Establishing an Appealing Cross-Platform Innovative Educational Gamified Learning System Product: A Complete User Experience Case Study

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Abstract

Gamification in Education has laid the foundations for the utilization of game-based mechanisms to nourish learners' inducements, curiosity and engagement, through active game-play experimentation, thence enhancing their problem solving, critical thinking, technical and employability skills. In this Paper, we commence by appraising how User Experience and users' perception of the usefulness, convenience, adaptability and efficacy of an educational product of interest may lead to an exemplary, usable, functional, desirable and user-friendly, User Experience Design, which may holistically improve Gamified Education. Our conceptualization is assessed upon our Case Study; a cross-platform, innovative authoring educational gamified learning system product, covering STEAM *(Science-Technology-Engineering-Arts-Mathematics)*-related material, funded by the Hellenic Republic Ministry of Development and Investments, *howlearn.* An extensive overview of its end users and interrelated Subsystems is introduced, upon which, an exhaustive User Research is employed, designating users' desires and needs, based on a sample of 156 learners and 23 instructors. We, subsequently, delineate the System's Personas and Empathy Maps. Thereupon, we prosecute its design phase: from Paper Wireframes and Digital Low-Fidelity Wireframes, to the conduction of a Usability Study (denoting the necessity for the design's refinement) and the formulation of the learning system's Digital Mockups and High-Fidelity Prototypes. We conclude that, accounting for Accessibility, User Experience Design Principles and Responsive Design Principles is imperative, so that the convenience and usability of the design solution are ensured, thus leading to the formation of a gamified, socially sustainable, multidimensional, inclusive educational learning system, advocating lifelong learning.

Keywords: accessibility; responsive design; usability study; user experience design; user research

1 Introduction

Learning is the process of attaining new comprehension, apprehension, expertise, principles, virtues, comportment and inclinations (Gross, 2010). By additionally assessing which learning methods/tools best suit an individual's needs, capabilities and potential, while taking into consideration, background, socio-economic and digital literacy boundaries, one may conclude that, establishing an optimal learning path, should not be considered an easy process.

Hence, the formulation of an – appealing to its users – learning process, capable of meeting the vast majority of their personalized needs, constitutes a rather challenging procedure, that cannot, solely, be provided through conventional learning approaches (i.e. through manuals/books), which are often the exclusive privilege of those who can cope with the financial implications related to them. Some of the latest technological advancements, however, have managed to facilitate the spread of innovative personalized learning, especially through the development of virtual game engines, simulating real thematic educational environments, as well as "virtual labs", where users complete a series of learning/thematic laboratorial tasks/educational activities, at no (or low) cost. Such online virtual environments, hence have the potential to provide their users with Distance Education *[the process of educating people who may not physically attend their classes (Kaplan & Haenlein, 2016 – Honeyman & Miller, 1993)* and curricula that would have, otherwise, never, been offered to them.

This is exactly where the idea of Gamification converges to the notion of Innovative Distance Education: Gamification in Education concerns the usage of game-based mechanisms and game dynamics to stimulate learners' incentives, peculiarity and engagement, all while enhancing their problem solving, critical thinking and interpersonal skills, so that specific educational objectives are acquired (Kapp, 2016). Gamified Education, thus, enables learners to develop their hard and soft skills, through active game-play experimentation, motivation and engagement, thence holistically improving the learning process. Consequently, the creation of an innovative learning system, stimulating multifaceted learning, by encouraging the application of modern technology, for the intensification of learners' skills, within time and cost effective frameworks, would enable Gamification to actively, positively, influence Education, cognitively, emotionally, socially and technologically.

It is for this reason that we proceeded with the conceptualization and inauguration of a Gamified Educational Innovative Learning System Product, *howlearn*, within which, game elements are applied over pre – defined educational activities of interest, therefore enhancing the gratification of the learning process, through closed – script game realization, within 3D virtual environments. By additionally incorporating a custom Authoring Tool feature, *howlearn* also manages to overcome barriers related to learners' potential lack of computational skills.

To this end, the primary objective of our Case Study was the enhancement of the overall design and functionalities of the various available virtual thematic workshops, by concurrent integration of additional supporting technologies and tools, such as STEAM*(Science-*

Technology-Engineering-Arts-Mathematics)-related simulations, interactive storytelling 3D scenarios, virtual case studies and user behavior analysis algorithms, in order to facilitate the amelioration and personalization of the learning process. Thereupon, our product would mainly focus on the formulation of a gamified platform, which would optimize the learning process, at all stages of compulsory and non-compulsory education, including lifelong learning, with an emphasis on primary education, secondary education and vocational training beneficiaries.

For the aforementioned process to be fully engaging, however, the primary focus would have to be on the end users of the System *(Educational Institution, Instructor and Learner in our case – for more information, please refer to Chapter 2.1 below)* and more precisely, on the creation of an exemplary, user-friendly and Accessibility-friendly, **User Experience Design**, for every single one of them; notion which constitutes the aim of this present Paper.

2 Methods

2.1 The Product – howlearn; a Comprehensive User Experience Design Case Study

howlearn is a cross-platform (Windows, Android/iOS and Web) innovative educational learning system product, **funded by the Hellenic Republic Ministry of Development and Investments**. It makes use of gamification concepts, within 3D virtual spaces *(i.e. laboratories, entrepreneurship offices, classrooms, sports facilities)*, where users participate in the realization of virtual, STEAM *(Science-Technology-Engineering-Arts-Mathematics)* – related Experiments/Exercises, all of which are produced within a cross – platform game engine *(Unity)*, as accompaniments to their subject material. Users, hence, participate in realistic case study scenarios, without having to physically attend their classes.

More precisely, *howlearn's* "Virtual Library of 3D Experiments" consists of virtual thematic experimental laboratory simulations (Physics, Chemistry and Biology), virtual labs (Mechanics and ICT), interactive storytelling scenarios (English and Mathematics), virtual simulations and case study scenarios (Literature and Arts), as well as interactive storytelling & decision-making educational scenarios, for the familiarization of Learners with the concepts of Entrepreneurship and Innovation. Therewithal, the System also operates as an Authoring Gamification Tool, since, an additional "Repository of Virtual 3D Objects" is available for the composition of new, fully engaging, Educational Modules, without programming skills requirements – all is succeeded via simple "drag-and-drop actions".

The **Use Cases** (Jacobson et al., 2011) of *howlearn*, upon which the product's User Experience Design is arranged, are the Educational Institutions, Instructors and Learners. Each Use Case comes with their own unique functionalities within the System *(for more information, please refer to Fig.2 below):*

- **Educational Institutions:** Administrators of an educational institution or organization. They have the ability to manage the entire learning product and, most importantly, assign/invite Instructors to Learners and/or Groups of Learners.
- **Instructors:** In addition to being able to edit their own account, they may edit their list of students and decide which exercises to assign to which of their students/classes of students.

Moreover, they may create their own Educational Modules, from scratch, by making the most out of the usage of all of the System's available supported files [PDF, XLS, XLSX, PNG, FBX *(adaptable file formats for 3D animation software)*].

