachers, who are responsible for selecting a proper methodology depending on learner's profile, for the enhancement of the learning process (**Figure 38**). The authenticated user is provided with an extra tab in his profile, called settings, where he can modify his user and learning profile. As a consequence of that, the registration procedure is quite simple, since only email, username and password fields are required, while the enrichment of the profile is possible at any time through the platform. A complete user profile is encouraged through an appealing GUI in order to facilitate the process of personal learning experience, which is the fundamental goal of our platform.

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PROFILE

OVERVIEW

**Anastasios Learner Barianos**  
Learner

Username: Learner\_Tasos  
Mother language: Greek  
Birthday: 1991-09-25  
Birthplace: Stockholm  
Education level: Bachelor's or equivalent level  
School type: mainstream schools

Interests:  
cinema  
motorcycles  
video games  
music

Competencies:  
problem solver  
creative thinker

HISTORY

current Developer computer game  
past Beekeeper  
past Painter building

LOCATION  
Kisthiniou  
Dodecanese Rhodes 85100 Greece

CONTACTS  
Phone: 6955956126  
Email: learner\_tasos@nile.gr

*Figure 38: Public Learning Profile*

Learner's profile is now connected with the third-party serious games collaborating with IOLAOS, in the sense that the appropriate flow of information based on learning profile is provided to create personalized gaming experience when the players uses IOLAOS credentials for the games.

Learners have other functionalities as well, such as receiving real-time classroom invitations from teachers and participate in video learning sessions.

### **User Role: "Teacher"**

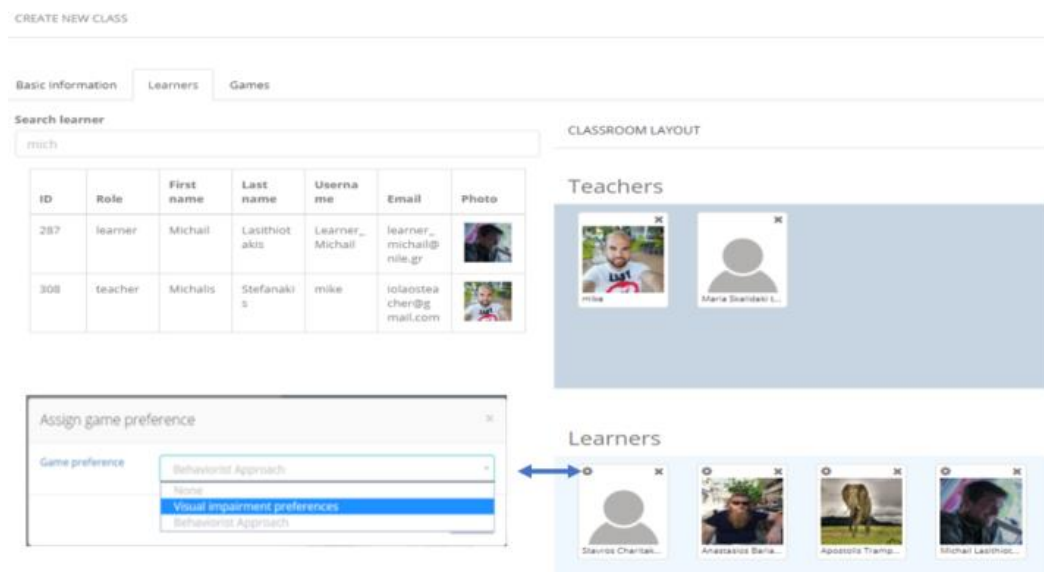
Another crucial role for the platform is the teacher, which is the intermediate link between learners and games. Teachers should be familiar with the game preference list since they can assign game preferences to learners according to their profile. More specifically, a teacher has access to a learner's profile, where he can check his information provided and finally conclude which game preference is more suitable for facilitating the learning process through the gameplay. With the use of game analytics in the platform, teachers can monitor learner's progress and try different learning approaches when needed resulting in a better evaluation of the learning procedure.

In the context of IOLAOS, teachers are not the creators of the serious games as it is seen in Chapter 2 in similar platforms. On the other hand, their role is limited to its

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educational character, which is to impart knowledge to a variety of individuals with different needs and unique approaches. Game players, nowadays, are used to video games with outstanding graphics, interesting storylines, and realistic avatars, which are created by a group of expertise people such as game developers, psychologists, writers, musicians, etc. Teachers are not experts in software development, and even though most platforms provide a user-friendly interface for game creation without requiring programming skills, the outcome of such games will always be outdated and most times unattractive for the audience. Hence, teachers in IOLAOS are not the tailors of their own games. Instead, they are responsible for creating personalized game experiences fulfilling in that way their primary objective which is to ease the learning procedure. Yet, they can affect the game creation by communicating with the game developers through the platform and proposing suggestions and instructions to improve the educational value of the games.

The system is built in a way to accommodate virtual classrooms, where teachers are the creators. This is achieved following a three-step procedure. Firstly, the teacher is asked to fill in the basic information about the classroom i.e. name classroom, relate it to a school (real or virtual) and give a brief description. The next step is to choose the participants of the classroom, by selecting learners and teachers. A user-friendly GUI is provided where participants can be fetched through a dynamical search table, while layout of the classroom can also be configured using drag and drop techniques. During participant's selection, teachers can assign game preferences to each learner individually, clicking on the gear icon as shown in **Figure 39**.



*Figure 39: Selection of classroom participants*

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The final step is the attachment of potential dedicated games to the classroom, which is later used for the learning sessions (**Figure 40**). When the virtual classroom is created, it is added to the classroom list of all the participants (**Figure 41**), while it can also be edited, i.e. add/remove participants, add/remove games, change classroom layout, by the teachers of the classroom.

