TRACKING LEARNING WITH EXPERIENCE API

by

DESPOINA ARVANITI

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Major Professor
Dr. Konstantinos Vassilakis

Abstract

The rapid development of the Information and Communication Technology (I.C.T.) has changed the way people live and learn. In education, the growing need to use distance learning, has made it imperative to use e-learning platforms that will support asynchronous distance learning.

For this purpose, a wide range of valuable educational information systems (e-learning platforms) have been developed and can be found on the internet. E-learning platforms add flexibility to the educational process, offering a variety of ways of learning outside of the strict spatial boundaries of the classrooms.

The volume of data produced by these platforms and generally through e-learning is very large and this has made it imperative to use them effectively, so that valuable conclusions can be drawn from them. This has contributed to the development of the fields of Educational Data Mining and Learning Analytics, which aim to improve the quality of education offered as well as the learning that takes place through it.

The data that are produced by students' activities, can be captured from diverse sources through the use of various authoring tools that adopt Experience API (xAPI) specification. This specification tracks the interactions that users have with learning resources and give to instructors valuable information about their perfomance.

In the context of this thesis, we developed an adaptive learning system that supports self-regulated learning and implemented it with the use of game elements. Students through interactive activities are acquainted with Scratch 3 environment in order to increase their knowledge and their ability to develop their own programs.

This learning system is accessible via web-browser from computers, tablets and smartphones. It is aimed at students of the fifth grade of Primary School in order to track their experience. The content is interactive, and the produced data are sent to a Learning Record Store (LRS). Through the Dashboard (a visual display with a combination of charts), these data are monitored and represented with charts where conclusions and decisions can be made from these.

Keywords: Learning Analytics, xAPI specification, adaptive learning system, gamification, self-regulated learning, adaptivity, computational thinking, Scratch 3.0.

Περίληψη

Η ταχεία ανάπτυξη της Τεχνολογίας Πληροφοριών και Επικοινωνιών (Τ.Π.Ε.) έχει αλλάξει τον τρόπο που ζουν και μαθαίνουν οι άνθρωποι. Στην εκπαίδευση, η αυξανόμενη ανάγκη χρήσης της εξ αποστάσεως εκπαίδευσης, έχει καταστήσει επιτακτική τη χρήση πλατφορμών ηλεκτρονικής μάθησης που θα υποστηρίζουν την ασύγχρονη εξ αποστάσεως εκπαίδευση.

Για το σκοπό αυτό, έχει αναπτυχθεί ένα ευρύ φάσμα πολύτιμων εκπαιδευτικών πληροφοριακών συστημάτων (πλατφόρμες e-learning) που μπορούν να βρεθούν στο διαδίκτυο. Οι πλατφόρμες e-learning προσθέτουν ευελιξία στην εκπαιδευτική διαδικασία, προσφέροντας ποικίλους τρόπους μάθησης εκτός των αυστηρών χωρικών ορίων των τάξεων.

Ο όγκος των δεδομένων που παράγονται από αυτές τις πλατφόρμες και γενικά μέσω της ηλεκτρονικής μάθησης είναι πολύ μεγάλος και αυτό έχει καταστήσει επιτακτική την αποτελεσματική χρήση τους, ώστε να εξαχθούν πολύτιμα συμπεράσματα από αυτές. Αυτό συνέβαλε στην ανάπτυξη των τομέων του Educational Data Mining και των Learning Analytics, που στοχεύουν στη βελτίωση της ποιότητας της προσφερόμενης εκπαίδευσης καθώς και της μάθησης που πραγματοποιείται μέσω αυτής.

Τα δεδομένα που παράγονται από τις δραστηριότητες των μαθητών μπορούν να συλλεχθούν από διάφορες πηγές μέσω της χρήσης διαφόρων εργαλείων συγγραφής που υιοθετούν την προδιαγραφή Experience API (xAPI). Αυτή η προδιαγραφή παρακολουθεί τις αλληλεπιδράσεις που έχουν οι χρήστες με τους εκπαιδευτικούς πόρους και δίνει στους εκπαιδευτές πολύτιμες πληροφορίες σχετικά με την απόδοσή τους.

Στο πλαίσιο αυτής της διπλωματικής εργασίας, αναπτύξαμε ένα προσαρμοστικό περιβάλλον μάθησης που υποστηρίζει την αυτορρυθμιζόμενη μάθηση και υλοποιήθηκε με χρήση στοιχείων παιχνιδιού. Οι μαθητές μέσα από διαδραστικές δραστηριότητες εξοικειώνονται με το περιβάλλον Scratch 3 προκειμένου να αυξήσουν τις γνώσεις τους και την ικανότητά τους στο να αναπτύσσουν τα δικά τους προγράμματα.

Το περιβάλλον μάθησης είναι προσβάσιμο μέσω προγράμματος περιήγησης ιστού από υπολογιστές, ταμπλέτες και έξυπνα κινητά τηλέφωνα. Απευθύνεται σε μαθητές της Ε΄ Δημοτικού, προκειμένου να παρακολουθήσουμε την εμπειρία τους. Το περιεχόμενο είναι διαδραστικό και τα δεδομένα που παράγονται, αποστέλλονται σε ένα Learning Record Store

(LRS). Μέσω του πίνακα ελέγχου (μια οπτική απεικόνιση με συνδυασμό γραφημάτων), αυτά τα δεδομένα παρακολουθούνται και αναπαρίστανται με γραφήματα όπου μπορούν να ληφθούν συμπεράσματα και αποφάσεις από αυτά.

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Acknowledgements

With the completion of my postgraduate studies, I would like to thank warmly all those who contributed to this achievement. At first, I would like to express my gratitude to the supervising professor of my dissertation, Mr. Konstantinos Vassilakis, for the trust he has shown in me as well as his valuable guidance. I would also like to thank Mr. Michael Kalogiannakis for his advice and suggestions.

Dedication

To my family

Introduction

In recent years, the development of technology in the fields of Information and Communication Technology (I.C.T.) has opened new horizons in education. The educational process has been enriched with a wealth of educational tools that enhance learning.

At the same time, the emergence of the Covid-19 pandemic has changed the way in which the educational process takes place. The suspension of in-school education at all levels made the adoption of distance education imperative. On the one hand, educational organizations (schools and universities) utilized electronic platforms to carry out distance learning. On the other hand, students and teachers became familiar with means and tools that meet the demands of the new situation.

Thus, nowadays e-learning has been widely adopted in formal, non-formal and informal education, leveraging technologies and methodologies to make learning more interesting and efficient. A particularly useful tool for the evolution of e-learning is Learning Analytics. Educational organizations develop and use Learning Analytics systems to improve understanding of how students learn and to support this process to achieve high learning outcomes. With Learning Analytics, students enjoy a unique learning experience tailored to their own needs and preferences.

xAPI is a Learning Analytics specification used to capture the learning experience of students as they interact with educational activities. These activities create activity streams called xAPI statements. XAPI statements are a structured form of data that describes what a user experiences through the learning process. In the xAPI architecture, the Activity Provider creates xAPI statements that are sent for storing in a database called Learning Record Store (LRS). The LRS provides access to xAPI statements, which are leveraged by Activity Consumers that use user experiences derived from xAPI data.

In this way, we access and monitor the experience of students when they interact with electronic systems and learning platforms. It is of paramount importance that the educational process experienced by the students be interesting and lead to the desired results. A technique widely used to achieve these goals is gamification.

Gamification utilizes game elements in education to make the educational process more interesting and engaging. Some of the game elements to consider when designing a system that uses gamification are points, badges, and leaderboards. Their application in the educational process strengthens children's interest and motivation to learn.

Apart from the entertainment elements, a modern system should support adaptivity. In other words, the system should have the ability to adjust its content according to the user's results and his interactions with the learning activities. The system must have variety in the presentation of the educational object, so that depending on the performance of the student, it can choose the form of the presentation that is most effective for each student. Furthermore, it must have different levels of depth in the subject, depending on the needs of each student. The system must detect the weaknesses or strengths of the student and offer them corresponding support material. Such a system in its design should take into account, among other things, the student's cognitive background and learning style.

During the educational process, in addition to knowledge, students should acquire all the necessary supplies and develop all those abilities and skills that will allow them to meet the demands of the time. In this context, it is particularly important that students acquire self-regulation skills and develop Computational Thinking.

Self-regulated learning enhances the educational process by enabling students to participate actively in learning as well as to cultivate self-regulation skills such as goal setting, observation and self-evaluation. Computational Thinking is considered a skill with which the students of the 21st century must be equipped from compulsory education. This skill is not only necessary in computers but also in everyday life, helping students to find solutions to different kinds of problems.

Despite the rich literature and scientific research that exists in the above areas, one area that we believe has not been sufficiently explored is the cultivation of Computational Thinking, through self-regulated learning in primary education. The aim of this thesis is to develop an adaptive learning system that supports self-regulated learning using game elements.

More particularly, through the system that we will develop we want to investigate the degree of student response to tools developed with this approach and the knowledge they acquired. The answers that will be recorded will give us valuable information about what and how students learn when they work in systems that support self-regulated learning.

In this system, through interactive learning activities containing text, images and videos, students cultivate Computational Thinking through their engagement with programming, using Scratch 3. This system is adaptive, meaning that the content presented to students adapts to the results they achieve in the activities included in it.

Additionally, in this system we have a very good application of self-regulated learning where students actively participate in the acquisition of knowledge and are in control of the flow of content. Here, the students' self has a primary role, as it is the one that dominates their learning and behavior, in order to achieve the goals they have set. In addition, by completing a unit, they decide whether to proceed to the next new unit or return to another unit they have already attended.

Our thesis is structured as follows. Part A contains the theoretical background of our work and it consists of six chapters. More specifically, Chapter 1 presents Learning Analytics, Chapter 2 xAPI specification, Chapter 3 Computational Thinking, Chapter 4 Gamification, Chapter 5 Adaptivity and Chapter 6 Self-regulated learning.

Part B presents the implementation of our learning system and it consists of four chapters. More specifically, Chapter 7 presents the learning system, Chapter 8 the learning content, Chapter 9 the Website and Chapter 10 the evaluation.

In Chapter 11 there is a discussion of the results of this thesis, and in Chapter 12 the conclusions drawn are presented. The bibliography and appendices follow. In appendix A we present in detail the units of the educational game and in appendix B we list technical details from the implementation of the system.

Part A: Theoretical Background

Chapter 1 - Learning Analytics

People in their everyday activities produce a very large amount of data known by the term ‘Big Data’. Big data is found in large quantities that are constantly growing, in various file formats like photos, videos, personal or location data, produced by diverse sources (Commission & Consumers, 2018; National Research Council, 2010)

In the field of education, the number of educational data produced by learners, through the use of educational environments such as LMSs, VLEs, PLEs, MOOCs, etc is increasing daily, creating the need to make better use of this data. That will offer valuable information to teachers and better learning experiences to their students.

Regarding the use of big data for educational purposes, the methods and tools for their collection and analysis that have been developed are Educational Data Mining and Learning Analytics.

Originally, these methods measure, collect and prepare data in order to be processed during the learning activities. Afterwards, these data are analyzed and decisions are made based on the results obtained from the above procedure.

Although these areas have much in common, they have substantial differences. Bienkowski, Feng and Means (2014) note that “Generally, educational data mining looks for new patterns in data and develops new algorithms and/or new models, while learning analytics applies known predictive models in instructional systems.”

Both scientific fields have been established in recent years and have a wide range of applications. In this thesis, we will focus on Learning Analytics.

1.1 Definitions

Many definitions have been given for Learning Analytics. The definition most adopted by researchers is based on the definition presented in the ‘1st International Conference on Learning Analytics and Knowledge’ where Long, Siemens, Conole, & Gašević (2011), defined that “Learning Analytics is the measurement, collection, analysis and reporting of data

about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs".

Another definition for Learning Analytics is from Erik Duval "Learning Analytics is about collecting traces that learners leave behind and using those traces to improve learning" ("Learning Analytics and Educational Data Mining | Erik Duval's Weblog," n.d.).

From the aforementioned definitions, we conclude that Learning Analytics have to do with the learners and the way they learn. According to the cycle for Learning Analytics that Clow (2012) proposed, the starting point of the cycle is the **learners**, who can be students who attend a course in either formal or informal education. These learners generate data through their interaction with educational environments, which **data** is the second point of the cycle. Then, after the data are collected, they are processed at the third point of the cycle so that the **metrics** emerge in order to have a better awareness of how the learners learn. The circle closes with the fourth point that concerns the interventions made to the students in order to achieve the desired results. This point can be omitted, but the whole process will not have the desired results.

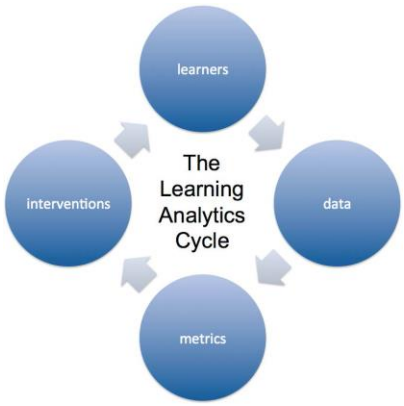

Figure 1.1 The Learning Analytics Cycle (Clow, 2012)

1.2 Goals and Objectives

According to Elias (2011), "Learning Analytics seeks to increase analytical skills, predict behavior, predictive pedagogical action, and then feedback the education system with these outcomes to improve predictions over time of the learning".

The goals and objectives of Learning Analytics differ depending on the point of view of each interested party, called 'stakeholder'. For example, from the side of a student, his purpose

is to know how the data he produces through a learning environment will be used in order to try to improve his grades and achieve his goals.

From the side of a teacher, the goal is to be informed about the performance of his students, if the teaching practices that follow have the desired results, which students succeed and which students are at risk.

Depending on the level of education, there may be other stakeholders, such as the staff involved in the training process, school directors, managers, inspectors and policy makers (Lepouras, Katifori, Vassilakis, Antoniou, & Platis, 2014; Gaftandzhieva, Docheva, & Doneva, 2020).

The Society for Learning Analytics Research (SoLAR) presents several of the most commonly accepted goals of Learning Analytics ("What is Learning Analytics? - Society for Learning Analytics Research (SoLAR)," n.d.) in which it:

- Assist students to develop all the necessary competencies that will enable them to learn throughout their lives.
- Provide to students individualized and on time response according to their actions.
- Support students to develop significant abilities in order to be able to collaborate and communicate with others, think critically and be creative.
- Sensitize students by encouraging them to know thyselves.
- Help teachers to provide quality transmission of knowledge by informing them about whether they have succeeded to be innovative in the field of pedagogy.

Hisham, S. R. A. S. B, Md Fadhil, M., & Rasul, N. (2019) highlight some other probable objectives of Learning Analytics, in which they aim to:

- Monitor and analyze the data that are produced by students through the learning environments so that decisions can be made from the reports that are generated.
- Predict and intervene; predict the student's future performance based on his current performance in order to intervene in case a student will need support.
- Tutor and mentor students that need support either in the educational process or in the provision of guidance for their personal and academic development.
- Evaluate and give feedback to students in order to be more effective and efficient when learning taking into account the feedback of those involved in the learning process.

- Adapt the educational material based on a clear reflection of the results of the student activity given by Learning Analytics.
- Provide a personalized approach to the learning process in order for the learning environment to meet student's individual requirements. The recommendations that will be given by this will help students to choose for themselves the way in which they will learn based on their needs.
- Help students reflect on their current work and experiences to improve their future experiences and didactic actions.

1.3 Learning Analytic Methods

In the context of Learning Analytics, the analysis of the data that are generated by the learners is based on four principal methods: Descriptive, Diagnostic, Predictive and Prescriptive Analytics.