- **Learners:** Learners may log into the System to gain access to the work that has been assigned to them, by their Instructor. Upon completion of their 3D Virtual Educational Experience, they receive Personalized Feedback Reports, informing them on their overall performance and in-game competency. This functionality is the result of the extensive application of Machine Learning Algorithms, assessing all users' game metrics. The Personalized Feedback Reports are also available to the Instructor who may, afterwards, adjust their learning material, accordingly, in ways that would allow for the amelioration of their students' performance *(for more information, please refer to Fig.2 below).*

Last, but not least, special importance has, additionally, been given to the compliance of the System with the **Accessibility** Specifications, as implied by WCAG 2.1 ("Web Content Accessibility Guidelines"), so that the content of *howlearn* is also accessible to people with disabilities, such as low vision, photosensitivity, color blindness and combinations thereof.

2.2 Innovation within the Concept of our Gamified Educational Learning System Product

To achieve the aforementioned objectives, our learning system product is divided into three main, interrelated **Subsystems**, as denoted in Fig.2 below, directly associated with the User Experience Design that is being applied upon it:

I. **Educational Content Development Subsystem:** This Subsystem contains all of the gamified educational material, in the so-called "Library of 3D Gamified Modules/Experiments". In other words, it refers to a database of prototyping content, within which, Educational Institutions, Instructors and Learners, may find a series of Virtual, STEAM *(Science-Technology-Engineering-Arts-Mathematics)* - related Experiments, as well as a fully functional Repository of 3D graphics, for the establishment of new educational material/exercises. Hence, this Subsystem guarantees the ease of use and independence of the platform, as Instructors may, not only provide their students with state-of-the-art virtual educational material *(created based on educational instructional design scenarios)*, but also, quickly and directly design new gamified educational processes for them, in a graphical "drag-and-drop" environment, without any computational skills requirements.

II. **Machine Learning and Recommendation System Subsystem for the Analysis of Learners' In-Game Performance** *(measurement and analysis of learners' learning experience).* This particular Subsystem is divided into two parts, one addressed to Instructors and one to Learners. The usage of Docker software, within the System, allows for the dynamic storage of all of the algorithmic results related to the transcription of learners' in-game metrics and educational behavioral patterns. As a result, learners' interests, weaknesses, overall performance, as well as the level of their satisfaction, with regard to the knowledge acquired through their Gamified Education, are being processed, through the extensive analysis of the System's in-game metrics

(player efforts, dwell time, Experiment success or failure etc.). The results of the analysis are, then, presented, both to the Instructor, as well as to the Learner, through a "Personalized Feedback Report Dashboard" *(please refer to Fig.1 below).*

III. **Personalized Feedback Report Dashboard – Performance Evaluation Reporting Subsystem:** The Reporting Subsystem uses the results of the previous Subsystem as inputs, to create a comprehensive analytical learner profile. It also provides information on the overall "class competency", by making use of advanced **Statistical Algorithms**, with an emphasis on data mining, deep learning analytics and **Clustering Algorithms**, so that learners, ultimately receive recommendations, based on: a. what other learners, similar to them *(in terms of their Experiment Preferences)* like and b. their Experiment Performance ***(2 Custom Collaborative Filtering Recommendation Systems)***, as well as c. other Experiments they might enjoy, according to their own Experiment Preferences ***(1 Custom Content-Based Filtering Recommendation System).***

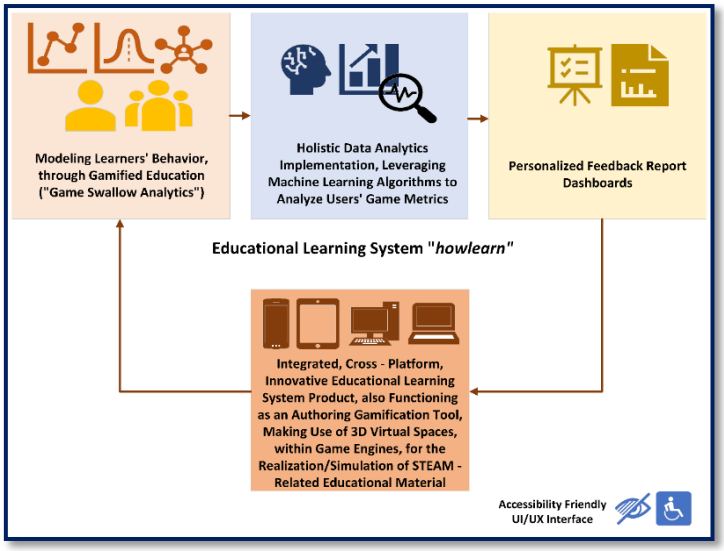

Figure 1: Visual Conceptualization of the Innovative Learning System howlearn.
Source: Authors, 2023.