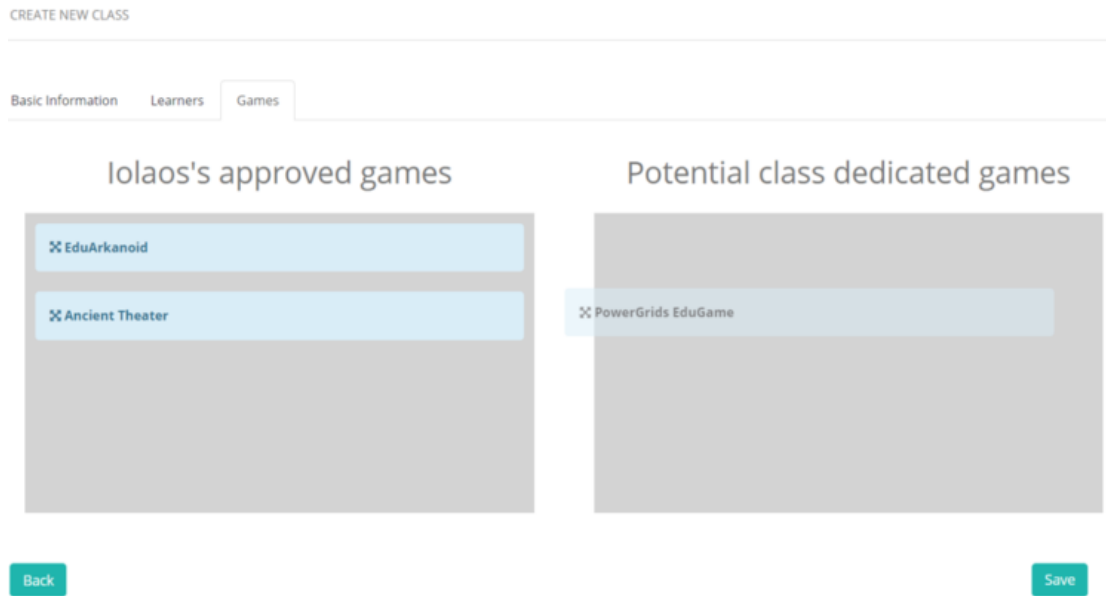
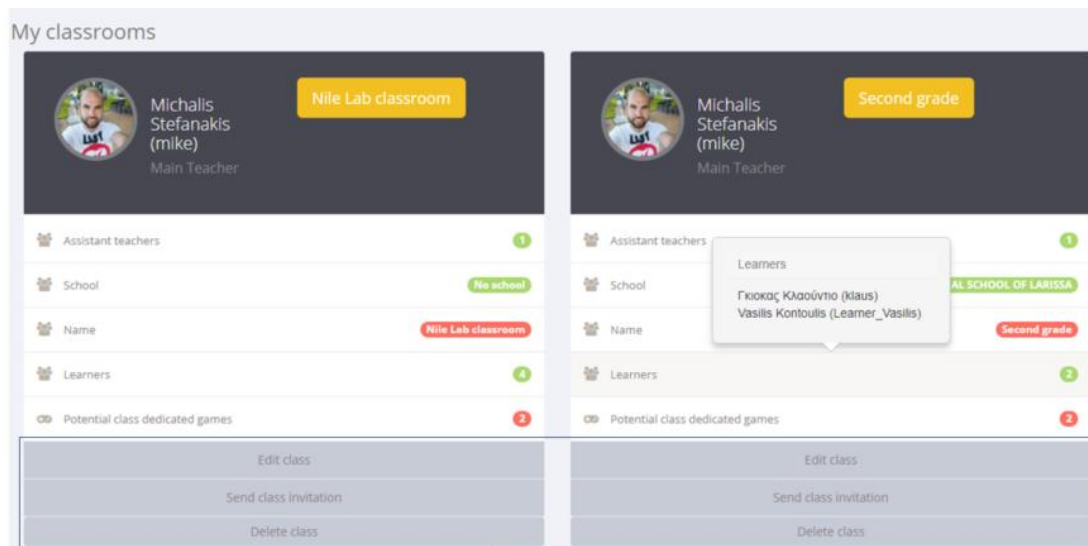


Figure 40: Attachment of potential classroom dedicated games



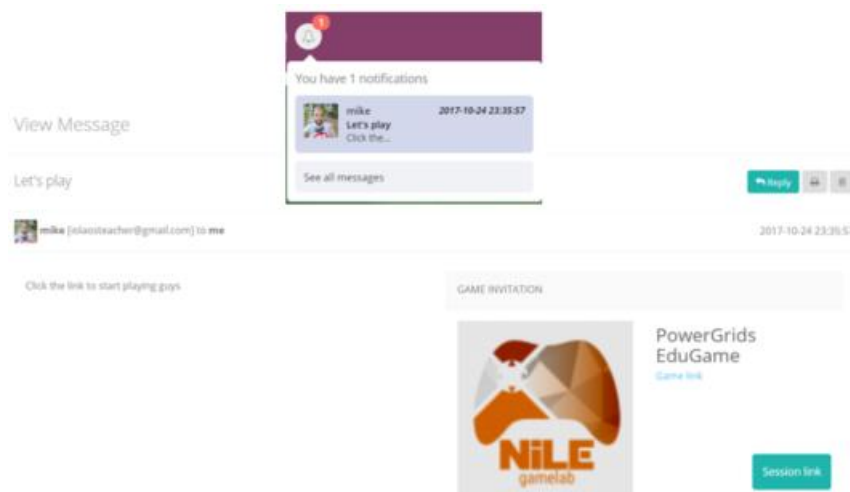
Available option for classroom's teachers

Figure 41: GUI for classroom list

The existence of a classroom is necessary for the creation of a learning session, which is achieved through the teachers of the classroom who send invitations to their participants.