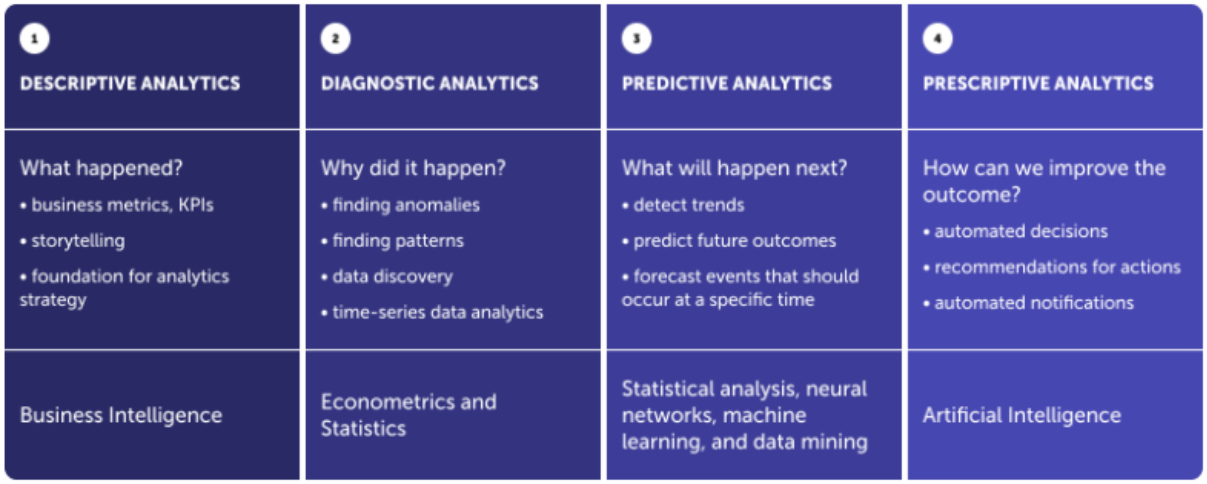

Figure 1.2 Methods of Learning Analytics (Khokhlova, 2021)

- **Descriptive Analytics** provides answer to the question "what happened?" utilizing techniques of “data aggregation and data mining” (“What is Descriptive Analytics? Definition & Examples,” 2019). It gives us a detailed picture of what a learner did in the past, generated from his interaction with the online systems. The generated raw data are related with his attendance, the grades he received, the reports compiled for him by the teachers, etc.

- **Diagnostic Analytics** provides answer to the question "why did it happen?" considering the Descriptive Analytics and help us investigate patterns in the aforementioned data. It gives us the opportunity to evaluate why an outcome has emerged using techniques such as “drill-down, data discovery, data mining and correlations” (Gartner Inc., 2016).
- **Predictive Analytics** provides answer to the question "what will happen?" and refers to what may happen in the future. It is a process with which we extract info from large data sets with the intention to estimate future results (Larose & Larose, 2015). It is based on models that evaluate historical and new data using algorithms and machine learning to make forecasts. These models include: Decision trees, Regression techniques and Neural networks (“What is Predictive Analytics? How does it work? Examples & Benefits,” 2019).
- **Prescriptive Analytics** provides answer to the question "what should I do?". Making use of the data derived from the aforementioned methods it helps users to define which actions can be taken in order to efface a problem that may appear in the future. It is “characterized by techniques such as graph analysis, simulation, complex event processing, neural networks, recommendation engines, heuristics, and machine learning” (Gartner Group, 2017).

1.4 Data quality

As is already known, learners generate a wide range of educational data as they interact with e-learning systems. The volume of this data is very large and many questions arise as to whether this data is qualitative. As stated in (“Data quality - Wikipedia,” 2021) “There are many definitions of data quality, but data is generally considered high quality if it is “fit for [its] intended uses in operations, decision making and planning”.” Giving a definition for data quality is not an easy process because of the numerous of contexts in which data is used and the point of view faced by interested users each time.

Siemens (2013) denotes that the most important challenges in educational analytics are not technical and highlights the concerns associated with data quality. It is critical to understand that raw data quality has a significant impact on analytics quality and its metrics. The collection

of raw data coming from the learning process in accordance with the goals that have been established is transformed to metrics.

These metrics will then be further elaborated to draw conclusions. If these metrics are bad then educators will be led to wrong conclusions and consequently to wrong interventions. This will result in distrust of the decision-making process based on these data.

It is obvious that data quality matters. In order for the data to be qualitative it must have some features like: accuracy, auditability, completeness, conformity, consistency, coverage, duplication, integrity, security, specifications, timeliness and uniqueness (Mihăiloaie, 2015). According to Cichy & Rass (2019) the most commonly accepted and used are: completeness, consistency, timeliness, accuracy and accessibility.

Completeness is related to whether all available data has been gathered and the data set is complete. With **consistency** the data that are gathered from every system of an organization must represent the same info. **Accuracy** denotes the degree to which data represents something that actually exists. **Timeliness** indicates that data has been gathered at the right time and is available to be used effectively. Finally, **accessibility** specifies in what degree information is accessible and can be retrieved with an easy and fast way.

1.5 Ethical and personal data protection issues

As already mentioned, a large amount of digital traces and metadata are produced and gathered during the everyday usage of the devices connected on the internet. In education, the collection and use of digital traces and metadata produced by learners' interaction with educational environments has allowed educational institutions to understand their learning needs in order to make the appropriate interventions. However, this entails many ethical issues and challenges.

Ethical issues have been attracting the attention of researchers for many years, beginning with the 2nd International Conference on Learning Analytics and Knowledge (LAK '12) where articles containing references to ethical issues were presented (Drachsler & Greller, 2012;Prinsloo et al., 2012).

Slade and Prinsloo (2013) acknowledged three wide subject areas of ethical issues that often overlap each other: "the location and interpretation of data; informed consent, privacy,

and the deidentification of data; the management, classification, and storage of data.". They suggested several principles that can be used as a guide to ethical practice in Learning Analytics: The first one considers Learning Analytics as a moral practice that focuses on what is proper and ethical essential. The second one focuses on the fact that students should participate as partners and not as passive recipients of interventions and services. The third one treats the identity and the performance of students, as dynamic constructions, which change over time and in different contexts. The fourth one presents student success as a multidimensional phenomenon. The fifth one emphasizes that transparency is important in terms of the purposes and conditions under which the data will be used, who will have access to data and how the protection of individual's identity is achieved. Finally, the sixth one stresses the need of using learning analytics in higher education institutions.

When learners interact with an educational environment, they should feel safe during this interaction. This means that this environment should respect their mistakes and no discrimination of any kind will take place within it. There should be respect for the privacy of their data as well as the way it is managed. At this point a distinction should be made between ethics and privacy. Drachsler & Greller (2016) point out that "ethics is the philosophy of moral that involves systematizing, defending, and recommending concepts of right and wrong conduct. In that sense, ethics is rather different to privacy". On the other hand they stress that "privacy is a living concept made out of continuous personal boundary negotiations with the surrounding ethical environment".

Ethics and personal data protection issues should be taken into account in all educational environments related to Learning Analytics at all levels of education; in primary, secondary and higher education. At the micro level of a classroom of a school or university with a small number of learners, it is possible to manage easily the systems addressed to either teachers or learners, if certain recommendations are followed.

It is worth noting that even Berners-Lee (2017) the inventor of the internet drew our attention to 3 trends that came to the foreground. One of them states that "We've lost control of our personal data". Among other things, he emphasizes that our personal data is collected, with our consent, from the websites we visit in exchange for free access to their content. As a result, on the one hand we lose control of our data so that we cannot choose with whom to share it and on the other hand, companies and governments monitor our movements on the Internet.

Jisc (2015) addressed the Code of Practice for Learning Analytics, so that educational institutions consider it when designing their educational environments. This Code consists of the following eight areas:

Responsibility: it must be determined who will be responsible for the proper and efficient use of Learning Analytics. It must be allocated who will be in charge of components like data collection, analysis, interventions, etc. in the classroom while stakeholder representatives should be asked about Learning Analytics issues.

Transparency and consest: involved stakeholders must be informed about what data will be collected from them and how it will be analyzed and presented. In addition, learners must be asked for their consent in order to collect and use their personal data.

Privacy: there should be a restriction on access to learners' data only to those who will legally need to do so. Also, special emphasis should be given to maintaining the anonymity of the users. In case of disclosure of the data to third parties, additional consent must be requested.

Validity: the data collected by the institutions must be of high quality, broad and valid. The analysis will be done in such a way as to ensure the correct use of Learning Analytics and to understand that the existence of inconsistencies, inaccuracies and false correlations will act to the detriment of the quality of the collected data.

Access: all learning analytics done on learners' data should be available in comprehensible and accessible form, and learners should be able to correct data that are not accurate and receive copies of this data in a portable digital format.

Enabling positive interventions: it must be specified who and how will make the interventions when Learning Analytics reveal that a learner maybe needs more help. Resources should be allocated in such a way that learners can be treated differently depending on their needs.

Minimising adverse impacts: it should be understood that Learning Analytics cannot fully depict the learning of each student and it should be ensured that there will be no bias of any of the stakeholders towards the learners.

Stewardship of data: there must be compliance of the data for Learning Analytics with the data policies implemented by the institutions and the DPA.

At the macro level of education, such limitations and issues should be taken into account when Learning Analytics are utilized by the institutions of a country that formulates

educational policies using the demographic data of the people that make up the educational community.

As one can conclude from the above, the need to develop valid and reliable Learning Analytics is of utmost importance. This has led to the production of ethics frameworks in order to identify any weaknesses in the process and correct them, developing a collection of rules and instructions in practical matters of ethics.

One of the first frameworks in Learning Analytics with an emphasis on ethics developed by Slade and Prinsloo (2013) followed by JISC in 2015, which developed the Code of Practice, as both stated above. Subsequently took place the development of the DELICATE checklist (Drachsler & Greller, 2016), the SHEILA Framework (Tsai et al., 2018) and "a set of guidelines for ethically-informed practice that would be valuable to all regions of the world" by International Council for Open and Distant Education (ICDE) (Slade & Tait, 2019).

On May 24 2016 entered into force a regulation and applies since 25 May 2018, for the "protection of natural persons with regard to the processing of personal data and on the free movement of such data" called GDPR (General Data Protection Regulation) ("Data protection in the EU," n.d.). The processing of personal data should be supervised by the following principles (Regulation, 2018):

- the people for whom the data is collected should know what data is collected and why,
- the collection of data should be carried out only for specific purposes,
- the data being processed should be the least possible,
- the data being processed should be complete and accurate,
- the collected data should be kept for the shortest possible period of time,
- all necessary measures should be taken so that during the processing of the data there will be no access to persons who do not have an official permission and who intend to destroy and cause damage to them.

1.6 Learning Analytics Specifications

Many Learning Analytics specifications have been developed over time and with the evolution of technology. IMS Caliper Analytics, IEEE Standard for Learning Technology and xAPI are some of them.

IMS Caliper Analytics is a Framework that enables educators to track and make use of the interactions that learners have during their course engagement in an educational environment It designates a way that institutions and corporations will make use of its platform, how to utilize the collected data and assess their efficacy. It utilizes all the means that standards of IMS Global afford so that all transfers are made in the best possible way (Gera, 2021).

This specification makes use of the triplet: “Actor” -“Action”- “Activity”. The “Actor” stands for the agent that carries out an action, the -“Action” refers to the action itself and the “Activity” corresponds to the action's focus (Batchakui, Djotio, Moukouop, & Ndouna, 2021).

Its information model sets a range of notions, principles, and relations in order to describe the actions that learners take. These actions are described with Caliper Profile (annotation, forum, session, etc.) which consists of Event Types, where stakeholders engage in activities defined by a vocabulary. The model also delivers Entity types (agent, attempt, result, etc.) to help explain the interacting relations among participants and elements (“Caliper Analytics 1.2 Specification | IMS Global Learning Consortium,” 2020).

The IEEE Standard for Learning Technology (IEEE 1484.11) is a specification that is based on “the Content Management Instruction (CMI) specification, a set of guidelines for interoperability between web courses and the LMS. The CMI provides both a data structure for student interactions with learning contents as well as an API for managing these data”. It is composed of two sections: the IEEE 1484.11.1 and the IEEE 1484.11.2. The first one describes the data model and the second one the communication (Del Blanco, Serrano, Freire, Martinez-Ortiz, & Fernandez-Manjon, 2013).

The xAPI (experience Application Programming Interface) specification is described in detail in the next chapter.

Studying the characteristics of the above specifications for learning analytics we identify several differences between them (Del Blanco et al., 2013; Griffiths & Hoel, 2016) which lead us to the conclusion that xAPI excels in many areas. Apart from its other features,

its flexibility, its simplicity and its ability to adapt were the main reasons that led us to us to choose and adopt the xAPI.

Chapter 2 - XAPI

2.1 From Scorm to Xapi

Systems that record user data have grown exponentially in recent decades. This led to the need for standards and specifications that would enable them to implement this recording from different sources and contexts.

Until 2000, organizations using e-learning systems faced many problems when they had to upgrade their systems or when they wanted to change vendors. The main problem was that in many cases they had to abandon the content of their systems and create new one.

In the year 2000, came SCORM which separated the content from the "tool" that created it and made it capable of being integrated into any application and system. With this standard, the ADL Initiative, enabled organizations to create content that will be reusable, resistible and platform independent ("Sharable Content Object Reference Model (SCORM®) | ADL Initiative," n.d.).

Various versions of SCORM have been released (SCORM 1.0, SCORM 1.1, SCORM 1.2, SCORM 2004 1st edition, SCORM 2004 2nd edition, SCORM 2004 3rd edition and SCORM 2004 4th edition) ("SCORM Versions: the Evolution of eLearning Standards," n.d.) with many of them still in use. The most recent is SCORM 2004 fourth edition.

Given the interoperability between different environments, the ever-increasing use of the internet and mobile devices in people's daily lives, results in online learning taking place anywhere, anytime. The utilization of LMS's in this case is minimal (Lim, 2018). Thus, the need for a new learning specification emerged.

Indeed, in 2008 the procedures for finding the successor of SCORM began. In 2011, an agreement that was reached between the ADL (Advanced Distributed Learning) Initiative and Rustici Software resulted in the development of a project named "Project Tin Can" which was later renamed to xAPI (experience Application Programming Interface). In April 2013, the 1st edition, xAPI 1.0, was officially released while at this time we are in version 1.0.3 ("Experience API (xAPI) Standard | ADL Initiative," n.d.).

Rustici Software Company has given an exact definition of what xAPI is. According to it xAPI is "an e-learning specification that makes it possible to collect data about the wide range

of experiences a person has within online and offline training activities"("What is xAPI aka the Experience API or Tin Can API," n.d.).

Figure 2.1 xAPI ("What is xAPI aka the Experience API or Tin Can API," n.d.)

The xAPI has influences from the Representational State Transfer (REST) architecture so architecturally it rests on the 'RESTful web-service APIs (i.e., HTTP methods for GET, PUT, POST, DELETE)' ("Experience API (xAPI) Standard | ADL Initiative," n.d.). In addition it utilizes the JSON data format and a Learning Record Store (LRS).

Its' Version 2.0 is in standardization phase. This release will have many changes compared to the current version in terms of better definition of relationships, the standardization of timestamps over all statements and the clear definition of what an LRS must do ("Anticipating the xAPI Version 2.0 Standard | ADL Initiative," n.d.).

2.2 Technical Specification

Activity Streams are the keystone for many of basic principals in the xAPI. Its' statement structure "Someone did something" is based on WC3 Activity Streams 1.0. And in order to meet the existing requirements in xAPI several additions were made to them (Bowe, 2013).

Activity Streams are used in social networks like Twitter and Facebook to give valuable information about what users do in these, for example "Despoina posted a video", "Maria is interested for an event", etc. In a similar way xAPI uses Activity Streams called "Statements" to

give description of the learner's interaction with a system element, e.g. “Despoina completed a course”.

2.2.1 Statements

XAPI statements are a structured form of the elements that describe what a user experiences through the learning process. They comprise three principal components, which are metadata, descriptive information and complementary data. Examples of data that these components include are: timestamp, actor-verb-object and context respectively (Bakharia, Kitto, Pardo, Gaševíc, & Dawson, 2016).