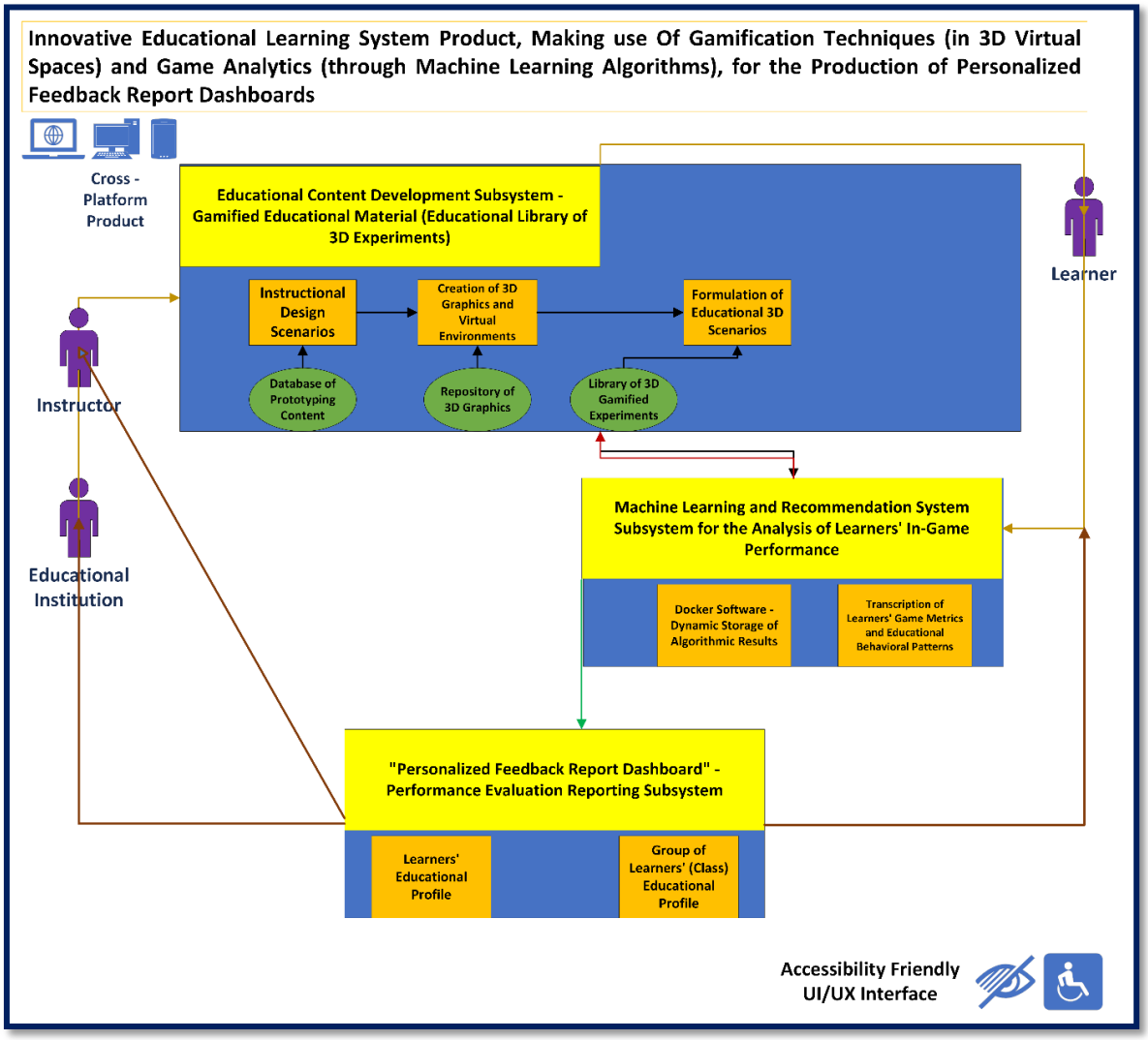

Figure 2: Innovation within the 3 Main Subsystems of howlearn.
Source: Authors, 2023.

2.3 User Experience

User Experience ("UX") refers to the manner in which a user interacts with, perceives and gets acquainted with a product, system or service. It includes a person's perceptions of the usefulness, convenience, adaptability and efficacy of the product in question (Norman & Nielsen, 2016). Therefore, enhancing the user experience is of major importance when creating/improving products, since a negative user experience will, most certainly, affect the impetus of the product and, consequently, its purchasing power.

User Experience Design *("UXD"),* on the other hand, is the process of identifying the experience that end users undergo with products/websites, as a result of the creation of interaction designs, supported by empirical or scientific evidence (Norman & Nielsen, 2016). User Experience Design includes all aspects of a user's perceived experience with a product or website, such as convenience, functionality, appeal/attractiveness, brand discernment and overall performance [*reason why User Experience Design is also considered to be a key*

component of customer experience ("Customer Experience, CX"), which includes all aspects and stages of a customer's experience and interaction with a company].

All of the decisions related to the design solutions in User Experience Design are, thus, guided by extensive **Research, Data Analysis** and **Pilot Testing Findings**, rather than personal preferences of oneself. As a result, to establish a scientifically supported User Experience, for a new product, like *howlearn*, it is deemed necessary to combine the Scientific Fields of **User Experience Design, User Experience Research and Data Analysis**, since, therein, ultimately, lie the successful or unsuccessful end results of the product in question.

2.4 Understanding the User – User Research

By **User Experience Research** or **User Research** ("UXR") we refer to the process of gaining valuable insights and understanding of users' behaviors, wants and needs, using different observation techniques and feedback methodologies, such as interviews and usability studies (Goodman & Kuniavsky, 2012). User Research is, hence, used to apprehend, not only how people interact with products, but also to assess whether certain design solutions manage to meet their needs (Rajput, 2022). This specific field of research, thus, aims to holistically enhance the User Experience of products, services or processes (Veal, 2021), by integrating methods of Experimental and Observational Research (Pelt, 2016), from which the delimitation of the design, development and improvement of a product arises.

User Research is used as a means of improvement for numerous products, such as websites, reason why we result to it, for the amelioration of our cross-platform learning system, *howlearn*. Since it is an iterative process that may as well be used at any stage of product development, while always focusing on the formulation of user-centered designs (Hall, 2013), it is being applied multiple times, throughout our implementation, with the first one being at very commencement of it: we, initially produced questionnaires examining how Students/Learners, as well as Teachers/Instructors, perceive gamification in education and handed them out to schools of Secondary Education. Data generated by these users were, afterwards, analyzed, so that, within the spectrum of a newly introduced gamified educational product, application-related and system-related potential problems would be determined (UX Booth Editorial Team, 2018). Our design solutions were, then, prototyped and tested within our target end users, well before the final launch of the product on the market *(process occasionally repeated, until all product milestones were met).*

Although multiple pilot tests were launched in the course of *howlearn's* production, we should, additionally, note that, even once our product is on the market, User Research will still be around the corner, so that further improvements or solutions to new arising problems are pinpointed, within time-effective frameworks (Interaction Design Foundation, 2023). After all, User Research's main contribution revolves around the conversion of user problems to insightful feedback, on how users interact with the respective product, hence beneficially affecting all stages of product development, from conceptualization (ideation), to market launch (Goodman & Kuniavsky, 2012).

2.4.1 User Research Overview

howlearn's virtual learning spaces, simulate realistic case scenarios, in which users complete gamified educational tasks. The product's ultimate intention is to provide learners with personalized feedback, through the extensive analysis of their performance, so that the System, eventually, dynamically adapts to their educational wants and needs. For this to occur, all users have to actively engage with all of the pre-processed thematic 3D environments, participating in virtual thematic experimental games and simulation processes, that genuinely attract their attention. In order to assess what an ideal, cross-platform virtual educational environment should look like, we, hence, surveyed Students/Learners and Teachers/Instructors of Secondary Education and proceeded with an extensive Analysis of their Data.

We, subsequently, constructed our Personas and Empathy Maps, to further conceive the needs of our end users and set "further improvement design elements milestones", all of which were taken into consideration, for the assembly of our finalized User Experience Design (*for more information, please refer to Chapter 3.1 and Chapter 3.2 below).*

The Ordinal Logistic Regression of the Students'/Learners' Questionnaire Data Analysis ($n = 156$ Students/Learners) highlighted the belief of youths that the constitution of a Gamified Product as a **Teaching Support System** could vastly contribute to the **Enhancement** of their (hard and soft) **Skills**, as implied by Eq.2, while concurrently acting as a **Means of Motivation** *(**Sex** seems to slightly modify learners' motivation)*, as implied by Eq.1 below. The general formulas of these models may be presented as follows:

First Ordinal Logistic Regression Model – Students'/Learners' Questionnaire:

$$logit(P(Teaching\ Support\ System) \leq j) = \beta_{j_0} - \eta_1 * Means\ of\ Motivation - \eta_2 * Sex \quad (1)$$

Second Ordinal Logistic Regression Model – Students'/Learners' Questionnaire:

$$logit(P(Teaching\ Support\ System) \leq j) = \beta_{j_1} - \eta_3 * Means\ of\ Skills' Enhancement \quad (2)$$