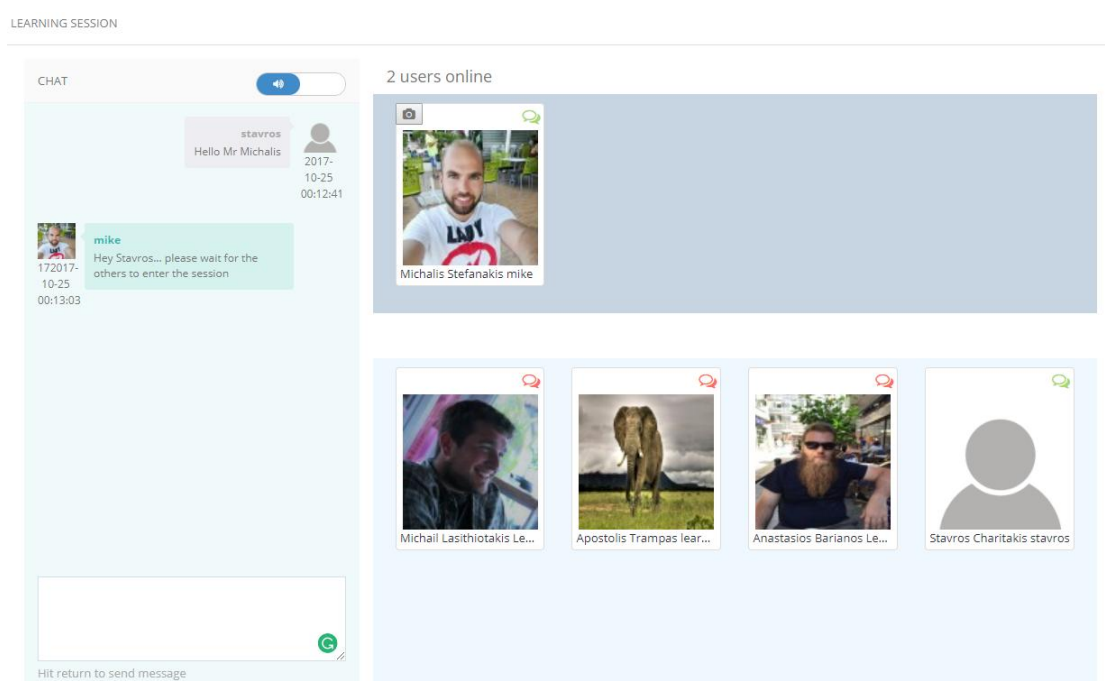
**Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το Heading 1 στο κείμενο που θέλετε να εμφανίζεται εδώ.**

The invitation is in the form of a message with a link redirecting to the learning session page. The participants entering the learning session are displayed as online while the others as offline respectively.



*Figure 42: Learning session notification*

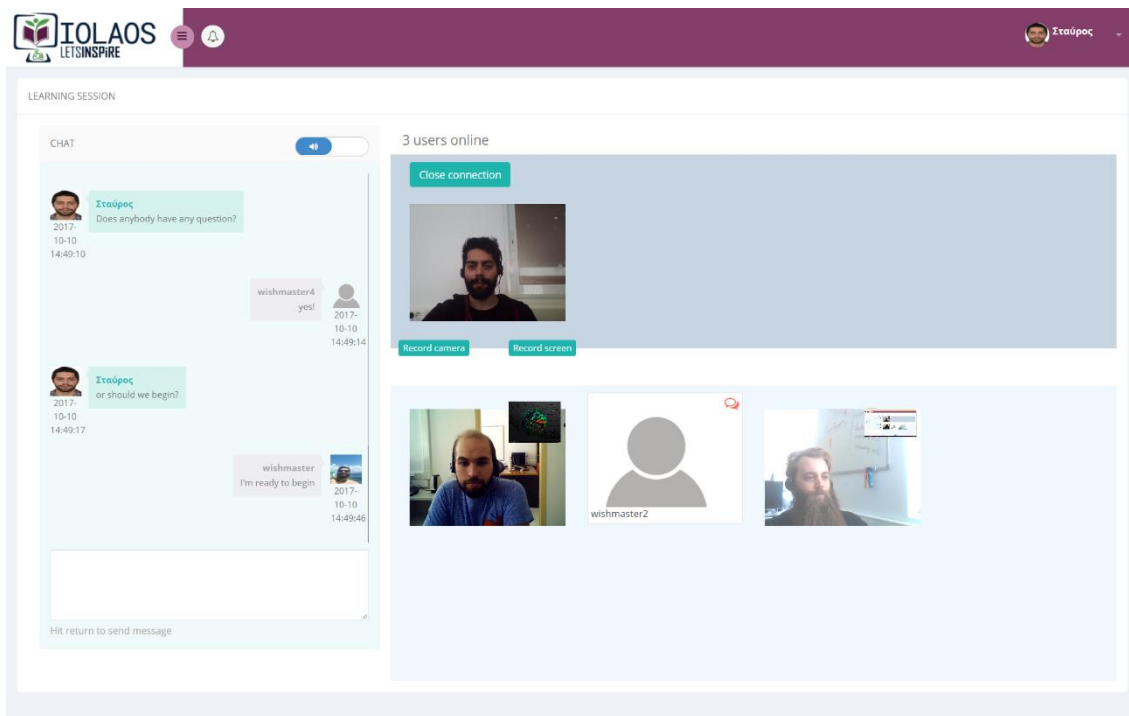
The learning session is equivalent to a lecture, where participants can communicate through the chat application of our system as show in **Figure 43**. Additionally, serious games may also take part in learning sessions, where learners can play the games while the teachers observe them and intervene when it is necessary, applying the concept of ZPD (see sub-chapter 2.1.2 Constructivism).