At its most basic level, the structure of a xAPI statement can be stated as [actor] [verb] [object]. The aforementioned tags correspond to titles of the elements on a statement object. Thus, in the sentence “Despoina experienced course 1” we conclude that “Despoina” is the actor, “experienced” is the verb and “course 1” is the object. This statement entity itself can be represented in JSON format like:

```
{
   "actor": "Despoina",
   "verb": "experienced",
   "object": "course 1"

}
```

Figure 2.2. JSON format

We notice in this statement that there is no unique identification of the component elements. There are more fields that can be attached to this in order to turn it to a valid xAPI statement (“Experience API Tech Overview: Frequently Asked xAPI Questions,” n.d.). In Figure 2.3 we present a valid xAPI statement.

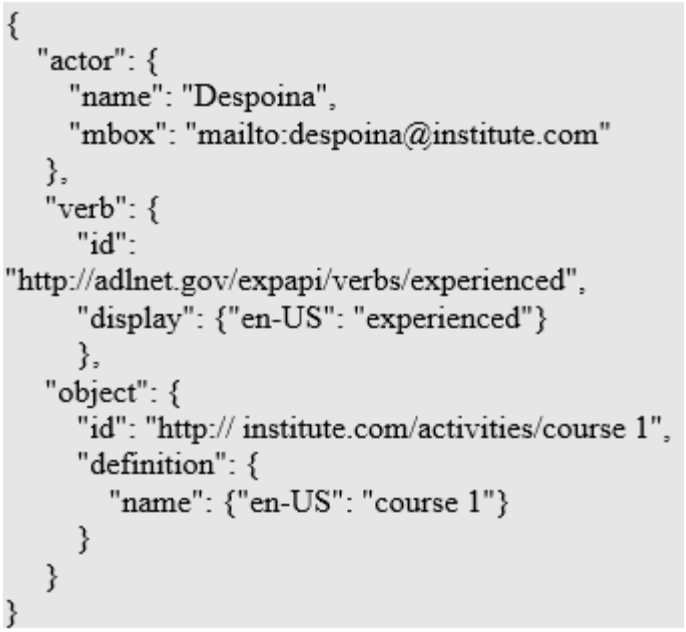

Figure 2.3 Valid xAPI Statement

2.2.2 Vocabulary

It is very important to use a vocabulary when statement objects are used to describe a learning experience. Objects are made with the use of a pair of braces {..}. Inside them, a key (the object properties which is in single or double quotes) pairs with a value. This value may be nested objects, text, numbers and arrays (Miller, 2013d)

In the triplets [actor] [verb] [object], the actor can be a single person, a system or a group whose tasks are recorded. A statement can be expressed with an inverse functional identifier, which gives to the agent a uniqueness in its recognition. It comes in many different forms like e-mail address, an OpenID URI or an account (a combination of a unique identifier and a unique representation) (Miller, 2013a)

The verb describes what an actor experienced during the learning process and refers to something that has happened and ended in the past. For this reason, the verbs must be in the past tense. Initially there was a predefined number of verbs that could be used in statements. With the advent of new versions, however, the community was given the opportunity to create new verbs. Verbs like “attempted”, “experienced”, “passed”, “failed”, “answered”, and “completed” are the one with the most use so far. However, there is the verb “voided”, which is used by the LRS to specify that an activity statement should be removed from the record. In

the xAPI Registry ("Verbs : The Registry," n.d.) there is a complete list of verbs that can be used to present a broad range of actions.

The third component of the triplets is the object. This mandatory part can have many types: Activity, Agent, Statement Reference, and Sub-statement, with the Activity to be the most in use (Miller, 2013c).

It is very important to set boundaries to an activity in order to know when and/or where something exactly happened. As a result, we are able to apply subdivision in the time or the area so that we can produce relatively small sets of activities.

The definition of the relations among activities cannot be bypassed. If we can group the activities, we will have the ability to produce better reports and make better decisions in the future. This will enable the activity to be re-used more and more, producing better and better opportunities for social reports.

The activity object includes three properties; the 'id' which is required, the 'objectType' and the 'definition' which are optional. The 'id' property gets a value which is an Internationalized Resource Identifier (IRI). In order for a system to be interoperable it must use identifiers that are resolvable by applications over the net (Miller, 2013e).

In the xAPI Registry ("Activity Types : The Registry," n.d.) there is a complete list of Activity Types that can be found in various types.

2.2.3 Activity Providers

Figure 2.4 xAPI architecture

In xAPI architecture (Figure 2.4), an Activity Provider can be any source that can generate xAPI statements depending on the actions taking place with it. For example, an Activity Provider can be a video, an email program, a mobile application, a flight or every

simulator, an LMS, etc. Generally, there is a long list of sources that generate xAPI statements during and after the learning process.

With this specification, we are able to track a wide range of activities taking place inside an e-learning environment or real-life events. This enables the interested parties to correlate data that previously could not ("What is an Activity Provider?," n.d.).

2.2.4 LRS (Learning Record Store)

In the core of xAPI we have the LRS (Learning Record Store). According to the xAPI specification the LRS is "A server (i.e. system capable of receiving and processing web requests) that is responsible for receiving, storing, and providing access to Learning Records." ("What is an LRS? Learn more about Learning Record Stores," n.d.).

It all starts with users participating in activities that generate activity streams. These activity streams can come from student activities that are involved in e-learning courses, activities that are performed on mobile devices, employee activities where their performance is recorded, webpages, simulators, social media, etc (Figure 2.5). In general, we can say that a variety of activities that take place in real life can be recorded.

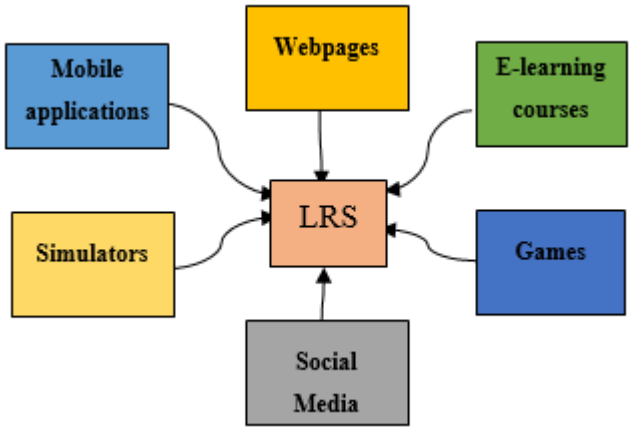

Figure 2.5 LRS.

All the activity streams produced from the above activities are stored in LRS as xAPI statements. The main job of this database is to save and provide access to xAPI statements giving the ability to configure the permissions on these.

As mentioned above, the concept of LRS is directly related to xAPI. It is in the center of the ecosystem and the other tools are just interacting with it. It can stand alone or it can be integrated in a Learning Management System. It can also communicate with other LRSs sharing users' learning data experience. Nowadays they provide a variety of features and have been extended to Learning Analytics Platforms going beyond simple data storage ("What is an LRS? Learn more about Learning Record Stores," n.d.).

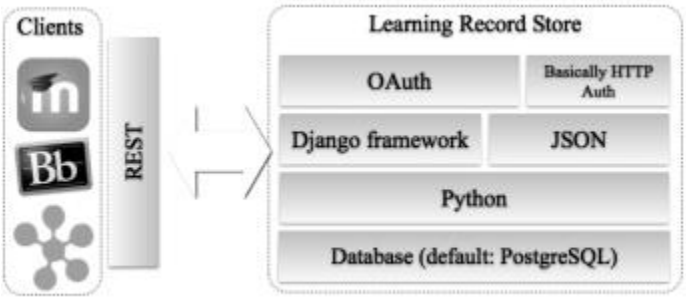

Figure 2.6 Software stack of a free LRS (Corbi & Burgos, 2014)

As shown in Figure 2.6, the LRS is just "a wrapper or API software layer to a SQL database" (Corbi & Burgos, 2014). It is founded on Python Programming Language and Django Web Framework. In order for the LRS to have secure communication with other tools, xAPI utilizes OAuth or HTTP Basic Authentication.

There are many companies in the market that have produced LRSs. Some of them are: Rustici LRS ("Rustici LRS: Add an LRS to your learning analytics platform or LMS," n.d.), Rustici Scorm Cloud LRS ("SCORM Cloud LRS: a free, integratable and hosted LRS," n.d.) and Learning Locker by HT2 Labs ("Learning Locker Documentation," n.d.-a), with the last one to be the one used in our implementation.

2.2.5 Activity Consumers

Activity Consumers and Activity Providers are related systems. They are software products that make use of what a user has experienced derived from xAPI data. For example, a Learning Management System can be an Activity Consumer. Furthermore, a scoreboard, a platform that issues badges or educational materials can play the role of an Activity Consumer (Drlik, Skalka, Svec, & Kapusta, 2018).

2.2.6 xAPI statement example

In the example of the Figure 2.10 we see the full development of the xAPI statement for the expression: student13 class1 completed Κεφάλαιο 7 - Η απελευθέρωση, taken from our LRS. In this example, between the other objects, we distinguish the object:

- actor with the properties: name, mbox and objectType (Figure 2.7),
- verb with the properties: display (with property: en-US) and id (Figure 2.8) and
- object with the properties: definition (with properties extensions and name), objectType and id (Figure 2.9).


```
"actor": {
  "name": "student13 class1",
  "mbox": "mailto:student13@myclass.gr",
  "objectType": "Agent"
},
```


Figure 2.7 The object "actor"


```
"verb": {
  "display": {
    "en-US": "completed"
  },
  "id": "http://adlnet.gov/expapi/verbs/completed"
},
```


Figure 2.8 The object "verb"


```
"object": {
  "definition": {
    "extensions": {
      "http://h5p&46;org/x-api/h5p-local-content-id": 12
    },
    "name": {
      "en-US": "Κεφάλαιο 7 - Η απελευθέρωση"
    }
  },
  "objectType": "Activity",
  "id": "http://users.sch.gr/arvanitdes/learning-experience/wp-admin/admin-ajax.php?action=h5p_embed&id=12"
}
```


Figure 2.9 The object "object"

```
{
  "refs": [],
  "stored": "2022-06-05T20:29:47.331Z",
  "active": true,
  "completedForwardingQueue": [],
  "failedForwardingLog": [],
  "client": "628fc029570aa9715f405cc4",
  "lrs_id": "628fc029570aa9715f405cc3",
  "completedQueues": [
    "STATEMENT_QUERYBUILDERCACHE_QUEUE",
    "STATEMENT_FORWARDING_QUEUE",
    "STATEMENT_PERSON_QUEUE"
  ],
  "hash": "5b38d5a8aad677d7f7ed4815d1846cb044024ca6",
  "statement": {
    "authority": {
      "account": {
        "name": "New Client",
        "homePage": "http://learninglocker.net"
      },
      "name": "client",
      "objectType": "Agent"
    },
    "stored": "2022-06-05T20:29:47.331Z",
    "context": {
      "contextActivities": {
        "category": [
          {
            "objectType": "Activity",
            "id": "http://h5p.org/libraries/H5P.SingleChoiceSet-1.11"
          }
        ],
        "grouping": [
          {
            "definition": {
              "moreInfo": "http://users.sch.gr/arvanitdes/learning-experience/lesson7/",
              "name": {
                "en": " | lesson7"
              },
              "type": "http://activitystrea.ms/schema/1.0/page"
            },
            "objectType": "Activity",
            "id": "http://users.sch.gr/arvanitdes/learning-experience/lesson7/"
          }
        ],
        "parent": [
          {
            "objectType": "Activity",
            "id": "http://users.sch.gr/arvanitdes/learning-experience/wp-admin/admin-ajax.php?action=h5p_embed&id=12"
          }
        ]
      },
      "extensions": {
        "http://id&46;tincanapi&46;com/extension/ending-point": "PT39S"
      }
    },
    "actor": {
      "name": "student13 class1",
      "mbox": "mailto:student13@myclass.gr",
      "objectType": "Agent"
    },
    "timestamp": "2022-06-05T20:29:47.298Z",
    "version": "1.0.0",
    "id": "04c4103a-775e-45cc-8745-3cfaac3fe795",
    "verb": {
      "display": {
        "en-US": "interacted"
      },
      "id": "http://adlnet.gov/expapi/verbs/interacted"
    },
    "object": {
      "definition": {
        "extensions": {
          "http://h5p&46;org/x-api/h5p-subContentId": "4cb93687-7467-4fd8-abe9-b442c73d9fc7",
          "http://h5p&46;org/x-api/h5p-local-content-id": 12
        },
        "name": {
          "en-US": "7.1 Ερώτηση πολλαπλής επιλογής"
        }
      },
      "objectType": "Activity",
      "id": "http://users.sch.gr/arvanitdes/learning-experience/wp-admin/admin-ajax.php?action=h5p_embed&id=12?subContentId=4cb93687-7467-4fd8-abe9-b442c73d9fc7"
    }
  },
  "hasGeneratedId": false,
  "deadForwardingQueue": [],
  "voided": false,
  "personaIdentifier": "629d0ace311374c3567e6bcb",
  "processingQueues": [],
  "person": null,
  "timestamp": "2022-06-05T20:29:47.298Z",
  "organisation": "5ffc60b654312f320d5e799c",
  "_id": "629d123b9e074671ab94eba7",
  "pendingForwardingQueue": []
```


Figure 2.10 xAPI statement example

2.3 xAPI applications

As mentioned earlier, in recent years there has been a growing interest in tracking users' experiences not only in education but also in areas such as entertainment and defense. A large number of companies have developed tools that implement xAPI, providing them either as open source software or for a fee.

2.3.1 xAPI adopters in learning

According to xAPI adopters list ("xAPI Adopters: See who is compliant with xAPI," n.d.), there are 110 adopters that have produced software and applications that are conformant with xAPI. The categories in which these products fall are many. Indicatively, we will mention some of these categories and representative adopters alphabetically, indicating next to them whether they are free or paid.

	Authoring tool	**Free**
1.	Articulate Storyline 360 https://articulate.com/360/storyline	No (Free Trial)
2.	Adobe Captivate https://www.adobe.com/products/captivate.html	No (Free Trial)
3.	H5P https://h5p.org/	Yes
4.	hihaho https://hihaho.com/	No (Free Trial)
5.	iSpring https://www.ispringsolutions.com/	No (Free Trial)
6.	Learning pool adapt builder https://learningpool.com/solutions/learning-suite/authoring/	No (Free trial)
7.	Lectora authoring tool https://www.lectoraonline.com/	No (Free trial)
8.	Alchemer formerly SurveyGizmo https://www.alchemer.com/	No (Free trial)

Table 2.1 Authoring tools that support xAPI

	LRS	Free
1.	**GrassBlade Cloud LRS** https://www.nextsoftwaresolutions.com/grassblade-lrs-experience-api	**No** (Demo is provided)
2.	**Learning Locker** https://learningpool.com/solutions/learning-locker-community-overview	**Yes** (Open source)
3.	**ADL LRS** https://lrs.adlnet.gov/	**Yes**
4.	**Scorm Cloud** https://rusticisoftware.com/products/scorm-cloud	**No** (A free Trial account is provided)
5.	**Veracity Learning LRS** https://lrs.io/home	**No** (A free plan is provided with basic dashboard)

Table 2.2 LRSs that support xAPI

	LMS	Free
1.	BlackBoard https://www.blackboard.com	No (Free Trial)
2.	LearnDash https://www.learndash.com	No (Demo)
3.	LifterLMS https://lifterlms.com	No (Demo)
4.	Moodle https://moodle.org	Yes
5.	Sakai LMS https://www.sakailms.org	Yes

Table 2.3 LMSs that support xAPI

2.3.2 xAPI and Constructivist Learning

The socio-cultural framework Activity Theory has a big influence on the experience API where Vygotsky's work is its foundation (Silvers, 2014). "Activity theory is a conceptual framework based on the idea that activity is primary, that doing precedes thinking, that goals, images, cognitive models, intentions, and abstract notions like "definition" and "determinant" grow out of people doing things" (Morf & Weber, 2000, p.81).

Hashim and Jones (2007) argue that the activity is the fundamental component of examination which is utilized to comprehend how a user acts. It is divided into three elements:

the subject which is the individual that is studied, the object which is the activity and the tool which is the mediator through which the action is carried out.