The Ordinal Logistic Regression of the Teachers'/Instructors' Questionnaire ($n = 23$ Teachers/Instructors), on the other hand, highlighted the belief of teachers that gamification in education may not **Negatively Affect** the **Educational Process**, should Educators wisely incorporate it, as part of their teaching process, as implied by Eq.3:

Ordinal Logistic Regression Model – Teachers'/Instructors' Questionnaire:

$$logit(P(Teaching\ Support\ System) \leq j) = \beta_{j_2} - \eta_4 * Negative\ Impact\ on\ the\ Educational\ Process \quad (3)$$

2.4.2 User Research – "Pain Points"

To successfully establish *howlearn*, we also focused on gaining insights with regard to issues arising from the implementation of its initial product design. These insights comprised the "Pain Points" of our users; problems that occurred throughout users' initial experience with the System, on three levels: interaction level *(pain points related to interactions with the product)*, customer-journey level *(pain points relevant to user journeys)*, and relationship level *(pain points pertaining to users' lifetime commitment with howlearn)* (Gibbons, 2021):

• **Interaction Level: Accessibility**: the initially proposed color palette was not accessibility-friendly, especially to individuals with color blindness.
• **Customer – Journey Level:** The **Information Architecture Design**, of the "Library of 3D Experiments" was considered somewhat troublesome, in terms of user navigation.
• **Relationship Level: Cross – Platform Product Responsiveness**: users feared that navigation between different devices/screen sizes (i.e. laptop – mobile) would be perplex.

The aforementioned Pain Points set the ground for the implementation of Accessible Designs *(for more information, please refer to Chapter 3.3 below)*, whilst User Experience Design Principles were taken into consideration, so that Responsiveness would also be accounted for *(for more information, please refer to Chapter 3.4 and Chapter 3.5 below).*

2.5 Personas

Personas, in "user - centered digital design" are fictional characters composed to illustrate a certain type of user, belonging to the main target users (end users) of the product in question (Lidwell et al., 2010). They, henceforth contribute to the analysis of a product's potential, limitations and end goals, in order to help guide decisions about the product's final morphology (features and interface interactions), as well as its final visual design. In most cases, they result from data, collected during user interviews (Humphrey, 2017). They are presented in 1-page descriptions, including information on the end users' behavior, goals, skills, attitudes, wants, needs, as well as reasons of indignation. The character is additionally framed by fictional personal details, to make the presented personage even more realistic.

Focusing on all 3 of our end users, we, therefore, concluded with the following **3 Personas**, for *howlearn*, as introduced in Fig.3, Fig.4 and Fig.5 below*:*

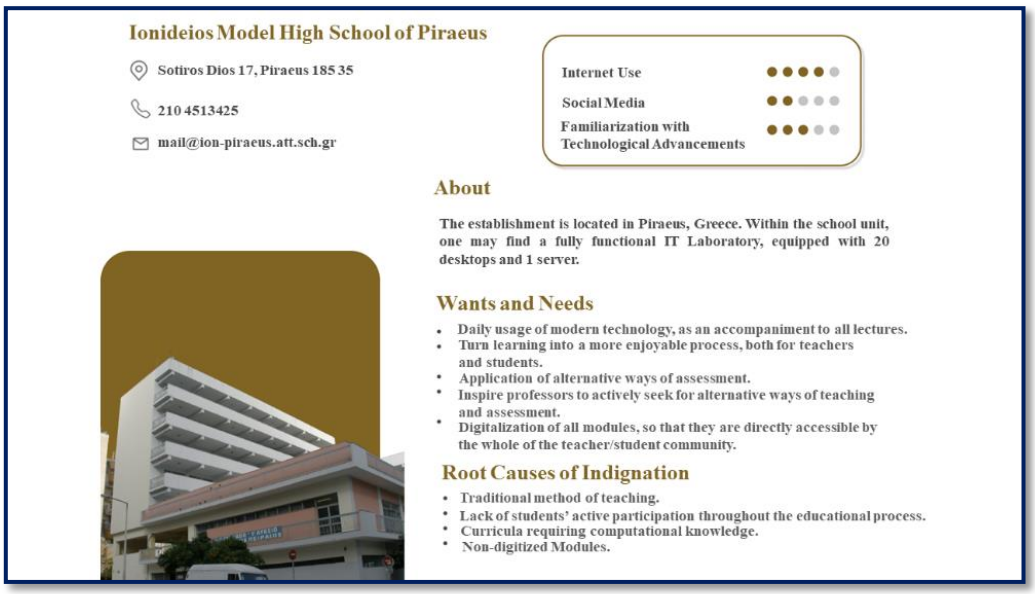

Figure 3: Educational Institution Persona - howlearn.

Source: Authors, 2023.

Figure 4: Instructor Persona – howlearn.

Source: Authors, 2023.

Figure 5: Learner Persona – howlearn.

Source: Authors, 2023.

2.6 Empathy Map - Empathy Map Pills

The **Empathy Map** is a well-known User Experience tool, the main purpose of which, is to offer a unified comprehension of what an end user is looking for in a product, hence providing the appropriate background towards an empathetic product which, primarily focuses on pleasing its users (Gibbons, 2018). It is broken down into four main classes (the so-called "**Empathy Map Pills**"): 1. **Says**, 2. **Thinks**, 3. **Does** and 4. **Feels**.

The center of the Empathy Map includes a user who acts as the sheer representation of the main end user of interest. Every grouping of the map illustrates a close-up to the person's beliefs and sentiments, all presented in non-specific chronological time spans. The first class, "Says", clairvoyantly represents some of the spoken words of the user, as expressed by them, throughout their survey. The second class, "Thinks", includes the thoughts of the user, usually the ones they may not want to publicly express, as a consequence of social factors related to the consciousness of oneself. The third class, "Does", refers to the user's actions and ways of comportment, encapsulating what they do and how they act upon the problem of investigation. Last but not least, the fourth class, "Feels", accommodates the user's state of emotions, with respect to their undergone experience, reason why it mostly provides insights about how they perceive that very experience (Gibbons, 2018).

However, over time, Empathy Maps have evolved so that they succeed in providing even more detailed information on the user's state of being (Gray, 2017). As a result, in addition to the four pre-mentioned classes, it is now common that the following two classes also appear in Empathy Maps: 1. **Sees** and 2. **Listens**.