*Figure 43: GUI for learning session*

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To that matter, an online video conference set up is supported by the platform, where each participant can join by clicking his/her camera button. Multiple peer connections are created, where teachers and learners can communicate with each other verbally and visually. Moreover, teachers can switch between camera and share screen options to observe the participants while playing as well as the game itself through their screens. The use of HTML5, also enables the participants to control the media stream of videos using video options such as pause, full-screen mode, etc. This is a powerful asset to our platform relating distance learning with serious games.



*Figure 44: Video conference - Teacher screen*

**Figure 44** presents the screen of a teacher during a video conference, while **Figure 45** the screen of a learner. The difference is that in learner's screen, the game, if it is a web-based game, can be imported in the same environment of the platform for better usability experience.



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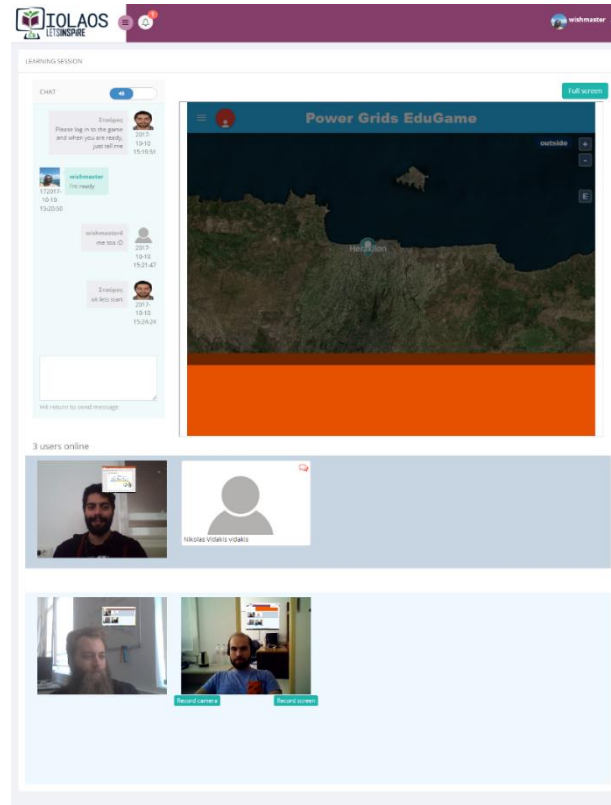


Figure 45: Video conference - Learner screen

Finally, camera and screen recording are available, which is a process controlled by the participants themselves. The recordings are stored in the system and can be displayed to the learners, as well as to the teachers of the learning sessions for better evaluation (**Figure 46**). These recording can also be used for emotional recognition providing valuable feedback for all the user roles of the platform. Principles, method and algorithms for Affective computing can be applied to help us analyze the video recordings of the learner while participating in a learning session and allow us for online, offline, and in action intervention. Further work is needed to be done in this area.

LEARNING SESSION 26

Game: Ancient Theater

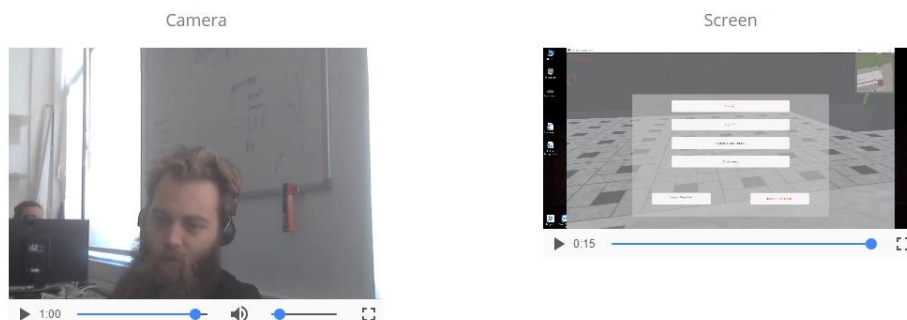


Figure 46: Recorded videos for of a user for specific learning session

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## Role-Based Authorization

Besides the user authentication, our platform deploys a role-based authorization to limit the access to the route for specific roles. For instance, if a game developer attempts to access the route for creating game preferences, he will be redirected to an error page e.g. 401 (permission denied). The following table (**Table 6**) summarizes all the functionalities of each user role of IOLAOS platform.

*Table 6: Platform functionalities and User Role Permissions*

User Role \ Functionality	Guest	Administrator	Educational Expert	Game Tester	Game Developer	Learner	Teacher
Browse games	✓	✓	✓	✓	✓	✓	✓
Browse companies	✓	✓	✓	✓	✓	✓	✓
Message application	✗	✓	✓	✓	✓	✓	✓
Rate & Review	✗	✓	✓	✓	✓	✓	✓
Assign game preferences	✗	✗	✗	✓	✗	✗	✓
Verify games	✗	✓	✗	✗	✗	✗	✗
Verify accounts	✗	✓	✗	✗	✗	✗	✗
Select IOLAOS maturity level	✗	✗	✗	✓	✗	✗	✗
Play games	✗	✗	✗	✓	✗	✓	✗
Create/Edit game preference	✗	✗	✓	✗	✗	✗	✗
Edit profile	✗	✓	✓	✓	✓	✓	✓
Participate in classroom	✗	✗	✗	✗	✗	✓	✓
Participate in learning session	✗	✗	✗	✗	✗	✓	✓
Create/Edit classroom	✗	✗	✗	✗	✗	✗	✓
Create learning session	✗	✗	✗	✗	✗	✗	✓
Send learning session invitation	✗	✗	✗	✗	✗	✗	✓
Record camera/screen	✗	✗	✗	✗	✗	✓	✓

## Chapter 5: Case Studies

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### Contents

**5.1 ThimeEdu**

**5.2 PowerGrids EduGame**

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**Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το Heading 1 στο κείμενο που θέλετε να εμφανίζεται εδώ.**

To provide an explicit insight on how IOLAOS collaborates with third-party games, two relevant case studies are presented. The case studies use third-party games developed in parallel with IOLAOS as final year projects at the NiLE lab. The first case study serious game namely, “PowerGrids EduGame” is developed by Apostolis Marios Trampas & Vasilis Kontoulis, and the second case study serious game namely “ThimeEdu” is developed by Anastasios Barianos & George Xanthopoulos.