From the aforementioned and in conjunction with all that has been presented in this unit we can find out the similarities of this theory with the xAPI, where the activity is in the center of interest for both of them.

Additionally, Activity Theory is inextricably linked on the one hand with constructivist learning theory where learners construct their knowledge through physical and mental learning activities that make sense to them, and on the other hand with social constructivist theory, where learners construct their knowledge interacting socially with other learners. If those who design educational products are indeed constructivists then the xAPI has something new to offers in terms of designing strategies oriented towards constructivism at all stages of their development. (Kevan & Ryan, 2016).

Chapter 3 - Computational Thinking

It is now widely understood that the current generation of students must be equipped with all of the necessary digital skills so that they will be able to succeed in the digital age. One of the most important skills that has attracted the interest of researchers in the scientific community in the last decades is Computational Thinking (CT). CT is one of the abilities that students should receive at compulsory education.

3.1 Overview

The beginnings of Computational Thinking date back to 1967 where Seymour Papert and his collaborators created the 1st edition of the LOGO programming language (Logo Foundation, 2015) where the main goal was for the students to acquire logical and mathematical thinking.

Later, in 1980, Papert in his book entitled “Mindstorms: children, computers, and powerful ideas” (Papert, 1980) established the basis for a new approach to education emphasizing that using LOGO children have the opportunity to enhance their algorithmic thinking. Several years later in 1996, Papert first introduced the term CT stating that “The goal is to use computational thinking to forge ideas that are at least as "explicative" as the Euclidlike constructions (and hopefully more so) but more accessible and more powerful.” (Papert, 1996).

Jeannette Wing with her three-page article in 2006, brought the CT to the forefront, emphasizing that people who belong to “pre-college” categories such as parents, educators and pupils should be approached (Wing, 2006). Since then this concept has been the subject of research by many people around the world trying to redefine its definition as well as how it can be integrated into education.

3.2. Definitions and concepts

According to J. Wing, Computational Thinking (CT) is an essential ability for all people, not just computer experts. Every student's analytical skills should be supplemented with CT in addition to reading, writing, and arithmetic. By utilizing core Computer Science (CS) principles it finds solutions to problems, it develops systems and comprehends the way that

humans behave. Additionally, it encompasses a variety of intellectual tools that mirrors the range of the field of CS (Wing, 2006). In this article, the features of CT are listed which are:

- CS and computer programming are not the same things. Being able to think as a computer scientist entails more than just knowing how to program a computer. It necessitates abstraction at various levels.
- It is a foundational skill that every individual is required to have in order to be able to succeed in today's life.
- It is a means for individuals to resolve problems rather than an attempt to make them ponder as machines.
- It "complements and combines mathematical and engineering thinking".
- It is concepts and not only objects made by human beings, and
- It is for everybody and to all places.

In continuation of the above, in 2011, following additional reviews, a new definition was adopted: "Computational thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent." (Wing, 2011). In this article, the advantages of using CT by everybody and experts are listed.

It should be noted that since the emergence of the concept until today, an attempt has been made to redefine both the concept itself and the way in which it can be used in education. To achieve this, several actions have been taken by various bodies. For example, the National Research Council (NRC) in a report presents a number of different definitions given during a workshop as well as the components of CT which are: "hypothesis testing", "data management", " parallelism", " abstraction", and "debugging" (Shute, Sun, & Asbell-Clarke, 2017).

The International Society for Technology in Education and the American Computer Science Teachers Association, identify nine essential concepts of CT (Yadav, Stephenson, & Hong, 2017): "data collection, data analysis, data representation, problem decomposition, abstraction, algorithms and procedures, automation, parallelization, and simulation".

In 2015, a community for encouraging computing education in schools called Computing At School, issued a guide for introducing CT in education (Csizmadia et al., 2015).

In this guide CT is presented as a cognitive or mental procedure that utilizes "logical reasoning" to resolve issues and comprehend more effectively processes, structures and objects made by humans. It includes the capabilities to think:

- in an algorithmical way,
- concerning the decomposition of a problem,
- generalized, recognizing and exploiting patterns,
- abstractly, selecting appropriate depictions and
- appreciatively.

3.3 Activities that enhance Computational Thinking

There are many types of activities that can be used in the classroom in order for an educator to teach Computational Thinking skills. Mannila et al., (2014) categorize these activities into the following categories:

- Unplugged and kinesthetic activities: Unplugged activities can be implemented without using technological equipment. They are kid-friendly activities that attempt to introduce CT without using a computer. Typical examples of these activities are CS Unplugged ("CS Unplugged," n.d.), CS4FN ("Computer Science for Fun - cs4fn: HOME," n.d.) and Abenteuer Informatik (Gallenbacher, 2012). Kinesthetic activities aim to make the people who implement them move without the use of paper or pen.
- Cross-disciplinary projects: Frequently those involved in the process of creating an artifact at school through the information technology, focus on the implementation of the project but lose what is hidden behind this process. It is therefore very important, activities that are oriented to Computational Thinking to be integrated into all fields and subjects in order for an interdisciplinary approach to all subjects to be achieved.
- Programming for addressing CT aspects: With the intention to use all the potential of CT through programming, there must be a common acceptance as to how it is introduced in education. This will result in the utilization of the programming to be done

in the same way by all students and schools through graphical programming environments.

- Storytelling: It has played an important role in education for thousands of years. It is also a tool for helping students and adults with learning difficulties. In computer era, the evolution to digital storytelling combines the benefits of tradition with the acquisition of programming knowledge. Students create their stories with digital tools like Scratch through an entertaining procedure.
- Educational robotics: It includes activities using various kinds of machines that pupils program and guide. These machines can be humans (for example, students program each other) or made using technology like Bee-Bot and Lego NXT.
- Creating interactive cards and posters. Students from their first years are painting and creating cards and posters. With the use of digital tools like Scratch they are getting familiar with ‘problem decomposition’, ‘algorithms’, ‘automation’, ‘data collection’ and ‘analysis’.
- Experimenting and simulating. With creating models and making experiments students have the opportunity to better understand the natural world and its phenomena. Through their various actions, students are able to implement many CT activities like data collection, data representation and data modelling as well as simulations.
- Playing educational games. Another way to develop CT to students is to use educational and commercial computer simulation and strategy games. Typical examples are The Sims and Civilization.

3.4 Computational Thinking in Compulsory Education

In recent years, a large number of countries around the world, recognizing the importance of Computational Thinking and the need to integrate it into the educational process, are proceeding with the revision of their curricula so that students from the first years of compulsory education get in touch with CT.

In a publication (Chioccariello et al., 2022), the European Commission reviews the integration of Computational Thinking into the Compulsory Education of the members of the European Union (Figure 3.1). According to it, there are countries like Slovakia where many

years ago it recognized the importance of CT and incorporated its concepts in the Information Technology course. Along the way, other countries such as Austria, France, Sweden, etc. began to use concepts of CT in Compulsory Education. However, there are countries such as Italy and Romania where, although there is no direct reference to the term CT, concepts related to it are used and promoted in schools.

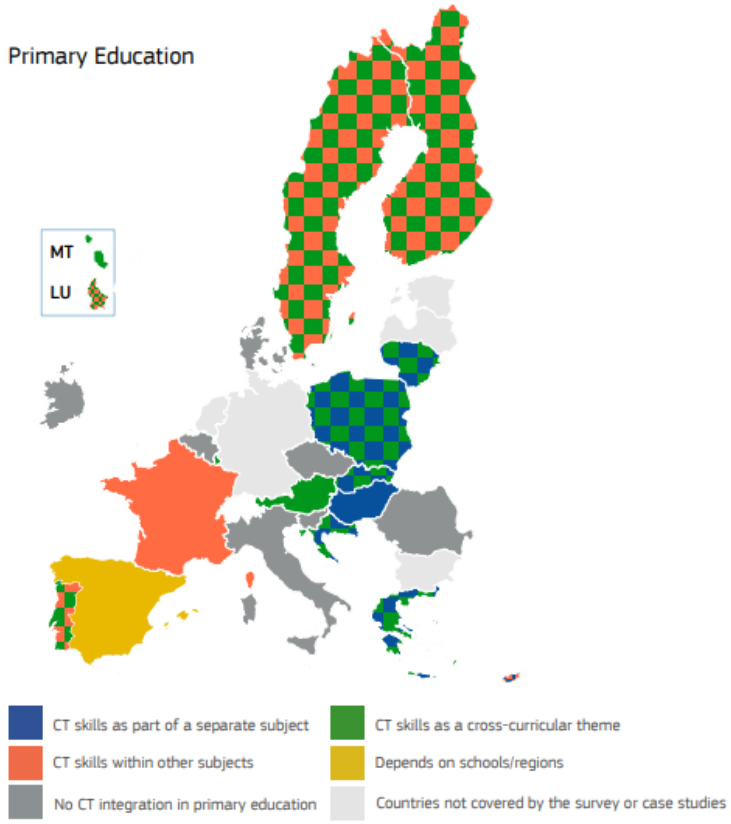

Figure 3.1 CT skills integration in EU Member (Chioccariello et al., 2022),

In Greece, CT has been introduced in all levels of education. More specifically, in Primary Education, according to the current Curriculum for I.C.T., for the fifth grade and 6th grade, students are expected to become familiar with programming in a playful way, with available visual programming educational environments and are requested to implement activities that will enhance their programming skills.

In the school year 2021-2022, the new Curriculum was implemented for the first time, which was piloted in 112 schools of the country. The next school year will be implemented in more schools while the school year 2023-2024 will be extended to all schools in the country.

According to this Curriculum, students from the first grade are taught CT concepts such as algorithmic and computer systems programming.

3.5 Computational Thinking through programming

As mentioned before, one of the activities that enhance CT is programming. According to Grover & Pea (2017) "programming is therefore seen as an especially useful platform for teaching CT since it brings together several of the elements – both concepts and practices – that are central to CT".

As a result, among the most important factors to take into account while presenting CT concepts is the programming environment that will be utilized. Choosing an environment that does not require code writing and learning syntax is crucial. There are several programming environments that are block-based and can be used by children of all ages. The advantages of using such environments for students are (Curran, 2017): they don't have to memorize syntax and this results in them not making syntactic mistakes, the blocks that are provided are visible to all and blocks frequently conceal complicated logic or actions in a single block. All these advantages help students to create their own representations and programs without adding unnecessary mental burden to what they are doing.

There are many programming environments, which are friendly to children such as Alice, Kodu and Scratch. Alice ("Alice – Tell Stories. Build Games. Learn to Program.," n.d.) is a block-based programming environment through which a student can create animated stories, digital narratives, or 3D games that he or she can share with others online. Thus, students come into contact with basic programming concepts and especially with object-oriented programming through an attractive interface. Kodu ("Kodu Game Lab | KoduGameLab," n.d.) is a visual programming environment that provides an engaging way for children to learn to program and get in touch with the fundamentals of programming. The environment allows users to create their own world, their own characters and program them to behave the way they want. Scratch ("Scratch - About," n.d.) is a children-friendly programming environment that is used to foster CT in schools. With its "simple visual interface", students can create stories, games and simulations and share them with others.

We decided to adopt Scratch in our learning environment because it will motivate students to learn to program and create their own projects. Below is a more detailed description of the environment.

3.6 Scratch 3.0

Scratch is a development of the Massachusetts Institute of Technology (MIT) Media Lab's Lifelong Kindergarten Group ("Scratch - Scratch Wiki," n.d.). Its first version was Scratch 1.0 and was made available to the public in 2007, followed by versions 1.1, 1.2, 1.3, 1.4 and 2.0. Its current version is Scratch 3.0 and was released in 2019.

Scartch's online editor can be accessed through any browser (Chrome, Mozilla Firefox, Microsoft Edge, etc.) and on any device (computer, tablet, smartphone) by simply typing the address https://scratch.mit.edu. If someone wants to use Scratch without an internet connection, the application can be freely downloaded and installed to devices that run Windows 10+, macOs 10.13+, Android 6.0+ and ChromeOs. This version of Scratch does not support installation on smartphones.

Scratch environment is divided into several sections (Figure 3.2):

- The Navigation Bar, which is located at the top of the window and includes the area for changing the language, the menus and the tutorials.
- Below the Navigation Bar, there are three tabs: with the **Code** tab, the user activates the Code Area of his object and places the command blocks from the Block Palette. With the **Costumes** tab, the user changes the look of his items through the available costumes of the item that is selected. Here, the user can edit (change colors and size) or remove existing costumes and create new ones. The **Sounds** tab is used to import audio from the available Scratch sounds. The user has the ability to edit sounds, add his own, delete existing sounds and record new ones.
- On the left of the screen there is the Block Palette which contains commands grouped in colors based on specific features, allowing students to write their own programs without syntax errors (Freina, Bottino, & Ferlino, 2019). Clicking on each of the block category the available commands are presented

in the adjacent area. The available categories are Motion, Looks, Sound, Events, Control, Sensing, Operators and My Blocks. Additionally, some extensions may be added like Pen, Music, etc.

Figure 3.2 Scratch User Interface

- The Code Area is located in the center of the screen. In this area, the commands that the user selects and drags from the previous area are stored. Each command transferred here must be merged with the others to create a command block.
- The Stage is located in the top-right corner where the user's sprites come to life by executing the commands given to it.
- The Sprite Pane is below the Stage. Through this area, the user can insert in the project an existing sprite, paint or upload a new one. In addition, for each of the sprites of the project, changes can be made in its name, in its location, in its visibility, in its size and direction. Finally, by clicking on each sprite in the bucket located in the upper right corner, it is deleted.
- Next to the Sprite Pane, there is the Stage Pane where Backdrops are inserted in the project. Same as above, the backdrops may be available from Scratch or the user can paint or upload a new one.

Scratch’s slogan is "Imagine, Program, Share". It all starts with a concept that someone imagines, then follows the implementation of this concept through programming and finally this concept is published in the community.

According to community’s statistics (“Scratch Statistics - Imagine, Program, Share,” n.d.) since 2007 103.075.618 projects have been shared, 89.651.833 users have been registered, 624.183.951 comments have been posted and 30.939.985 studios have been created. Over 200 countries worldwide are using Scratch and a user can program among over 70 languages.

The goal of the development team was to create an environment that would be easy to learn for children who had not come into contact with other programming environments and did not know how to program. It is mainly aimed at ages 8-16, but can be used by people of any age regardless of their interests or background.

Scratch can be used at all levels of education and across many disciplines. The range of projects that can be implemented is very large, letting users to make from interactive greeting cards to physics simulations (Papadakis, Kalogiannakis, Zaranis, & Orfanakis, 2016).

All of the aforementioned have made Scratch the programming environment chosen by a large number of teachers in compulsory education. As Marcelino, Pessoa, Celeste, Salvador, & Mendes (2018) note, Scratch has been widely utilized, as evidenced by the large number of references discovered in the literature.

Chapter 4 - Gamification

The new generation of students have been born and raised in digital technology. Teachers, wanting to adapt their teaching to the requirements of this generation, are looking for new teaching methods and techniques to attract their interest. The fact that the new generation is having fun playing digital games has not gone unnoticed by the educational community, utilizing them in the educational process. This resulted in the utilization of game elements in education and is called gamification.

4.1 Overview

Gamification is a field of research that has attracted the interest of researchers in recent years. This term was initially used in 2008, but it did not gain general acceptance until the second period of 2010. Although new similar terms come to the foreground, this term is the one that has been widely adopted (Deterding, Dixon, Khaled, & Nacke, 2011).

Its origins date back to the beginning of the last century where in America the Scouts proceeded to adopt a way of rewarding their members with badges after some achievement ("The History of Gamification: From the Beginning to Right Now," 2019). Along with the aforementioned Sperry & Hutchinson (S&H) company introduced a type of gambling where various retail stores offered their customers stamps as a reward for the amount of money they spent in the store. Customers collecting a number of stamps could exchange them for various products. Over the years many companies have followed this example of rewarding their customer loyalty (Kim, Song, Lockee, & Burton, 2018).