The first class, "Sees", contains the kind of information that users observe with their own eyes. The second class, on the other hand, "Listens", contains information about what the user is listening to and the ways in which what they are listening to influences their decisions *(i.e. conversations of the user with other users).* Focusing on the four main classes of the Empathy Map, the Empathy Map Pills and the Empathy Map itself *(as presented in Fig.6),* for *howlearn*, may be summarized as follows:

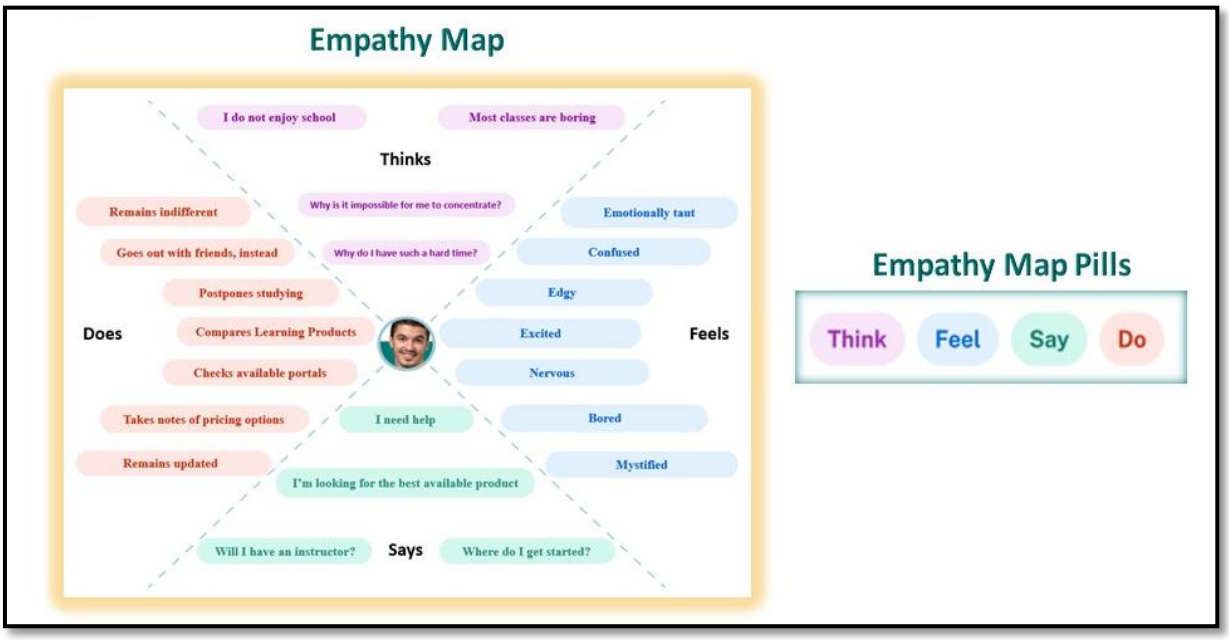

Figure 6: Learner's (one of the End Users of howlearn) Empathy Map and Empathy Map Pills.

Source: Authors, 2023.

2.7 Initial Design

To proceed with the establishment of *howlearn*'s User Experience Design, we followed a thorough exploratory research methodology on its design solution, from beginning to end, the concepts of which are presented below:

2.7.1 Low-Fidelity and High-Fidelity Wireframes

The depiction of the design process of a cross-platform product does not solely lie within the required complex coding and digital interfaces of its User Experience Design. A website **wireframe**, the so-called illustration or screen outline/sketch, refers to a pictorial guide depicting the structural framework of the website's user interface (Brown, 2011). The term arises from fields making use of blueprint skeletons, representing shape, as well as volume in three dimensions (Angeles, 2014). Wireframes are, hence, produced so that screen elements are appropriately arranged to successfully fulfil a specific pre-defined purpose and are conventionally driven by business aspirations. On that account, wireframes concentrate on:

- the span of the website's available functions,
- the general structure, rules and layout of the presented pages and
- the visual outcome of different scripts/scenarios on display (Brown, 2011).

In consequence, a Wireframe outlines the overall functionality, composition and page content of the website in question (Garrett, 2010). Designs are usually initiated with simpler blueprints, the so-called **Low – Fidelity Wireframes**, which might be in paper (**Paper Wireframes**) or digital format (**Digital Wireframes**). More often than not, they do not illustrate extensive graphics, color or typographic styles, since they primarily focus on the overall behavior, functionality and content priority of the website, i.e. on what the screen does and not on what it looks like (Brown, 2011). A website wireframe, hence, connects the underlying conceptual structure, or information architecture, to the visual design of the website (Garrett, 2010). Wireframes, thus, assist the establishment of the overall functionality and relationships between different screen templates of a website.

Creating wireframes is an effective way to make rapid prototypes of pages, while measuring the practicality of a design concept, since they allow us to process the product's implementation, far before we formulate its final realistic model/prototype. This is a crucial step to be taken, since it provides a time and cost effective framework of trials, over designs that will, most probably, be revised multiple times, before they result to the end product.

2.7.2 Low-Fidelity Design vs. High Fidelity Design

Fidelity refers to the level of detail and realism of a Wireframe's or Mockup's design *(for more information, please refer to Chapter 2.7.3 and Chapter 3.2 below).* When designing a Wireframe or Mockup, the Fidelity Level may range from a basic outline on paper, the so-called **Low-Fidelity design**, to a more in-depth – potentially even interactive – application design, the so-called **High-Fidelity design** (Lucid Content Team, 2022).

With respect to Wireframes, as mentioned above, they may be Low-Fidelity or High-Fidelity, depending on the undergone phase/stage of the User Experience. When designing Low-Fidelity Wireframes, sketching is done on paper, whiteboard and/or digital format,

allowing for the definition of the basic outline of the design (Usability First, 2015). Conversely, when designing High-Fidelity Wireframes, more details are included, potentially even portraying simple workflows and interactions between the pages comprising the website/system. In other words, High-Fidelity Wireframes give a better grasp of the design presented via Low-Fidelity Wireframes, since they illustrate a more detailed solution, also incorporating foundational user interactions with the system in question, as well as application flows, such as system login and uncomplicated navigation flows within the website.

Consequently, Low-Fidelity Wireframes were deemed necessary, to easily and quickly visualize, not only the key concepts of our design solution (visual and typographic hierarchies delimiting interactions), but also the navigation process between pages, thus demonstrating the structure of the application's interface. We, hence, proceeded with the conduction of Low-Fidelity Wireframes, in all early design stages of *howlearn*, all of which were revisited, throughout its pilot implementation phases (*as portrayed by howlearn's Usability Study, workflow issues arose during the first pilot release, resulting in partial redefinition of its workflow, in renewed, High- Fidelity Wireframes, leading to the learning system's Mockups – for more information, please refer to Chapter 2.8, Chapter 2.8.1, Chapter 3.1 and Chapter 3.2).*

2.7.3 Paper Wireframes

Our initial Wireframes were encapsulated as Paper Wireframes; a user-centered design process, allowing us to generate design solutions capable of meeting our users' wants and needs, with the intention to develop and test the initially proposed user interface. The idea lies within the concept of producing as many rough and unpolished drawings of the interface in question as possible, which will then be used as models/prototypes, ultimately leading to the Wireframes, Mockups and final User Experience Design of the product. Although a simple procedure, this usability testing methodology *(for more information please refer to Chapter 2.8)* is known to supply useful feedback to aid the design of user-friendly products (Snyder, 2003).

2.8 Usability Study – Usability Study Parameters

Usability Study, more specifically, **Usability Testing** indicates a user-centered interaction design to assess a product by unmediated evaluation on its end users, so that the resulting feedback reflects how the system's users use and feel about the system (Nielsen, 1994). It is, hence, primarily revolved around the design intuitiveness of the product, reason why the latter is tested on a pool of users having no prior knowledge and exposure to it. Such testing methodologies are of predominant importance towards the success of the end system, since a cross-platform product causing skepticism amidst its users will, most certainly, not last long (Mejs, 2019). Thereupon, Usability Testing knuckles down to measuring the capacity of a human-made product to meet its intended purposes, by evaluating the usability *(ease of use)* of a pre-determined set of its objectives.