Both games embody pedagogy and address multiple modes of learning. Identifying which aspects of games connect with specific accepted and desirable facets of education conduces to facilitating acceptance. To that end, Table 4 illustrates which of Gagné’s Instructions are present in these games, while Table 5 identifies most of Gardner’s “intelligences”, applied in the games.

*Table 7: Third-party serious games versus support Gagné’s Nine events of Instruction*

<b>Game</b>	<b>ThimeEdu</b>	<b>PowerGrids EduGame</b>
<b>Gagné’s Instruction</b>		
Gaining attention (reception)	✓	✓
Informing learners of the objective (expectancy)		✓
Stimulating recall of prior learning (retrieval)	✓	✓
Presenting the stimulus (selective perception)		
Providing learning guidance (semantic encoding)		✓
Eliciting performance (responding)	✓	✓
Providing feedback (reinforcement)	✓	✓
Assessing performance (retrieval)		
Enhancing retention and transfer (generalization)	✓	✓

*Table 8: Third-party serious games versus supporting Gardner’s learning styles*

<b>Game</b>	<b>ThimeEdu</b>	<b>PowerGrids EduGame</b>
<b>Gardner’s Learning Style</b>		
Linguistic	✓	✓
Musical	✓	✓
Logical-mathematical		✓
Spatial	✓	✓
Kinesthetic		
Intrapersonal	✓	
Interpersonal		
Naturalistic	✓	

**Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το Heading 1 στο κείμενο που θέλετε να εμφανίζεται εδώ.**

The game developers followed the registration procedure of IOLAOS and imported their games. The administrator of the platform verified the user roles and granted them with the appropriate permissions. API documentation, along with a unique game token became available to them to successfully connect and exploit system's web services while proper instructions were provided to optimize certain parameters of their games. Game testers involved to validate the procedure by ensuring that the games apply the primary principles of the platform in order to award them with IOLAOS maturity levels. The administrator, make the games available to the public game list of IOLAOS, once the proper feedback from game testers is received. Finally, learners can play these games, experiencing customizations according to their learning profile.

Below, we provide a brief presentation of each game along with some game customizations applied during the gameplay based on learning profile. It is noteworthy, that both games are developed with different technologies and engines, but still collaboration with IOLAOS is possible, following the same procedure.

### **5.1 ThimelEdu**

The ancient theater of Greece is considered as a crucial part of cultural inheritance. Through the ages, it has offered a lot to education and entertainment, while concurrently it has influenced political actions and whole societies, and has been an integral part of religious rituals. The ancient theater has contributed to the evolvement of acting, rhetoric, writing, architecture, and engineering. However, only a small number of theatrical plays are preserved, thus even fewer buildings and none of the machines used in the ancient Greek drama.

In education, students are taught about ancient theater mainly through the tragic plays. Therefore, an increase in interactivity and dedication to the educational process through a three-dimensional experience in a virtual free depiction an ancient theater is vital in today's technology-driven world.

ThimelEdu is a serious educational game, aiming at teaching students of all school levels about the ancient theater of Greece. It is a free roam game, where the player explores the architecture of an ancient theater, as well as the machines and tools used during performances. Consequently, learning is achieved through experience as the player acquires knowledge by interacting with environmental objects and solving quiz games

**Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το Heading 1 στο κείμενο που θέλετε να εμφανίζεται εδώ.**

The game was created using Unity3D, one of the most stable and widely used game engines supporting the export of multiplatform games. Yet, all 3D models, included in the game, were made in Blender, an open source 3D authoring tool, of which only the modeling and rendering features were used.

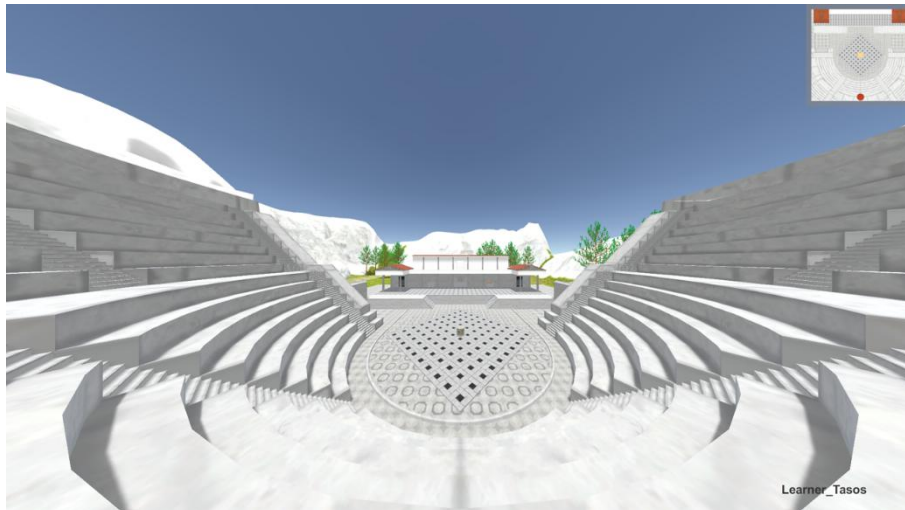
The collaboration of the game with IOLAOS is illustrated in the following figures, where two different learners enter the game, using IOLAOS credentials. The first learner (user 1) plays the game based on a package of game preferences, called ‘Behaviorist Approach’, while the second (user 2) is attached with the ‘Minimal Approach’ game preferences. The difference between the two users’ gaming experience is quite distinct at the very beginning of the game. As seen in **Figure 47**, user 1 is supplied with more game features, such as a score table and rewarding options.