4.2 Definitions

One of the first definitions given for gaming was in 2011 by Deterding et al. where they suggested that "Gamification is the use of game design elements in non-game contexts". In the continuation of the article, the definition is deconstructed in order to make it more understandable.

First, a distinction is made between the "game" and "play", emphasizing that gamification is related to the "gaming" and not to "playing". Subsequently, there is a limitation for gamification on elements that are characteristic of the games and one finds them in most of

them, emphasizing that their existence in them plays a decisive role. The following is the clarification that it is preferable to use the term "gamification" only when referring to the usage of game design, rather than game-based technology or practices in the broader game ecosystem. Finally, in the context of gamification, it can use game elements for social, historical and cultural reasons, which are far from entertainment.

Gamification is also defined by Hamari, Koivisto, & Sarsa (2014) “as a process of enhancing services with (motivational) affordances in order to invoke gameful experiences and further behavioral outcomes”. By conceptualizing this term, they concluded that this might be considered to have three primary components: “1) the implemented motivational affordances, 2) the resulting psychological outcomes, and 3) the further behavioral outcomes”.

Kapp (2012) in his book, combines components from different definitions and he concludes that “ Gamification is using game-based mechanics, aesthetics and game thinking to engage people, motivate action, promote learning, and solve problems”. Then deconstructs the definition and analyzes each of the elements that compose it: “game-based”, “mechanics”, “aesthetics”, “game thinking”, “engage”, “people”, “motivate action”, “promote learning” and “solve problems”.

In addition to the aforementioned, there is still a plethora of definitions, where each of them focuses on a different characteristic depending on the desired result.

4.3 Gamification Frameworks

Since gamification was introduced in several aspects of our lives, various frameworks have been developed, giving tips on how to design and use it. One framework that is used in game design is the MDA framework, where MDA is the abbreviation of the words: Mechanics, Dynamics and Aesthetics. This framework was designed and used at a Conference for Game Developers in San Jose 2001-2004.

Hunicke, Leblanc, & Zubek (2004) in their article present the MDA Framework as a formal perspective to comprehending games. It aims to act as an intermediary among the plan of the game and its development, its critique, and the studies on this subject. In this framework

the game is broken into its distinct elements: “Rules”, “System” and “Fun” where then the design equivalents are found: Mechanics, Dynamics and Aesthetics.

Mechanics specifies the game's specific elements. Dynamics specifies the way the mechanics behave during game execution, on what a player gives as input and what is given as output with the passage of time. Lastly, aesthetics specifies the desired emotional reactions elicited in the participant, during his interaction with the system.

Because gamification features are built on MDA, this framework is at the point of reference of many gamification models. In addition to this, a large number of gamification design frameworks have been developed and have been classified into categories according to their various characteristics.

For example Mora, Riera, Gonzalez, & Arnedo-Moreno (2015) present many gamification frameworks which have classified them into two major categories: Generic and Business-specific, based on time, background and scope. Simões, Redondo, & Vilas (2013) introduce a social gamification framework applied in K-6 learning platform aimed at children aged 9-12 years old. Lastly, regarding the involvement of the inhabitants of a city, Kazhamiakin, Marconi, Martinelli, Pistore & Valetto (2016) developed a complete gamification framework for gamifying applications in a Smart City.

4.4 Key elements of Gamification

As mentioned before gamification utilizes game design elements. However, simply integrating them into existing systems does not indicate the anticipated behavior shift will occur automatically. The proper design of the ‘components’, ‘mechanics’ and ‘dynamics’ that will be used in order to achieve the desired goals that will be set must be done. In the following paragraphs these three features are analyzed according to the proposal of Wood & Reiners, (2015) and they are summarized in Figure 4.1.

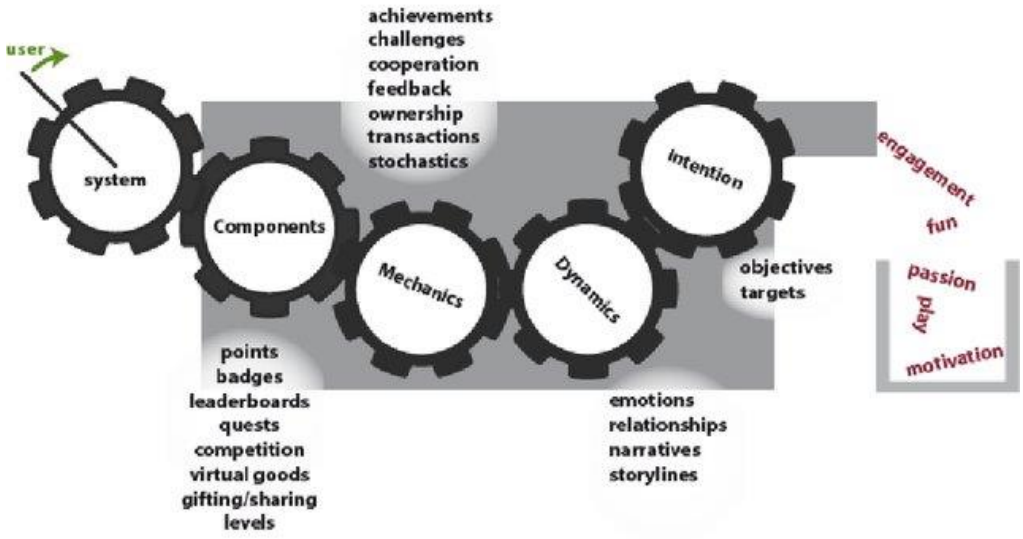

Figure 4.1 How a gamification system works (Wood & Reiners, 2015)

4.4.1 Components

When designing the system, the following elements must be taken into account depending on the purpose, for which the system is implemented, the users to whom it is addressed as well as the available resources and tools. These elements are:

- **Points**: are used to track progress and give a summary of achievements.
- **Badges**: are used to state out what users have succeeded and are known from the beginning in order to prompt them to accomplish the goals they had set
- **Leaderboards**: are used to show how users have progressed and how successful they have been in comparison to their competitors.
- **Quests**: are challenges that a user must carry out for achieving a certain goal in order to be rewarded.
- **Competition/challenge**: two users come face to face and one competes with the other in who will be the winner.
- **Virtual goods**: will have a specific price and, when gained by a player, will offer him an advantage and make him feel distinct from the other players.
- **Gifting/sharing**: give to users the opportunity to taste the joy of teamwork, altruism and help.

- **Levels**: are getting difficult as they follow each other in order to keep the interest of the users undiminished.

4.4.2 Mechanics

The mechanics of gamification deal with how certain components change during time or with what way users are getting involved in the system. Some game mechanics are:

- **Achievements**: are the goals that must be achieved by the users, and they reflect landmarks in the plot of the story.
- **Challenges**: are activities that demand user effort to accomplish and are characterized by a set of goals that must be met.
- **Cooperation**: amongst users to achieve a goal that is impossible to do alone.
- **Feedback**: is given to users via different graphical or informational representations and is informing them of their progress so far and for the incoming activities.
- **Ownership of resources** that users can utilize to their advantage.
- **Progression** in the plot of the story: is a graphical depiction that is used to inform the user about his progress in an activity.
- **Transactions**: user-to-user exchanges that enable them to trade resources.
- **Stochastic elements**: create to users a feeling of unpredictability and enjoyment.

4.4.3 Dynamics

The dynamics are the conducts and interplays of the users that have been resulted by the aforementioned components and mechanics. They are influenced by the users' temperament and experience so the game dynamics must take them into account when designing. Such dynamics can be:

- **Emotions**: users' emotions, including curiosity or competitiveness, can be used to achieve the expected results.
- **Relationships**: that arise through the users' interplay can result in emotional dependencies.

- **Narratives and storylines**: are essential for the success of the system by making sense and a context in which the plot of the story unfolds, on more than one level.

4.5 Fields of adoption of gamification

In recent years, gamification has become widely used in a wide range of fields, including education, health and marketing. When adopted, it is a means of exerting a positive influence on individuals whether they are students, patients or customers, improving their interest, trust and commitment.

In marketing, a large percentage of companies use customer loyalty programs, through which they reward them with points, gifts and special privileges. In addition, the reward can be the awarding of badges or an increase in the ranking of the company's customers.

McDonald's Monopoly is a typical example of the use of gamification in marketing. This game appeared in 1987 and over time many McDonald's around the world adopted it. The aim was to collect particular items by purchasing products from the company. These coupons offered many gifts to the participants resulting in an increase in the company's customers and consequently in its sales (Hulsey, 2019).

In the field of health, the contribution of gamification is vital and contributes to the self-management of many health problems and diseases. For example, several applications have been developed for the management of diabetes Type I (Alsalman, Ali, Alnosaier, Alotaibi, & Alanzi, 2020) while for the treatment of rheumatoid arthritis in the study carried out through web-based interventions, the results showed that gamification contributed positively to the quality of life of patients (Allam, Kostova, Nakamoto, & Schulz, 2015). Finally, Rajani, Mastellos, & Filippidis (2021) in their study showed that the integration of gamification functions in applications aimed at smoking cessation increased their effectiveness.

In recent years, there has been a continuous increase in the integration of gamification techniques in education. Teachers are looking for new methods to attract the interest of their students in order to achieve greater participation in the lesson. Many applications have been developed in this field and several studies have been conducted highlighting its contribution to increasing students' motivation for active participation. Papadakis & Kalogiannakis (2018) carried out a study that showed that the utilization of ClassCraft "for Supporting an

Introductory Programming Course in a Secondary Education Classroom" helped the students to be actively involved in the class.

In addition to ClassCraft, a plethora of notable instances of utilization of gamification in education have been recorded like Multiplayer Classroom (Sheldon, 2020) and CodeCombat (CodeCombat Inc, 2019). For the classroom management the platform of ClassDojo has been developed ("ClassDojo," n.d.) while Kahoot (Kahoot, 2020) utilizes gamification for student assessment.

Chapter 5 - Adaptivity

In recent years with the development of technology and especially after the emergence of the pandemic, there has been an increase in the number of systems developed to support distance learning. There is a shift from traditional teaching to a classroom, to a teaching that is ubiquitous and can take place anywhere, anytime.

Students either attend a class in a school classroom or remotely via an electronic device do not have the same background and their needs vary. It is therefore very important to take into account the specifics of the students when planning the teaching wherever it takes place. Especially, in distance learning is crucial to create learning environments that will utilize adaptive technologies.

5.1 Overview

The concept of adaptivity is not new. Many decades ago, long before the development of technology, teachers were interested in providing students with the learning experience they needed in the classroom. In addition to the aforementioned, this concept has attracted the interest of other scientists such as psychologists, cognitive scientists and novelists (J. L. Plass & Pawar, 2020). Caya & Neto (2018) in their bibliometric review concluded that adaptivity has been steadily increasing in the last seven decades. In terms of publications on this subject, there has been a steady increase in them since 1991.

Undoubtedly, the revolution of digital technology has revealed a slew of new options for satisfying the necessities of learners. At this point, the clarification of the concept adaptivity as well as other concepts related to it becomes necessary.

5.2 Definitions

The definitions given for this concept vary depending on the context in which it is applied. Regarding the interaction of the learners with the system, the adaptivity is characterized as the process that personalizes the learning material delivery and sequence to meet the learner's needs (Alshammari, Anane, & Hendley, 2016).

When adaptivity is adopted in a learning system, the result produced is an adaptive learning system that adjusts its content according to the user's results and interactions with the

learning activities. In the case of educational systems a definition for adaptivity that is given is "the ability of a system to adjust instruction based on learner abilities and/or preferences, at any particular point of the instruction process, with the goal of acting on identified learner characteristics and improving the efficiency and efficacy of learning" (Slavuj, Meštrović, & Kovačić, 2017, p.3).

According to Jameson & Gajos (2012) a user-adaptive system is "an interactive system that adapts its behavior to individual users on the basis of processes of user model acquisition and application that involve some form of learning, inference, or decision making" (p.1). In this case, the system has an adaptive behavior, which is:

> the ability of an entity, at any moment, to decide performing a self-modification, by executing a set of proper actions, of its own features, structure and/or behavior, or even its environment, when facing new incoming events perceived in its surroundings while pursuing a particular goal in order to suit more efficiently the new context of its performance (Caya & Neto, 2018, p.2).

It should be emphasized here that adaptivity should not be confused with adaptability. When adaptivity is adopted in a system, the student's learning experience depends entirely on this system while when adaptability is adopted the student can intervene to regulate the way in which the system will be adapted (J. L. Plass & Pawar, 2020).

In addition, a term related to adaptivity and adaptability is personalization. When a learning environment adopts personalization, it incorporates adjustments regarding student choices and those on diagnosed student factors. In other words, the behavior of the system depends on what students want and how it is pre-defined to respond according to their performance (Plass, Mayer, & Homer, 2020).

Studying the above terms leads us to the conclusion that with adaptivity the system behaves autonomously based on how it has been made to behave and without the intervention of its users. With adaptability, the users of the system, i.e. the students, can intervene in its behavior according to their preferences, while in the case of the personalization we have a combination of what users want with the independence in decision-making from the system.

5.3 Adaptive Parameters

In order for an adaptive system to be considered successful, it must be decided during its development which characteristics of the student or parameters will be taken into account. These parameters are (Leka, Kika, & Greca, 2016):

- Student Knowledge, i.e. the knowledge of the learner on one particular topic.
- Learning Styles, i.e. the way by which learners acquire information.
- Cognitive Abilities, i.e. the method by which learners acquire information.
- Learning Behavior And Motivation, i.e. the way learners behave.

Additionally, Matzavela & Alepis (2017) add the following parameters:

- Cultural Perspectives, i.e. the way that learners are influenced by their environment.
- Emotional State, e.g. learner's feeling
- User Environment, e.g. learner's personality.
- User Intervention, i.e. the learner be able to influence the system's functionality.

5.4 Adaptive environments

As is already known, adaptive learning environments offer students learning experiences that are tailored to them taking into account the above adaptive parameters. These environments fall into several categories, which are (Slavuj et al., 2017):

- Intelligent Tutoring Systems: These systems are a good illustration of micro-adaptivity application, where tutoring can be accomplished in the following ways: by providing problem-solving assistance to students and by putting in order the learning activities that must be followed in order to achieve the goals that have been set.
- Adaptive Hypermedia Systems: Students are directed to relevant learning resources via hyperlinks and icons and by content adaptation reduce the amount of time it takes to complete an instructional course.
- Collaborative Learning Environments: Students work in groups of two rather than working alone assisting each one another via interaction and this may lead faster to knowledge acquisition. In this case, the system should be adapted to all team members.

- Computer-Supported Ubiquitous Learning: utilizing state-of-the-art technology equipment such as Wi-Fi and sensors, it adapts teaching based on where, when, by what means, etc. learning takes place.

5.5 Our adaptive learning system

Our learning system adopts adaptivity. The aim of this thesis was to develop a system where, depending on the performance of the students, it will adjust the content that will be shown to them. More specifically, every time students interact with educational activities, a record of that activity will be made. Based on these recordings and after appropriate processing the system will decide on what content will be shown to the student next.

Therefore, in the system we developed, we wanted the student to participate actively in the acquisition of knowledge, but not to participate in the decisions that the system will make. That is, the decisions the system will make will be based entirely on what it has been programmed to do without the intervention of the students in the way it will behave.

Chapter 6 - Self-regulated learning

Students of the 21st century should not be passive recipients of knowledge but actively participate in its acquisition. The development of the internet, as well as a multitude of tools for distance education, has enabled students to study and ultimately learn beyond the time and space boundaries of a classroom. This enables them to acquire all the necessary supplies but also to develop all those abilities and skills that will allow them to meet the demands of the times.

Since not all students learn in the same way or at the same time, learning systems that support self-regulated learning provide a prime opportunity for students to learn in the way they want and they can.

6.1 Overview

How students learn, has been the subject of study by researchers for many decades. Back then, students were trained in various learning strategies to apply them in learning contexts. However, it was observed that in situations outside the learning process they did not use these strategies. Thus, the need for their effective implementation along with other self-regulation processes was born.