In our case, therefore, the conduction of a Usability Study was imperative, to examine the interaction of our learning system with its end users, so that adjustments would, subsequently, be applied, to make *howlearn* easier to use, by all its end users (Educational Institutions, Instructors and Learners). The parameters according to which *howlearn*'s Usability Study took place may be condensed as follows, in Fig.7:

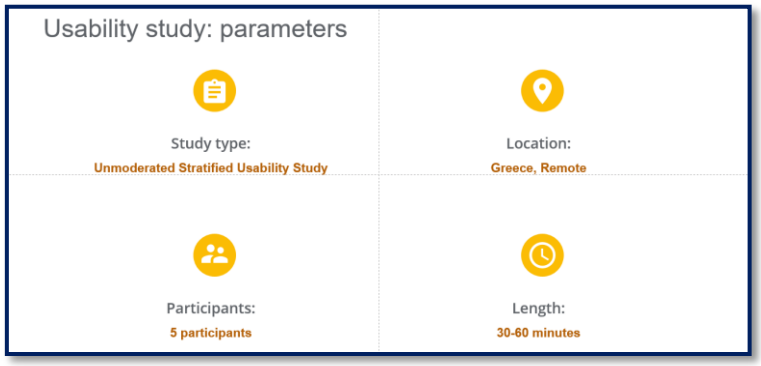

Figure 7: howlearn's Usability Study Parameters.

Source: Authors, 2023.

2.8.1 Round 1 and Round 2 Findings towards the Optimization of the System

Upon completion of the first round of our Usability Study, we concluded to the following refinement actions *(for more information, please refer to Chapter 3.1 and Fig.8 below):*

1. Addition of a "Library of Experiments" Tab/Button.

2. "My Results/Personalized Feedback" Tab/Button amelioration, for easier navigation within the users' Analytics/Results Dashboard.

3. Insertion of a "Repository of 3D Objects" Tab/Button, so that users may easily "drag-and-drop" all available 3D Objects to the "Create New Module" Section.

After the readjustment of our System, based on the findings of the First Round of our Usability Study, we proceeded with a Second Usability Study Round, to investigate further potential aspects of improvement. The following issues arose (the solutions to which, were provided in our Mockups – *for more information, please refer to Chapter 3.1 and Fig.8 below):*

1. Experiments to be filtered according to the Module in which they belong.

2. "Modules Activity" Tab to be inserted, for easier overview of the learners' activity.

3. Different color palettes to be used, as distinctive indicators of the equivalent end user of the System (Educational Institution, Instructor, Learner).

3 Results

3.1 Redesigning the Implementation – Digital Mockups

Wireframes constituted the initial stage of our User Experience Design. However, designing an application or website requires, not only Wireframes, but also a series of tools iterating all of the potential design solutions exhaustively, with each solution assisting

designers in the mapping and visualization process of the design, at different levels of detail and functionality, namely: i. **Wireframes,** ii. **Mockups** and iii. **Prototypes.**

We, therefore, had to proceed with the enrichment of our Wireframes, with stylistic and visual user interface details, so as to have a realistic representation of *howlearn's* web page final design. This new material formatting constituted the so-called "**Mockups**", an example of which is demonstrated in Fig.8 below. While a Wireframe is nothing more than a design, a Mockup is a visual model of our implementation; a static Wireframe, additionally, visually enriched with: i. **colors, styles, graphics and typography**, ii. **buttons and styled text** and iii. **navigation graphics and component spacing** (Lucid Content Team, 2022). Establishing the final interface design was crucial, so that stakeholders would preview its styling options, before turning it into a working prototype *(for more information, please refer to Chapter 3.2 below).*

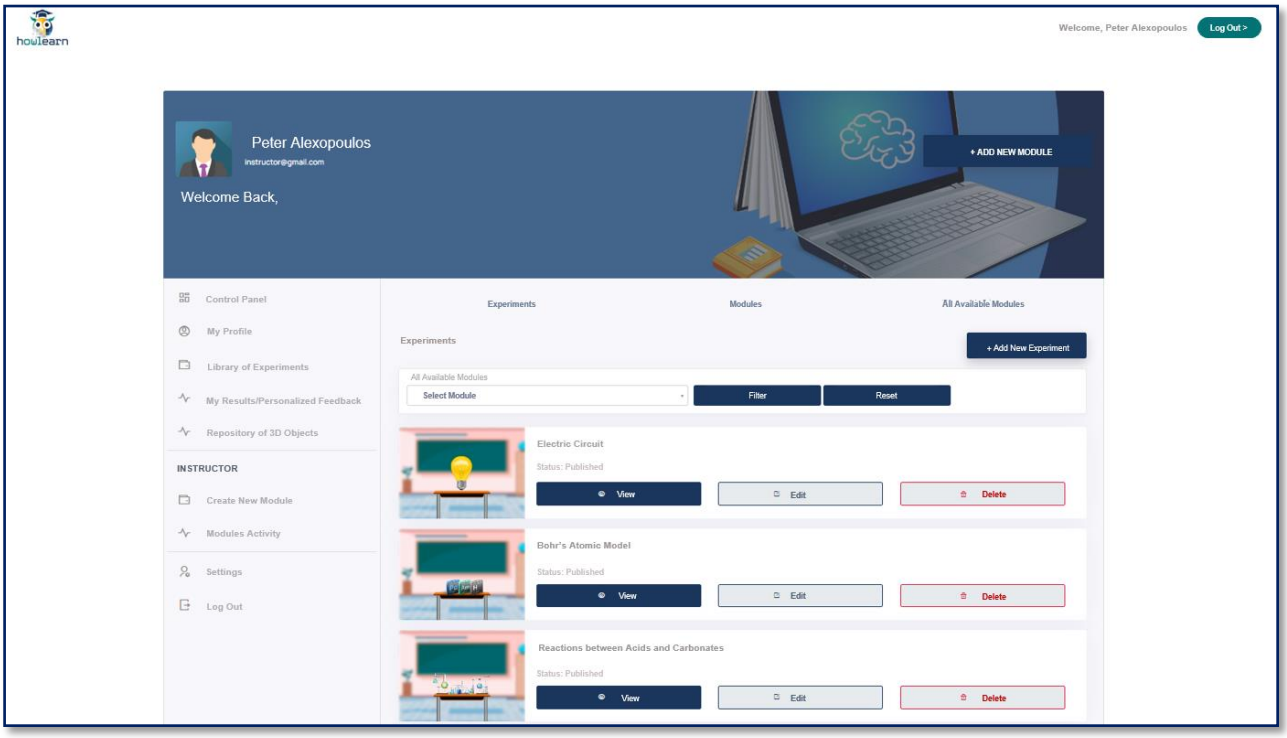

Figure 8: howlearn's Portal: Main Page – Final Design (Mockup), Including a "My Results/Personalized Feedback" Separate Tab, as well as a "Library of Experiments" Tab, a "Repository of 3D Objects" Tab, a "Create New Module" Tab and a "Modules Activity" Tab.