*Figure 47: ThimelEdu - User 1 gameview*

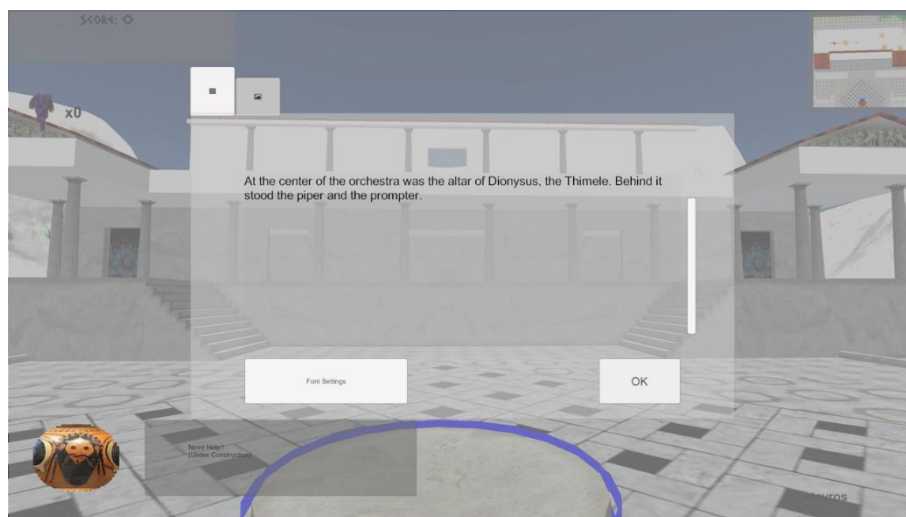
On the other hand, user 2 is assigned a package of game preference that do not allow the existence of scaled rewarding and scoring. Instead, user 2 has a wider field of view, as it is apparent from **Figure 48**. Between users, more customizations are applied in the game that cannot be depicted in the figures, i.e. less sound volume and disabled run option for user 1.

Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το Heading 1 στο κείμενο που θέλετε να εμφανίζεται εδώ.



*Figure 48: ThimeEdu - User 2 gameview*

More modifications are observed in **Figure 49** and **Figure 50**, where user 1 sees views with text color while an option for hint is also enabled in order to provide him with appropriate hints when it is needed. On the other hand, user 2 is equipped with a smaller font, colored in red, without the option of hints due to the definition of the game preference that are attached with user 2. The language preference is also configured in the game, based on the mother language of the users, as declared in IOLAOS platform, during the registration procedure.



*Figure 49: ThimeEdu - User 1 quiz view*

Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το Heading 1 στο κείμενο που θέλετε να εμφανίζεται εδώ.



*Figure 50: ThimelEdu - User 2 quiz view*

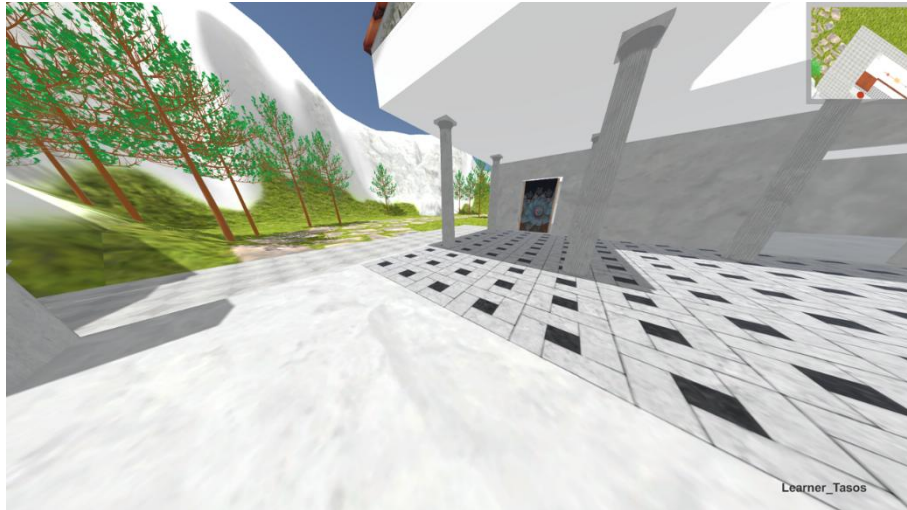
Furthermore, there are slight differences between user's game experience that are hard to distinguish such as the existence of shadows in game objects (**Figure 51** and **Figure 52**). Even these minor changes can have an impact on the learning process depending on the user needs.



*Figure 51: ThimelEdu - User 1 no shadows*



**Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το Heading 1 στο κείμενο που θέλετε να εμφανίζεται εδώ.**



*Figure 52: ThimelEdu - User 2 shadows*

## **5.2 PowerGrids EduGame**

Electrical power has always been the driving force for the world's subsistence, providing services essential for modern life. Daily, electrical power is used for a variety of purposes, such as heating, cooking cooling, etc., while it makes a huge impact on industries and transportation. The electrical power flows through a network, called power grid. The latter contains a variety of components, such as generators, transformers, solar panels, and wind turbines. Those components, when connected describe a power grid system.