A milestone in self-regulation research was a symposium held in 1986 where a comprehensive definition was given for self-regulation learning (SRL). According to it, SRL is the extent to which students actively engage in their own learning from a metacognitive, motivational, and behavioral perspective (Zimmerman, 2008). In the 1980s, several studies were conducted and a significant number of tools were produced that evaluated SRL as a metacognitive, motivational, and behavioral concept. These provided unequivocal proof that SRL was a significant concept deserving of additional study. And indeed, since then we have had a significant development of the field.

6.2 Definitions

At this point, it is important to clarify the term self-regulation. Schunk & Zimmerman (1997) stress that among other self-regulation:

> incorporates motivational processes such as setting performance goals and outcomes; holding positive beliefs about one's capabilities; valuing learning and its anticipated outcomes; and experiencing positive affects (e.g., pride, satisfaction) with one's efforts (p.2).

A typical definition of what SRL is was given in paragraph 6.1. Additionally, according to Pintrich (2000) self-regulated learning is:

> an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment. These self-regulatory activities can mediate the relationships between individuals and the context, and their overall achievement (p. 453).

From the above we conclude that in SRL the self of the learner plays an important role and who is the one who dominates his learning and behavior in order to achieve the goals he has set.

6.3 Zimmerman's SRL Model

Various models have been developed aiming at the analysis and interpretation of self-regulated learning. Some of them are "Zimmerman; Boekaerts; Winne and Hadwin; Pintrich; Efklides; and Hadwin, Järvelä and Miller" (Panadero, 2017). Bellow, we will present Zimmerman's SRL model because it is more suitable for 11-year-old students, to whom the educational system developed in the context of this thesis is addressed.

The aim of developing Zimmerman's SRL model which was first introduced in 2000, was to enable students to actively participate in the learning process as well as to cultivate self-regulation skills such as setting goals, observing and evaluating themselves. This model includes 3 phases: forethought, performance or volitional control, and self-reflection (Figure 6.1) (Zimmerman, 2008). These 3 phases create a 'cycle', where the processes of each phase are influenced by the processes of the previous phase and affect the processes of the next phase.

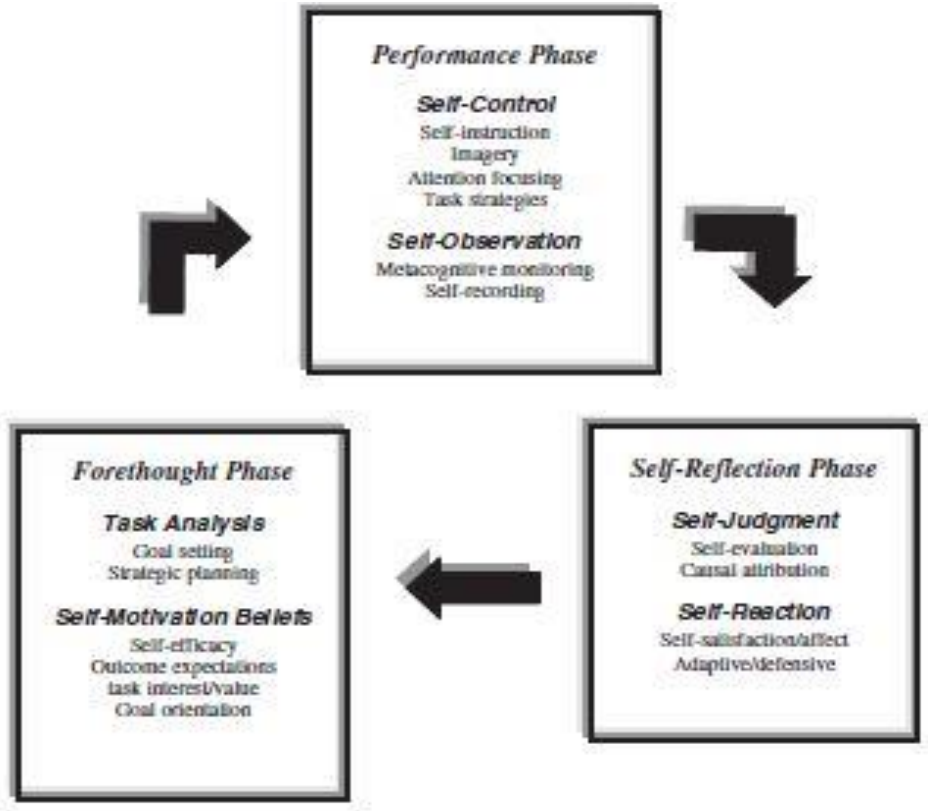

Figure 6.1 Phases and Subprocesses of Self-Regulation (Zimmerman, 2008).

- Forethought Phase. This is the 'before' phase of the cycle. This is where 'Task Analysis' takes place, which includes 'Goal setting' and 'Strategic planning'. Motivation plays an important role in this phase, which is related to 'Self-efficacy', 'Outcome expectations', 'task interest/value' and 'Goal orientation'.
- Performance Phase. In this phase, the learning process is implemented. It consists of two main processes: 'Self-Control' and 'Self-Observation'. In 'Self-Observation' process, students can carry out two types of tasks, 'Metacognitive monitoring' and 'Self-recording'. In 'Self-Control' process, students can use a variety of strategies in order to accomplish a task like 'Self-instruction', 'Imaginery', 'Attention focusing' and 'Task strategies'.
- Self-Reflection Phase. In this phase, students evaluate their effort and interpret the reasons that had the specific results. It is constituted by 'Self-Judgement' and 'Self-Reaction' processes. In the 'Self-Judgement' process, the evaluation of the students' performance takes place by the students themselves and consists of the

‘Self-evaluation’ and the ‘Casual attribution’. In the ‘Self-Reaction’ process which includes ‘Self-satisfaction/effect’ and ‘Adaptive/defensive’ sub-processes, we meet the students' reactions to their performance on a cognitive and emotional level.

Studying Zimmerman's SRL model we conclude that the three phases of the cycle are performed repeatedly until the goals set by each student are achieved.

6.4 Self-passed learning

The term of SLR is closely related to the term of Self-passed learning (SPL). In order for students to be able to engage in activities that are not limited by space, time and place, they should already have mastered the skills of autonomy and self-regulation that SLR cultivates (Bergamin, Werlen, Siegenthaler, & Ziska, 2012).

As is already known, learning can be done either offline or online. With regard to offline learning, the SPL gives to students the opportunity to learn at their own speed, in their own location, and on their own schedule with the support of printed books or portable technology like tablets and smartphones. In terms of online SPL, this type of learning enables students to learn online at their own speed, on their own schedule, and perhaps from anywhere (Naidu, 2008).

SPL strengthens students’ autonomy and flexibility since they have the ability to start attending a course throughout the year and finish it at their own pace. It is also known as "learner paced", "unpaced", "self study" or "independent study" (Anderson, Annand, & Wark, 2005).

Part B: Implementation

Chapter 7 - The learning system

7.1 System overview

The purpose of the system is to provide users with a pleasant learning system for learning visual programming in Scratch. This system supports self-regulated learning and makes use of game elements. It is addressed to fifth grade Elementary School students who are at the age of 11 and are coming into contact with programming for the first time. The system is adaptive and self-regulated and depending on the performance of each student, it displays the appropriate educational content.

There are two levels of users in the system, students and teachers. In general, students have access to educational materials and teachers have access to information about students' progress and performance.

The educational material is created by the H5P authoring tool, which adopts xAPI. The material is structured in educational units in which we present the learning object and offer comprehension activities. The educational material is adaptive, and the course of the units that the student will attend depends on his performance. Students can access the educational material at different times and continue their effort from where they stopped. Each time the student interacts with the educational material his activity is recorded. Thus, when the student connects to the system, it checks his progress so far and shows him the appropriate material.

In addition, the system records the progress and performance of students by providing the teacher with the necessary data to draw valuable conclusions about the learning progress of his students. The teacher has the ability to view a student's progress or aggregate statistics for all students.

7.2 System architecture

In Figure 7.1, we present the system architecture. The system includes two main nodes, the website with the educational material and the Learning Record Store (LRS), which stores the student activity.

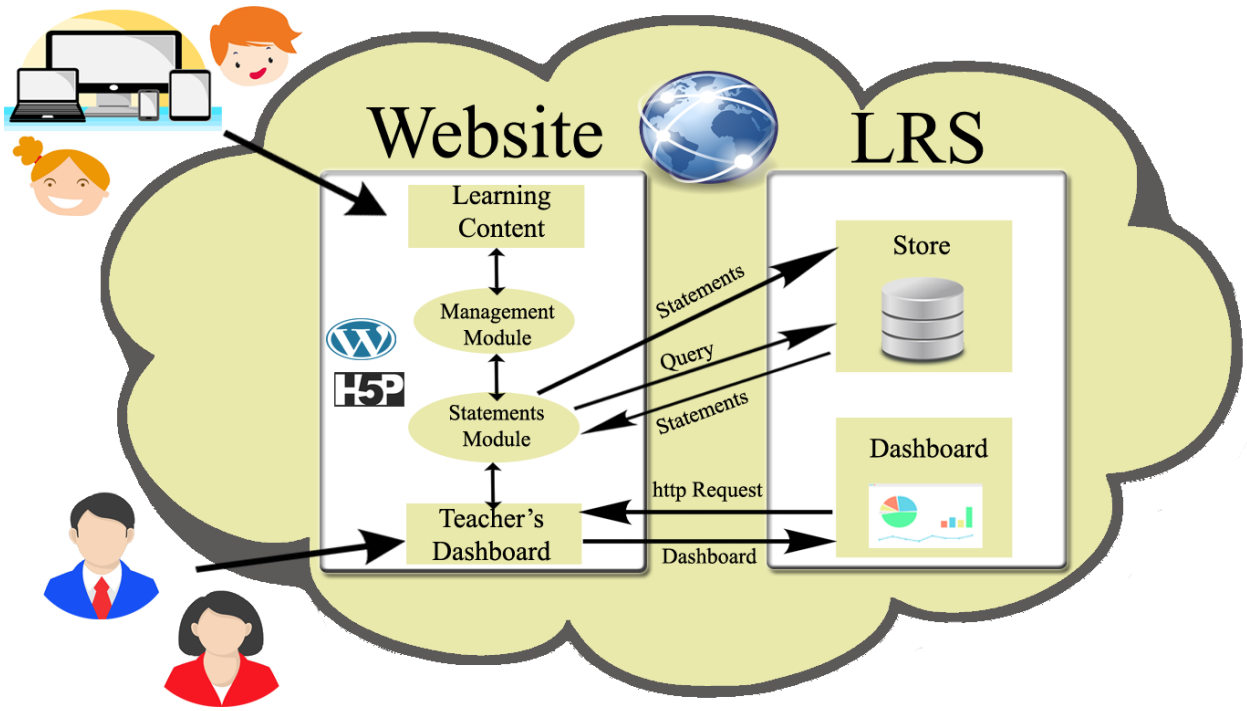

Figure 7.1 The system architecture

7.2.1 The Website

The Website is the node that hosts the application. It contains the educational material, the user interfaces and the mechanisms for managing the educational material and the course of the students. In particular, the Website consists of the following parts:

- The **Learning Content.** It consists of units of learning objects and comprehension activities.
- The **Teacher's Dashboard**, which provides information on student performance. It consists of the student's statistics of each student and the aggregate statistics of all students.
- The **Management Module** is the brain of our application. It displays the appropriate content, depending on the type of user (teacher or student). It also selects which data it needs to retrieve from the LRS and asks the Statements Module to provide it. After

receiving them, it processes them and gives them the appropriate form so that it can use them. The Management Module evaluates the student's condition and adjusts the material to be displayed. Finally, it manages the display of statistics to the teacher.

- The **Statements Module**, which controls the management of xAPI statements. This module compiles queries to LRS and receives xAPI statements. It then submits them to the Management Module for further processing. In addition, it captures the xAPI statements created by student activity and sends them to the LRS for storage.

7.2.2 The Learning Record Store (LRS)

The Learning Record Store is a separate node of the ecosystem, and is hosted in a separate installation. Its main object is the management of xAPI statements created by the Website. More specifically, the LRS node consists of the following parts:

- The **Store**, which is the storage space of xAPI statements created by the Website. The Store on the one hand stores the new xAPI statements and on the other hand accepts queries from the website and returns the results.
- The **Statistics tools**. The LRS provides tools, with which we can compile queries on the xAPI statements of the store. The results of the queries can be displayed graphically, choosing from a variety of graphs. Graphs can then be integrated into dashboards, which are shareable in applications other than LRS.

7.3 Development tools

For the development of our learning system, we utilized a variety of tools. For the backbone of our system we used the open source Content Management System (CMS) WordPress ("Blog Tool, Publishing Platform, and CMS | WordPress.org," n.d.). With WordPress we developed our website and there we integrated the other necessary modules. The xAPI storage was installed on a remote server using the Learning Locker LRS.

We used the H5P WordPress plugin ("Interactive Content – H5P – WordPress plugin | WordPress.org," n.d.) to create and preview the educational content. The Management Module was developed with PHP and for the Statements Module we used the TinCanJS JavaScript library.

7.3.1 CMS WordPress

WordPress is a free Open Source Content Management System under GPLv2, which was originally aimed at creating blogs. It is written in PHP and can work with MySQL, MariaDB or SQLlite to store its data. Its ease of use and scalability soon helped it dominate the web design industry. There is a huge technical support community of bloggers, developers, designers and ordinary users around the world makes WordPress so functional, powerful and stable.

WordPress content, by default, can be presented through pages or posts. Pages are used to present “static” content, while posts have blog-oriented content. Posts have an author, a date and they accept comments. In addition, WordPress permits us to modify the template it uses for pages and posts, or to use our own custom templates to achieve the content display we want.

Furthermore, WordPress has the ability to extend its functionality by adding plugins and themes. There is a plethora of plugins, which we can use to add features to our website, giving to it capabilities for e-shop, multilanguage site, media management etc. Additionally, with the WordPress themes we can change the design of a website quite easily.

7.3.2 H5P WordPress plugin

To develop the educational environment we used the H5P software and embedded it in the Website using the corresponding WordPress plugin.

H5P is a free and open source technology for developing, sharing, and reusing interactive HTML5 content. H5P is a very flexible authoring tool and the generated content can apply to models such as those of Mixed Learning and Reverse Class. H5P offers 17 different types of content, such as interactive videos and presentations using a variety of multimedia elements, multimedia historiographies and branching scenarios.