Source: Authors, 2023.

3.2 High-Fidelity Prototypes

A **Prototype** is an early model of a product, built to test the implemented design (Blackwell & Manar, 2015). It is, hence, considered to be a working (non-theoretical), interactive simulation, including all of the stylistic details of the final deliverable, which allows developers to appraise how the product in question works (in terms of bugs, design flaws and general user flow) in a real environment and how usable the suggested design is (Gero, 1990). The ultimate goal of this process is the extensive testing of the design solution,

prior to the investment of money and time in the development process of the full product (Lepore, 2010).

High-Fidelity Prototypes, in particular, are computer-aided and usually incorporate realistic user interactions *(mouse-keyboard)*, thus leading us to a realistic representation of the user interface in question. They are, preferably, being implemented only after an initial brainstorming session has taken place and immediately once the basic structure and outline of the system has been mapped out. Certainly, prior to their assembly, **Low-Fidelity Prototypes** are established, which do not include the additional color, style, typography, spacing and interaction details that the High-Fidelity Prototypes do. High-Fidelity Prototypes were, hence, implemented within *howlearn*, as a means towards the successful, realistic, model visualization of its design and overall *usability*. Since High-Fidelity Prototypes are no longer static but functional representations of the System, "Interactions Flow Charts", allowed for the holistic representation of all of the System's navigational flows.

3.3 Accessibility

Apart from all the functional and technical details accompanying the User Experience Design Process of our implementation, additional importance was given to the compliance of the System with the WCAG 2.1 ("Web Content Accessibility Guidelines"), as established by the Worldwide Web Consortium ("W3C") initiative. These guidelines ensure that the content is accessible to a wider spectrum of people with disabilities, such as low vision, color blindness, photosensitivity and combinations thereof.

In summary, with foreground and background colors required to possess a contrast ratio of 4.5:1 at Level AA and a contrast ratio of 7:1 at Level AAA, it falls into place that, in *howlearn's* case, the entire User Experience of the Integrated Educational Learning System is fully compliant with the WCAG ("Web Content Accessibility Guidelines"), accumulating a score of **AAA – "Excellent"** *(color palette: #FFC845 #1B365D #007478 #FFFFF #00000).*

3.4 User Experience Design Principles - Overview

User Experience Design Principles constitute the frameworks within which, the appropriate selection, creation and organization of the User Experience elements and features of a specific product of investigation, ultimately, lead to easy-to-use, user-friendly designs (Masooma, 2019). The User Experience Principles based on which *howlearn* was substantiated, may, thence, be abridged as follows in Fig.9 (Google UX Design Professional Certificate, 2023):

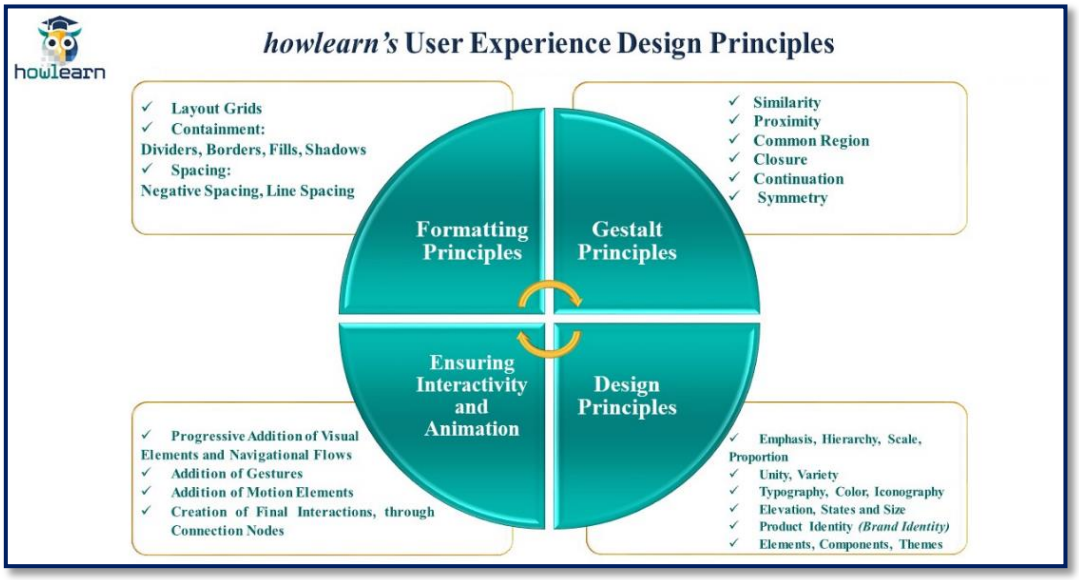

Figure 9: howlearn's User Experience Design Principles.

Source: Authors, 2023.

3.5 Responsive Web Design for Mobile Screens (Android – iOS) and Advantages of Responsive Web Design

Responsive Web Design (Responsive Design in short) appertains to the subsection of web design concentrated on the dynamic and immediate adaptation of a web page, on a variety of potential devices or screen sizes, from minimum to maximum display size, to ensure usability and contentment (Marcotte, 2010 – Schade, 2014). Thusly, when a user navigates a Responsive website using, for instance, their smartphone, the website will be laid out in such a way that they need not zoom in or tilt their device, to access its content easily. Consequently, thanks to Responsive Design, a website will, automatically, simultaneously, function as a web application, when accessed from a mobile device (i.e. iPhone, iPad, Android), which greatly enhances the product's convenience and potential sustainability, especially nowadays, that internet browsing, via mobile devices, has taken over.

Responsive Web Design was applied upon *howlearn (for more information, please refer to Fig.10 below),* to ensure maximum usability and contentment, regardless of the user's device of access. Through its implementation, the subsequent benefits were additionally guaranteed:

- Uncomplicated Updating Process: it is no longer necessary to maintain/update two distinctive websites (a website for computers and an application for mobile devices); a central website is all that is required *(making the implementation time-effective and cost-effective).*
- Increase in Usability and Time Spent on the Website: A user's stay on the website is proportional to the ease of browsing that very website; when the website is Responsive, the chances of the user spending a consistent amount of time browsing all of the product's services, from all of its available screen sizes, are much higher.
- Adaptability: A Responsive website is capable of adapting to any resolution, making the product more accessible to all of its potential users.