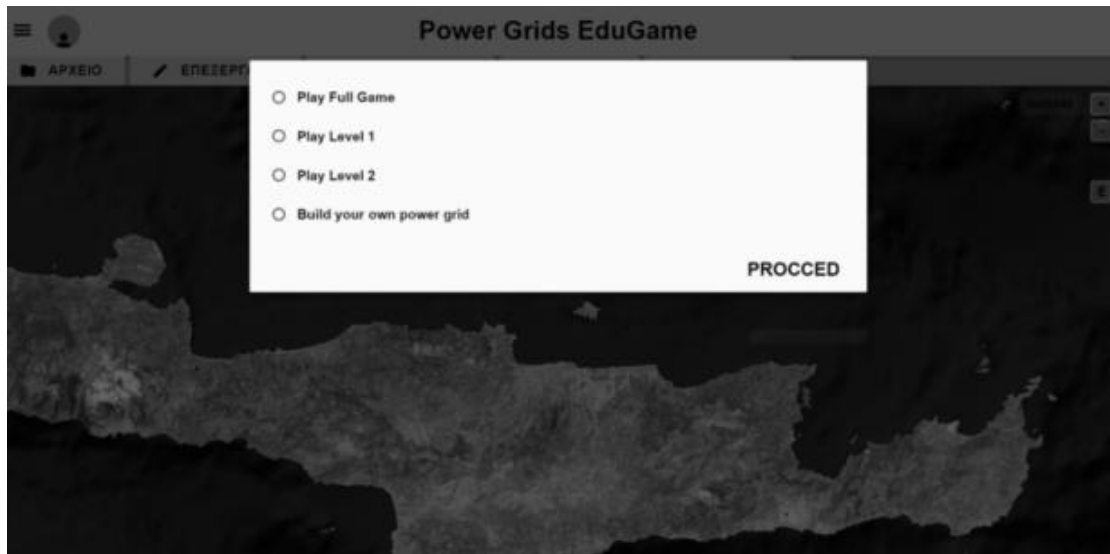
PowerGrids EduGame is a serious game with the main goal of educating power grid systems at electrical engineering students of all ages. The learning process is enforced through the setup of power grid systems on real-world maps, where proper modifications are needed according to specific scenarios for optimal performance.

The game is built upon new web technologies, such as HTML5 and JQuery. For the representation of real-world maps, the OpenLayers API is used, which is a JavaScript library for map visualization, while it also enables interactions with map objects. The User Interface (UI) design of the game focuses on anticipating what players might need to do and ensuring that the interface has elements that are conceivable and easy to access. To this end, the GUI is based on Materialize, which is a free front-end framework for faster and easier creation of responsive designs. All 2D power grid's components were made in Blender for visually enhanced user experience.

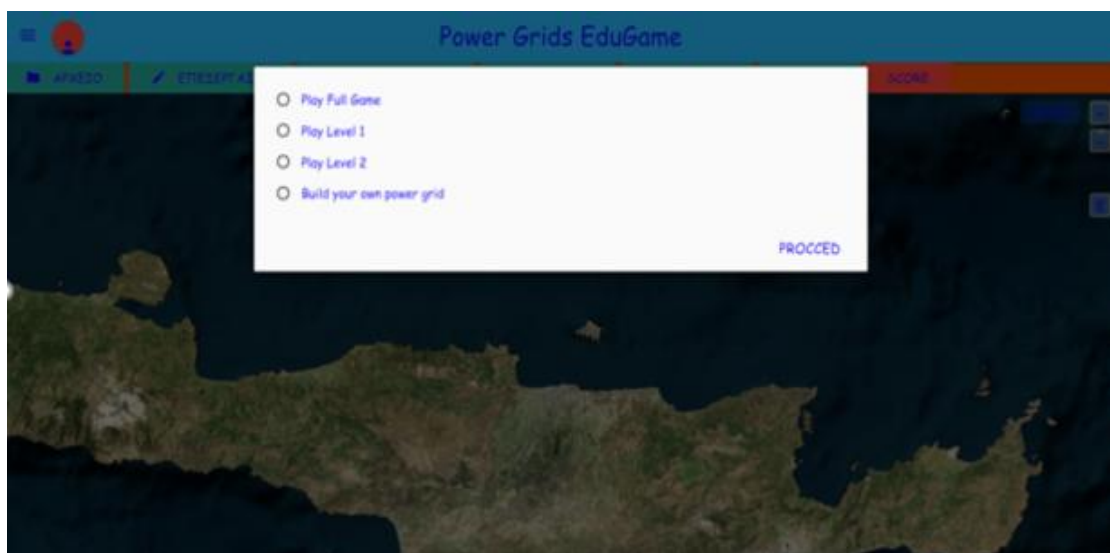
The collaboration of the game with IOLAOS is illustrated in the following figures, where two different learners enter the game, using IOLAOS credentials. The first learner (user 1) plays the game based on a package of game preferences, called 'Visual impairment

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minimal approach’, while the second (user 2) is attached with the ‘Advanced all-included approach’ game preferences. User 1 has a colorless game experience due to its vision problems defined in his profile. Additionally, a specific font is selected with an increased size and a distinct font family (**Figure 53**). In contrast to these preferences, user 2 receives a fancier colored font, since visually appealing factor is essential for its defined package of game preference (**Figure 54**).