It should be noted that xAPI coverage is not supported by all H5P Content Types. The two main types that contain a wide range of xAPI statements are Interactive Video and Course Presentation. This is because within these two Content Types, other Content Types can be inserted such as drag and drop, drag the words, multichoice question, summary and Single Choice Set. All these aforementioned types are the ones on which our educational material was

built. Figure 7.2 and Figure 7.3 present the detailed xAPI Coverage for Interactive Video and Course Presentation:

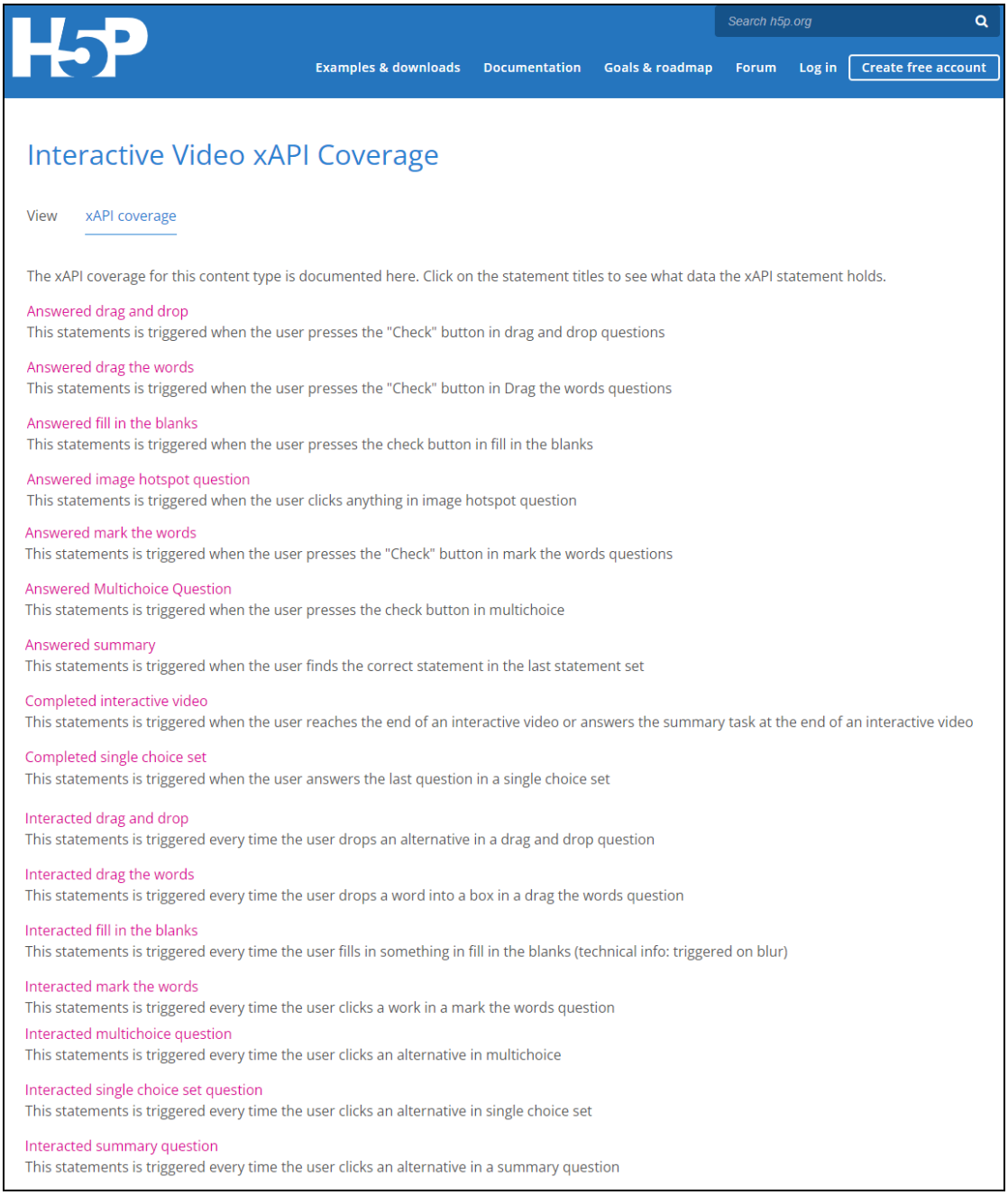

Figure 7.2 Interactive Video xAPI Coverage

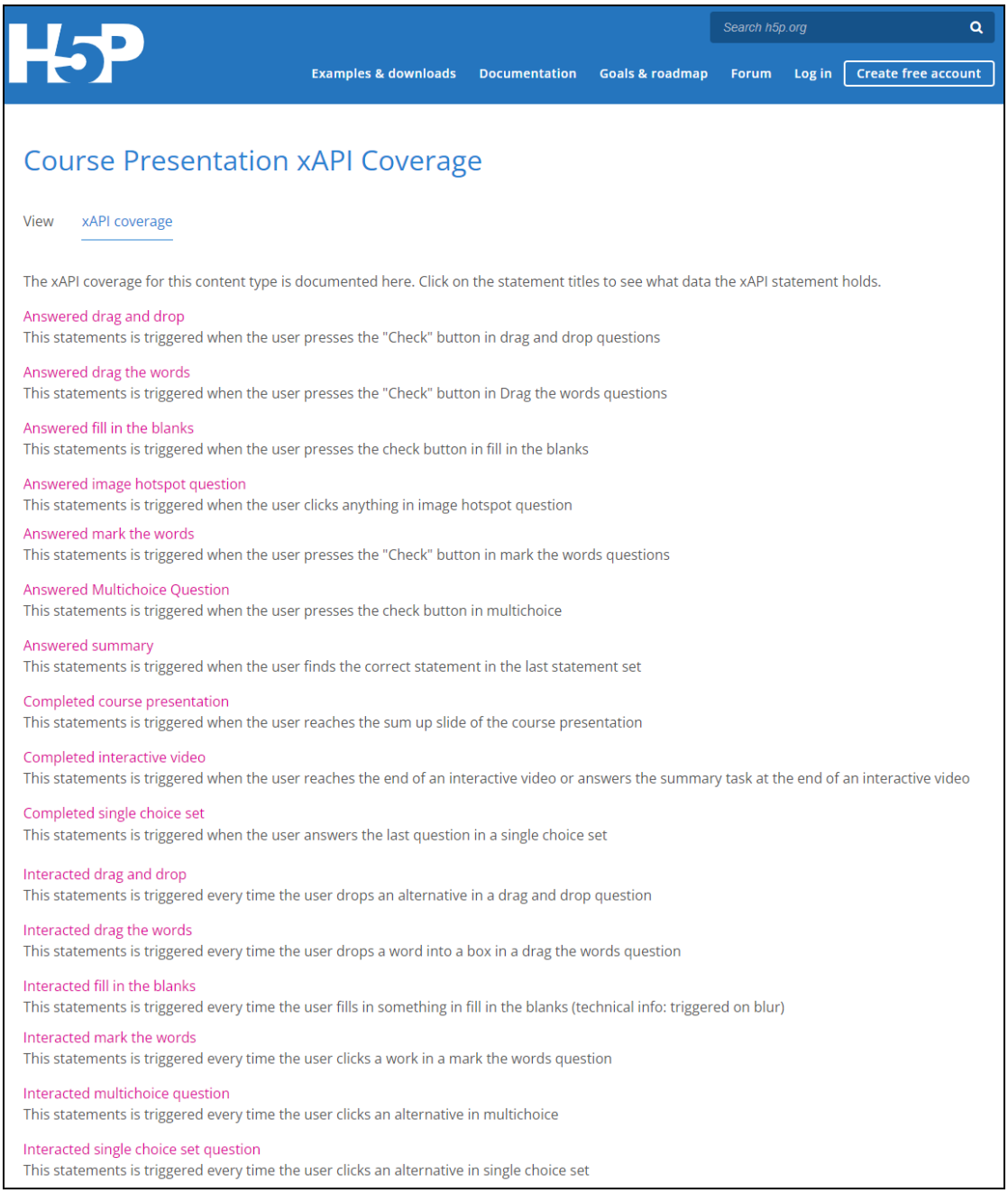

Figure 7.3 Course Presentation xAPI Coverage

We can use H5P in two ways:

1. by creating an account on the H5P website and developing activities online. Then, we can integrate the activities into websites or LMS and view them on either computers or mobile devices.
2. by installing the H5P plugin and developing content in WordPress, Moodle or Drupal.

Main features:

- It is a free open source application.
- Provides easy development of interactive content and has ready-made templates that speed up content creation.
- Content reusability.
- Content is mobile friendly.
- Collaborates with existing LMS or CMS to create rich, interactive HTML5 content.
- Generates content in a single file, easy to manage and transfer to web pages.
- Offers universal function updates.
- Provides licensed multimedia content.
- Provides opportunities to expand or create custom content formats and applications.
- Supported by a user community where users can share their knowledge, content types and code.
- There are several types of content available today and even more are under development.

By installing the plugin, we are enabled to create H5P educational content through the WordPress admin environment. We can also import H5P content created on the H5P website or other installations.

The installation of the plugin offers us an environment with basic functions. Moreover, we can expand its functionality by installing additional libraries or by upgrading the already installed ones. By installing additional libraries, we can use additional content types or add our own content types.

The plugin also allows us to present H5P content on our website. We can embed the content in pages or posts using shortcodes.

In addition, the plugin presents basic statistics on user performance when using content. The information it displays for each user is:

- when he started the activity,
- when he completed the activity,
- how long he was involved in the activity,
- what was the score he achieved in the activity questions,

- what was the maximum score of the activity.

The above statistics contain only basic information, which does not cover the data we need for our research. Thus, we chose to create the infrastructure for statistics, which we describe in next chapters.

Finally, H5P contains effective event handling. It captures the student's activity and generates the relevant xAPI statements. Additionally, H5P exposes an external event dispatcher, which enables other applications to register event listeners.

7.3.3 PHP

The acronym PHP which is abbreviation for "PHP: Hypertext Preprocessor," is a general-purpose server-side scripting language, and a powerful tool for making dynamic and interactive web pages. Learning the syntax of the language, which is based on already known languages such as C and Java, does not present difficulties ("PHP: Preface - Manual," n.d.)

PHP is open source, runs on various platforms and operating systems and is compatible with almost all major webservers. It can work with a wide range of database categories such as SQL and NoSQL databases (Tatroe, MacIntyre, & Lerdorf, 2013). It is accompanied by a good documentation and provides a repository called PEAR. "PEAR is a framework and distribution system for reusable PHP components" ("PEAR - PHP Extension and Application Repository," n.d.)

WordPress is built with PHP. A website that is developed with WordPress is cooperating with a MySQL database for storing all data related with it. PHP is responsible for extracting certain data from the database and combining it with other data to create an HTML web page ("What is PHP? How PHP is Used in WordPress?," n.d.).

7.3.4 TinCanJS

TinCanJS is a JavaScript library created by Rustici Software for the Experience API. With TinCanJS, we achieve to communicate with an LRS, and exchange xAPI statements. Its integration is simple, as with all JavaScript libraries.

TinCanJS initially provides the functionality for authenticated connection to the LRS. It also allows us to write queries that we will submit to the LRS. Then, using two following basic methods, it manages the communication:

- queryStatements(): handles the sending of a query to the LRS and receives the corresponding xAPI statements. This function is used, so that:
    - the student can continue his effort from the point where he had stopped
    - the student has access to his progress so far
    - the teacher has access to the progress of a specific student
- saveStatement(): handles the sending of the xAPI statements generated by the users' activity to the LRS.

7.3.5 Learning Record Store (LRS) - Learning Locker

7.3.5.1 Overview

The Learning Record Store (LRS) plays a key role in the xAPI ecosystem. First, the LRS receives xAPI statements from the Activity Provider and stores them. It then shares the data with Activity Consumers for further processing.

Learning Locker is an Open Source LRS and was developed in 2014 by HT2 Labs, whose name now is Learning Pool. Learning Locker is "a type of data repository designed to store learning activity statements generated by xAPI (Tin Can) compliant learning activities" ("Learning Locker Documentation," n.d.-b).

"Learning Locker is divided into two Github repositories, one for the Learning Locker application and one for the xAPI service." The Learning Locker application is divided into three elements: "the browser interface (UI), the HTTP interface (API), and the workers". In order to be able to share resources, these elements are run as separate processes. The xAPI service comprises 4 elements: "statements, activity profiles, agent profiles, and state". It gives access to the HTTP Interface, which offers the opportunity to interact with the xAPI as stated in the specification("Learning Locker Documentation," n.d.-c).

7.3.5.2 Structure

Learning Locker has the necessary mechanisms for classified data access. xAPI statements are organized into organizations and stores. The organization is a broader structure

and is used to make logical groups of statements. Every organization consists of stores and clients. An organization can contain multiple stores. Stores are smaller collections of data.

Data access is regulated using users and clients. Users access the LRS through the Learning Locker's browser interface. Each user has access only to the data of the organizations assigned to him. At the same time, an organization can be assigned to many users. Using clients, we provide access to the LRS' data via HTTP interfaces. Clients' access can be limited to selected stores.

7.3.5.3 Data management

When we login to Learning Locker and choose our organization we can see a list of choices that we can make in the left side of the window. In the Data section we can find the following choices: Dashboards, Visualize, Source and Statement Forwarding.

7.3.5.3.1 Dashboards

Through this option, we are given the opportunity to create dashboards that meet our needs and to present our visualizations. By clicking to "NEW DASH" we can create as many dashboards as we wish. In each dashboard, we can add one or more visualizations that we have created from the choice "Visualise" by clicking the button "Add Widget". These dashboards are shareable and we can make it by clicking the "Share "button. Then we define who can see the dashboard and we can apply filters by selecting queries. The shareable link is given and the dashboard can be viewed from the web.

Figure 7.4 Sharing a dashboard

7.3.5.3.2 Visualise

With the option “Visualise” we can make visualizations of the statements using a variety of graphs like Bar, Correlation, Column, Line, Counter and Pie (Figure 7.5), exploring possible relationships and tendencies.

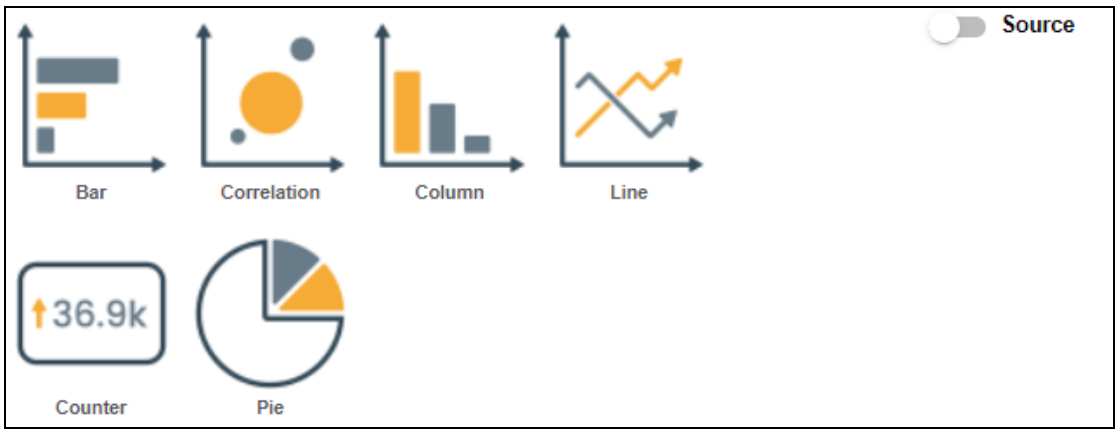

Figure 7.5 Visualizations

7.3.5.3.3 Source

In the Source section, we find all the statements that have been sent from our learning system and are related to the actions that a student took inside it. The statements screen is divided in two areas (Figure 7.6). In the right area where we see the aforementioned list of statements and in the left area where we can find the Query Builder for filtering this list of statements.

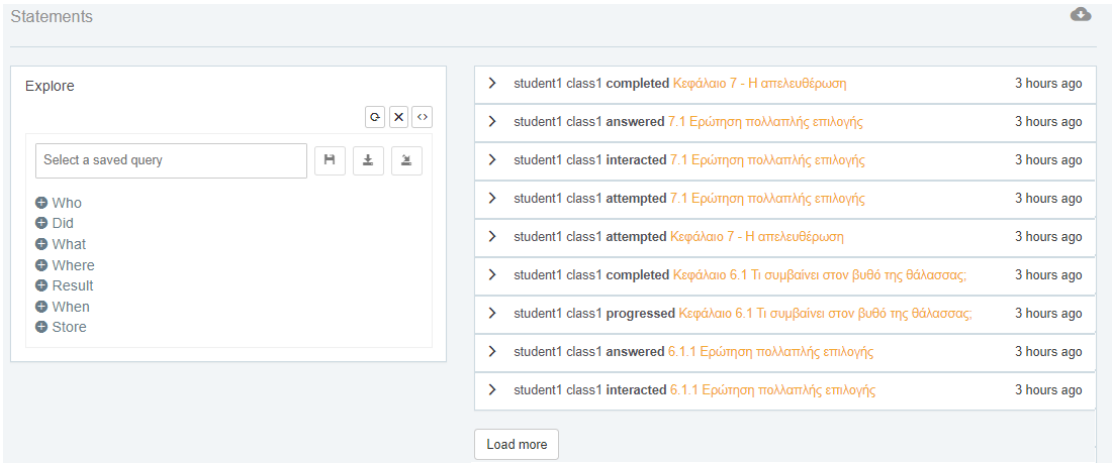

Figure 7.6 The Source Screen

7.3.5.4 Statement Forwarding

With Statement Forwarding we can forward received statements to another system. With the given options (Figure 7.7), we can forward all the statements or a number of them that satisfy certain conditions through queries.