• Cost: Responsive Design solutions are cost-effective, when compared to their "separate websites for each available device" counterparts *(since only a central website is required).*

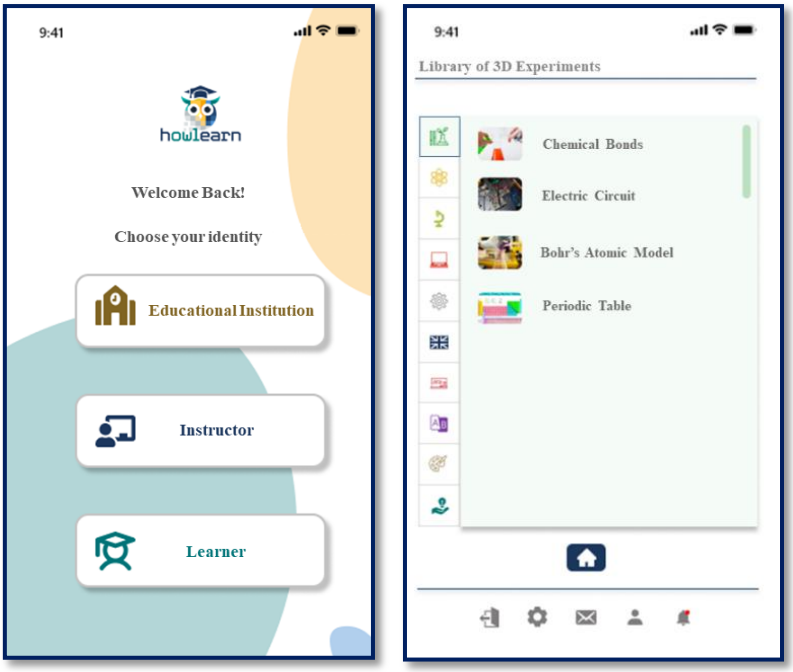

Figure 10: howlearn's Responsive Design Mockups, for iOS Screens (iPhone SE).
Source: Authors, 2023.

3.6 User Experience Design within *howlearn*'s Virtual Spaces - Unity Game Engine

Nevertheless, *howlearn*'s User Experience Design does not solely touch upon the formation of an appealing cross-platform product; the ease-of-use, desirability, usefulness and responsiveness of the implementation is also holistically applied within the game engine's educational Experiments. Below, we present a snapshot from our "Library of 3D Experiments", concerning the fulfilment of a Biology Experiment, on the Composition of Human Cell, as demonstrated in Fig.11:

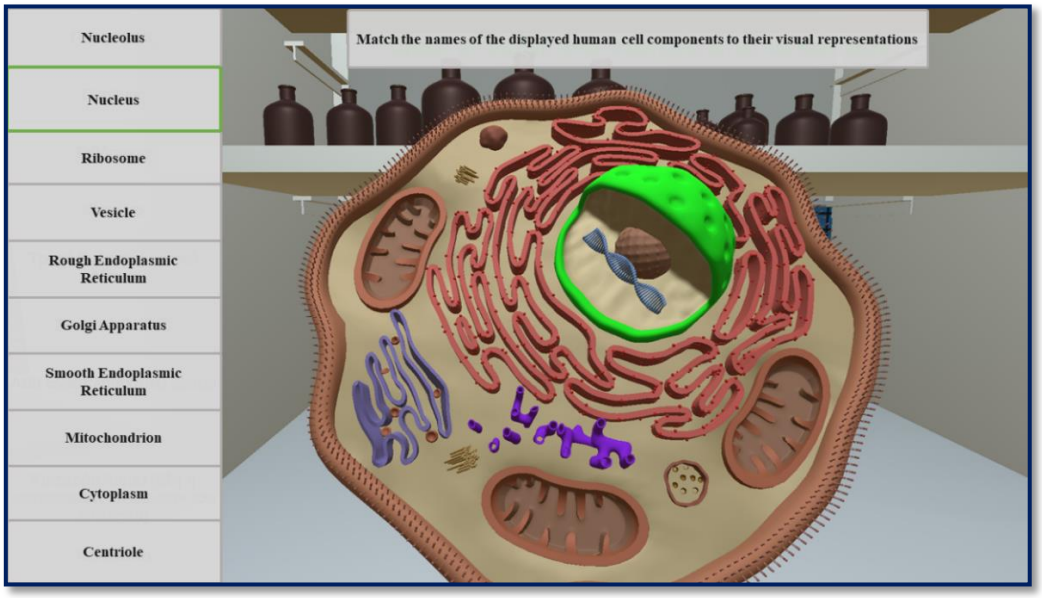

Figure 11: 3D Biology Experiment: Composition of Human Cell, within howlearn's Virtual Biology Lab. Source: Authors, 2023.

4. Conclusion

The User Experience Design of the innovative educational learning system *howlearn*, initially focused on the definition/extensive overview of its Subsystems and the innovation within them, as well as the designation of its end users. An extensive User Research was, then, employed, which transformed users' opinions, on the importance of Gamified Education as a Teaching Support System, in information, insightful enough to demonstrate how users would manage to optimally interact with the respective product. This process enlightened the subsequent delineation of the System's Personas, as well as their equivalent Empathy Maps, upon the insights of which, the implementation's target goals emerged.

Upon completion of the aforementioned steps, we prosecuted the design stage, which included the creation of Paper Wireframes and their subsequent conversion into Digital Low-Fidelity Wireframes. The latter revealed the necessity to perform a Usability Study, out of which, considerations for aspects of further investigation/improvement emerged. The next step was, therefore, the redesign of the design solution, through Digital Mockups and High-Fidelity Prototypes, the latter of which, additionally, denoted all of the users' potential interactions with the System/product.

Nonetheless, to ensure that the educational learning product in question would be convenient, uncomplicated and suitable for all its end users, supplementary actions had to be taken, so that, not only would its Accessibility be ensured, but also its harmonization with the User Experience Design and Responsive Design Principles would be guaranteed.

The product's multiple design revisions permitted us to reach its final configuration, which, now, fully demonstrates the complexity and multidimensionality of the User Experience Design of an innovative learning system, ultimately, serving a multitude of educational needs, with regard to its target audience (Educational Institutions, Instructors and

Learners), hence, constituting an initial attempt towards multidimensional, inclusive, socially sustainable, innovative, learner-centered Education (Raftopoulou & Pallis, 2023).

Nevertheless, since there is always space for further improvement, especially when applying state-of-the-art technological advancements, which are, typically, being updated regularly and systematically, the succeeding actions have been routed:

✓ Responsive Design to be employed for Tablet screen sizes, so that *howlearn* reaches a greater audience *(this will further eliminate socio-economic boundaries related to Educational Institutions or Learners who may not easily gain access to computers/large devices).*

✓ Expansion of the educational learning system's Accessibility features, to additionally account for hearing loss impairment.

✓ Conduction of First Official Pilot Release, so that the System's Subsystems are evaluated *(through questionnaires and interviews)* and reparametrized, according to user insights and the exhaustive analysis of their data. The evaluation will focus on the assessment of the degree of the learning system's adaptation to the personalized needs of its users, the apprehension of which, will exemplify the potential Machine Learning Algorithms leading to the formulation of *howlearn*'s Optimal Custom Recommendation Systems and its further Personalized Feedback Report Dashboard customizations.

✓ Second Official Pilot Release and final configuration of the System, for the assessment of its overall readiness and it functionality as a state-of-the-art collaborative educational learning system.

Acknowledgment

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