*Figure 53: PowerGrids EduGame – User 1 gameview*



*Figure 54: PowerGrids EduGame – User 2 gameview*

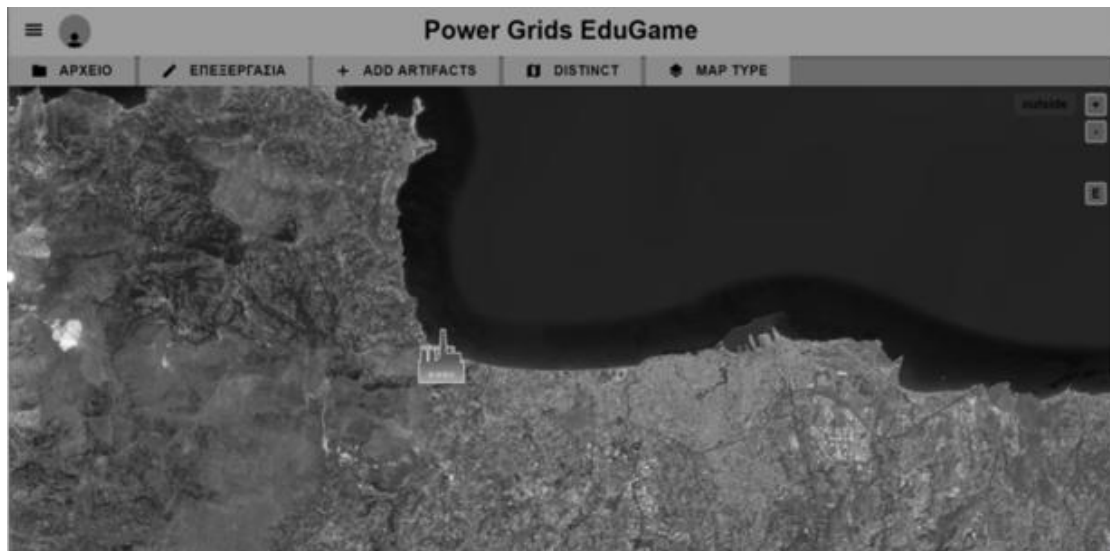
Furthermore, there are some divergencies between the learning method approaches used for each user individually. User 2 is allowed to use hints anytime at the game, while the

Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το Heading 1 στο κείμενο που θέλετε να εμφανίζεται εδώ.

scoring is available to provide a sense of progress in the game (**Figure 55**). From another learning perspective, based on a minimal approach, help does not exist in the game concept, while the score is not displayed, since scaled rewarding is prohibited for the user 1 (**Figure 56**).



*Figure 55: PowerGrids EduGame – User 2 learning preferences*



*Figure 56: PowerGrids EduGame – User 1 learning preferences*

## Chapter 6: Conclusions

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### Contents

#### 6.1 Future Work

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**Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το Heading 1 στο κείμενο που θέλετε να εμφανίζεται εδώ.**

The main topic of this dissertation has been to consider whether serious game platforms improve the learning procedure. Although serious games can be a very powerful pipeline for increasing learner's interest in education, most existing frameworks for the development of such games do not provide proper guidance that validates their potential and value in education. As a matter of fact, empirical studies are fragmented and face various issues relating to the accuracy of content, limited experimental evidence about the educational impact and on how to enhance effectiveness.

In this thesis, our attempt is focused on making serious games a mainstream activity as part of the educational system and the world of education in general by proposing a framework that will deliver and empower substantial evidence and experimental findings for the benefits of games in learning. Towards this goal, we have made endeavors to sketch the organizational underpinnings of our platform, presenting a pilot effort that aims to build an open generic online free technological framework for educational games for students and lifelong learners. Under this scope, we investigate the gap between game design and education in order to find a communication basis for the two most valuable yet completely different aspects (learning and fun) of serious games. We have analyzed and developed an operational model for carrying out the codification of learning theories, methods and styles, by identifying educational models which already exist in the concept of games.

The objective of the codification of learning theories, methods and styles is to provide an AEGMP, enabling educational experts to share concrete information about the game based on their knowledge of educational theories and practices, as well as define specific features based on specific target groups with special needs and preferences. The digitalization of this information is used to customize certain parameters of third-party games resulting in personalized game experience according to user and learning profiles.

IOLAOS clearly differentiates from all previous similar works, in the sense that it does not deliver an authoring tool to educators for game creation. Instead, the platform aims to reinforce the collaboration of different groups of people, each one adhered to its own user role and specialty in order to generate third-party serious games, customized and tailored according to player's user and learning profile. This idea is based on our philosophy that the outcome of platforms that produce serious games created by none computer experts (educators) will always be restricted and obsolete, failing to satisfy the needs of today's digital natives who are familiarized with extra ordinary game graphics and storylines. Additionally, educational theories and pedagogical principles are considered as an integral part of the game design, where most platforms are either unwilling or unable to fully adopt.

**Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το Heading 1 στο κείμενο που θέλετε να εμφανίζεται εδώ.**

Consequently, our framework allows educational experts to deal with the educational models and game developers to stick to the game development, while communicating with the platform to receive information for game customization. The user role of teacher is limited to its educational character since the platform also provides an inclusive learning environment, fostering constant monitoring and evaluation of the learners.

### **Future Work**

Ongoing work covers a variety of issues both technological and educational. However, as outlined in Chapter 3: IOLAOS Platform, the component-based architecture of our system supports upgrades and reconfigurations without requiring a lot of effort. Some of the issues to be addressed in the immediate future include:

- a) Platform's server migration from HTTP to HTTPS, exploiting the benefits of HTTP/2 as well as the additional SEO and security advantages.
- b) Introduction of xAPI protocol for in-game data and analytics.
- c) Further exploration of learning styles and educational theories in collaboration with experts and educator professional associations.
- d) Further exploration of User and Learning profile in order to cover a wide variety of learners with specific learning and special needs.
- e) The embodiment of Affective Computing for exploiting user emotions from the learning session videos in the learning process.
- f) Run various use cases in vivo with the guidance and involvement of experts and educator professional associations to measure the effectiveness of the digitalized learning styles and educational theories, as well as the personalized game plays.
- g) Artificial Intelligence (AI) for automated game preference classification according to User and Learning profile.
- h) The IOLAOS platform becomes multilingual in order to be tailored for different audiences.
- i) Crowdsourcing for specific technological parts of the components in the different modules of the IOLAOS architecture.

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