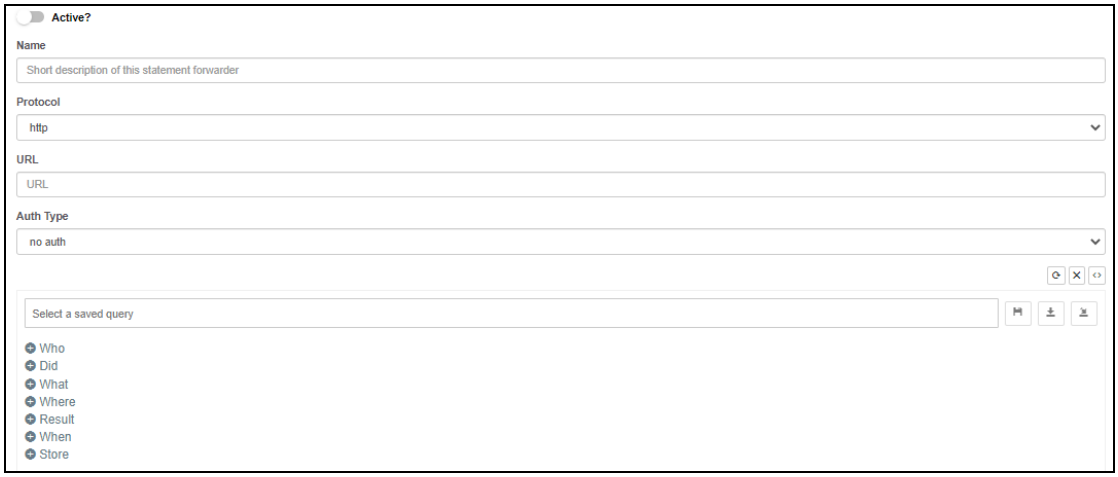

Figure 7.7 Statement Forwarding

7.4 System implementation

7.4.1 Website

The website is hosted in the Greek School Network with an Apache webhost that uses PHP 5.6.40 and MariaDB 10.1.31. The Greek School Network is the national network of the Ministry of Education and Religious Affairs that supports all the schools, teachers and students of Primary and Secondary education. The url of the website is http://users.sch.gr/arvanitdes/learning-experience.

We used WordPress 5.8.4 to develop the website that is the backbone of the system and hosts the educational content. Based on the basic functionality offered by WordPress, we provided:

- user management,
- register and login functionality, classified access to users,
- webpages with informative content,
- access to educational content.

Using the H5P WordPress plugin, we expanded its functionality to:

- host the tools for developing the educational content,
- integrate the educational content into web pages,
- integrate students' statistics and aggregate statistics.

To add the necessary functionality and decision making mechanisms we created the Management Module and the Statements Module. For their development, we used PHP and JavaScript code that we embedded in the website through custom PHP templates.

More specifically, with PHP we developed the Management Module, which:

- processes the xAPI statements and displays student's progress,
- applies adaptivity by choosing the units that the student will attend depending on their educational needs,
- implements gamification by collecting the scores, calculating badges and energy,
- integrates the statistics produced by the LRS.

With TinCanJS, we developed the Statements Module, which:

- sends the xAPI Statements to LRS for storing,
- creates and submits to LRS the necessary queries and receives the relevant xAPI statements,
- incorporates the Listener that captures the xAPI Statements created by the H5P plugin.

In Chapter 8 - we present the website in more detail.

7.4.2 Learning Record Store

For the LRS we used a Learning Locker v2.0.4 installation that was provided by the Natural interactive Learning Edification Games Laboratory (NiLE-lab). NiLE-lab is a unit of the Department of Electrical and Computer Engineering of Hellenic Mediterranean University (HMU) ("NILE," n.d.).

To manage the statements, we created the “Arvaniti” organization (Figure 7.8). Inside this organization, we created the store named “xAPI store” (Figure 7.8) and the client named “xAPI_user” who will have access to the specific store (Figure 7.9). The Statements Module of the Website, using the url of the xAPI Endpoint and the credentials of the specific client gains access to the xAPI Statements it needs, as we will see in more detail in Appendix B.

Figure 7.8 Our Organization

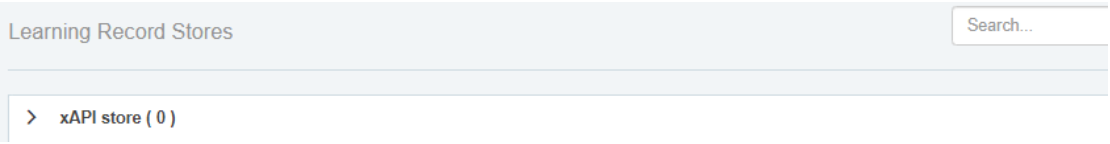

Figure 7.9 Our Store

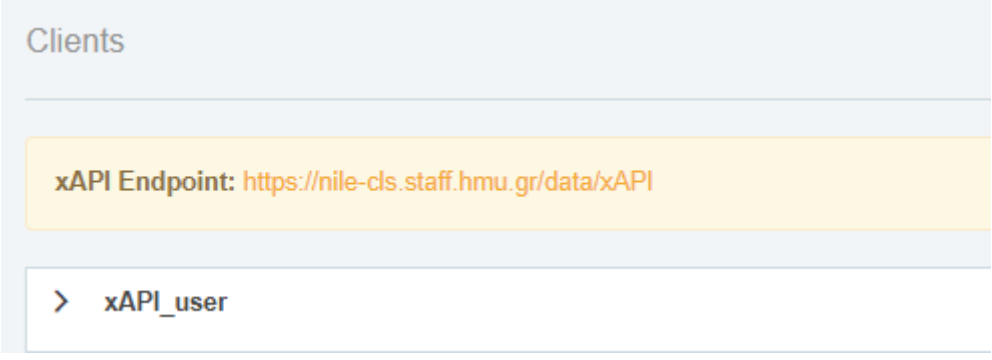

Figure 7.10 Our Client

7.4.3 Website and LRS communication

7.4.3.1 Data management

The data stored in the LRS, the xAPI statements, play a key role in the operation of the Website and the game. Website and LRS communication is two-way. The Website sends to the LRS for storage all xAPI Statements created by student activity. It then retrieves them and utilizes them when needed. Specifically, data has the following formats:

1. **Raw xAPI Statements**. This format is used when we retrieve data about the activity of an individual student. This case occurs when we want to determine the status of a student, after he logs in or when the teacher searches for the status of a student. To achieve this we compile and send to LRS the appropriate query. In response we receive raw xAPI Statements from the LRS, which we process and present to the user of the Website.
2. **Formatted Statistics.** This format is used when we obtain aggregate data on student performance. In this case, we create queries in the Learning Locker environment. Learning Locker allows us to create graphs with the query results and then share them with other applications. We embed these graphs on our website and display them to the teacher.

To display the appropriate content while the student is connected, it needs to have a picture of the actions the student has taken. For this reason, as long as the student is logged in, the Website maintains an appropriately formatted copy of the student-generated xAPI statements, in session variables. In session variables, we store the information needed to the Management Module to make decisions for managing the application. In addition to the XAPI statements, we store additional information, such as the status of each unit, the score, the badges, the student's energy and the next unit to attend. When a student is logged in, the session variables store the xAPI statements related to that student's activity. When the teacher is connected, the session variables store the corresponding data for the student for whom he is looking for information.

7.4.3.2 Transactions between the Website and the LRS

The communication between the Website and the LRS takes place in the following cases:

1. **Determining the status of a student**. This procedure is executed in two cases. If the user is a student, the process is performed right after he logs in. Otherwise, if the user is a teacher, it is performed while searching for a student's statistics. In both cases, the Management Module asks from the Statements Module to fetch the xAPI Statements of the student from the LRS.

   The Management Module provides to the Statements Module with student information, which it then undertakes to compile and submit the appropriate query to the LRS. The LRS Store Module returns all the student's xAPI Statements to the Statements Module. The Statements Module delivers the xAPI Statements to the Management Module, which processes them and stores the necessary information in session variables, for further use. After this, the Management Module displays the appropriate content to the user.

2. **In every action of the student**. During the student's interaction with the educational content, every action that he takes produces a xAPI statement. The Statements Module captures the statements and undertakes to send them to the LRS Store module for storage. At the same time, it informs the Management Module for the new statements, which stores them in the appropriate session variables.

3. **Displaying students' aggregate statistics.** In this case, the information we want to display, has been created by the Statistics tools of LRS. Since the data processing happens in the LRS, the process of displaying them does not require any special processing in the Website. The Management Module, depending on the data it wants to display, executes the appropriate http request in the LRS to embed the corresponding dashboard in the website.

In appendix B, we present the communication between the Website and the LRS in more detail.

Chapter 8 - Learning Content

8.1 Educational game

We developed the educational content using the H5P plugin of WordPress. Students participate in an educational game, through which they meet, for the first time, the basic principles of visual programming using Scratch. The game is transformed into a fun educational process, using images, audio and video. The student can interrupt and continue the educational process later, continuing from the unit that had stopped.

Students watch the story unfold, and follow an educational path to complete it. This path is divided into educational units. Throughout this course, they watch presentations and videos with educational material, which provides them with knowledge about Scratch.

The student has an active role in the educational process and is not a passive recipient of information. First, it has control over the flow of information by choosing whether he wants return back to previous points or units. The student also actively participates by answering questions about the educational material he has attended and receives immediate feedback on the correctness of his answers.

Throughout the game, students can see statistics about the course they have followed. They can also, if they wish, repeat some of the previous units they have completed, to enhance their learning or to improve their grades.

The educational process is strengthened with game elements, which enhance the students' interest, offering additional incentives for participation. At the same time, we use adaptivity to provide the students with the appropriate educational content that meets the special needs of each student.

8.1.1 Adaptivity

The student follows an educational path to complete the game. The educational path is flexible and is adapted to the special needs of each student, based on his performance in the consolidation questions. The student, in order to continue to the next unit, must prove that he has achieved the learning objectives of the unit, achieving a minimum grade limit in these

questions. In case the student does not achieve the desired result, he repeats the unit or attends an additional unit that will help him to understand the subject better.

The educational path is not modified only to support students who have not achieved the educational goals. It is also modified to reward students who have achieved excellent performance, offering bonus educational units, enhancing student motivation.

8.1.2 Gamification

To make the educational process more attractive we have used game elements. In each unit, the student faces challenges by answering consolidation questions and collects points from the correct answers. Depending on his score and the units he has successfully completed, he is rewarded with badges. To complete the educational game, he must collect all the badges. At the end, the student can download a pdf file, which is the prize for successful completion of his mission.

To maintain students' interest, in addition to the reward system, the student must also face a factor of difficulty. The factor of difficulty we chose is energy. The student begins his course with a certain amount of energy. For each failed attempt to complete a unit, an amount of energy is deducted. If the student's energy is exhausted, he cannot continue the game. In this case, further actions are required from the teacher in order to investigate the reasons for the student's failure and to make appropriate interventions.

8.2 The story

The story we use follows the classic pattern of well-known fairy tales that the students have encountered. There is a group of heroes, who are facing a problem. To solve the problem they need the help of a third person, who will help them overcome it. Students are asked to take an active role in the story, participating in the group of heroes and helping them face difficulties. This is a simple story, without much plot, that attempts to provide a basic background for setting up our game. We want our story to be easily understood, without increasing the complexity of the game at the expense of the educational goal.

The educational game presents the story of two brothers Elli and Nikolas. The two brothers spend a lot of time in the countryside. One day, as they were walking on the mountain,

they saw a hole in the ground. Elli, strange as she was, ran to the hole and with a jump entered in. Nicholas wanted to follow her but as he approached, the hole became smaller. Elli was captured in the prison of the castle of the Magic Kingdom. Before the hole was completely closed, she managed to shout at her brother that in order to save her he had to collect the necessary symbols to unlock the prison locks.

The students undertake to help Nikolas collect the necessary symbols to free Elli. To collect the symbols they have to face some tests in Scratch. Depending on the test results, they acquire badges. The badges are the circle, the heart, the star and the moon.

8.3 Educational units

The educational content consists of nine units. For the needs of the story we present, we used Interactive Video and Course Presentation Content Types. In summary, the sections we have created are the following, which we will present in detail in CHAPTER 1 - Chapter 1 - Appendix A - :

- **Unit 1. Introduction-History.** In the first unit, the student watches the story of Eli and Nikolas and gets information about his mission.
- **Unit 2. Welcome!** In this unit, the student learns basic information about Scratch. After this, the student will know what Scratch is, what he can do with Scratch and to whom the Scratch is addressed. They will also learn how to download the program and work with Scratch.
- **Unit 3. Introduction to the environment**. In unit 3, the student is introduced to practical issues. He learns to identify the areas of the Scratch interface, distinguishing command groups and the commands in each of them. Finally, he will be able to create a new project, manage commands, objects, backgrounds and execute a program.
- **Unit 3.1. Introduction to the environment (extra)**. The student is led in this unit only if he fails in unit 3. It is an alternative presentation of the topics presented in the previous unit. Here, we use the Course Presentation Content Type, instead of the interactive video of unit 3.

- **Unit 4. Change costumes – Create Animation.** Here, the student gets familiar with costumes and animation. He also handles delays, backgrounds and sounds. At the end of the unit, he creates his own animation.
- **Unit 5. Motion.** In this unit, the student learns the motion commands. He also learns to combine motion commands with change commands to create animation.
- **Unit 6. Looks.** In unit 6, the student identifies and distinguishes speech and dialogue commands. He applies speech commands to his objects and creates dialogues.
- **Unit 6.1 What is happening at the bottom of the sea? (Bonus).** This is a bonus activity, offered to the student that achieved a high score in unit 6.
- **Unit 7. The liberation!!!** It is the last unit of the game. After the student has completed his mission, he watches the end of the story and receives his award.

8.4 Point system and educational pathways

The purpose of the game is to collect the necessary badges to free Elli. To succeed, the student participates in some tests by answering comprehension questions. In this section we describe the question grading system, how to obtain the badges and the educational paths that the student can follow during the game.

In **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** we see the number of questions that exist in each section and the maximum score that the student can achieve. We also see which is the next unit in case of success and in case of failure.

Unit	Activities	Max score	Min score for next lesson	Next Lesson	
				Success	Fail
Unit 1. Introduction-History	1	1	0	Unit 2	Unit 2
Unit 2. Welcome!	3	3	2	Unit 3	Unit 2
Unit 3. Introduction to the environment	8	14	10	Unit 4	Unit 3.1
Unit 3.1. Introduction to the environment (extra)	8	14	10	Unit 4	Unit 3.1
Unit 4. Change costumes – Create Animation	8	17	12	Unit 5	Unit 4
Unit 5. Motion	8	11	8	Unit 6	Unit 5
Unit 6. Dialogues	9	9	8	Unit 6.1	Unit 6
			6	Unit 7	
Unit 6.1 What is happening at the bottom of the sea? (bonus)	0	0	0	Unit 7	-
Unit 7 - The liberation	0	0	0	-	-

Table 8.1 Information for the system

In Table 8.2, we see the conditions for obtaining the badges. The prerequisites are a combination of the chapters completed by the student and the points he has accumulated in the activities of each chapter.

Badge	Name	Acquisition conditions
	Circle	13 points and completion of chapter 3
	Heart	26 points and completion of chapter 4
	Star	34 points and completion of chapter 5
	Moon	40 points and completion of chapter 6

Table 8.2 Badges

However, apart from the scoring system, the energy of the student plays a decisive role in the continuation or termination of the game. At the beginning of the game, the student has 100 energy points. Each time he repeats a chapter he loses 10 energy points. Whenever a chapter is repeated, we maintain the highest score the student has achieved. For the number of views of each unit there is a corresponding counter of its views. If the student's energy is exhausted then a message is displayed and the game is over.

In Figure 8.1, we see a diagram with the educational paths that the student can follow during the game.

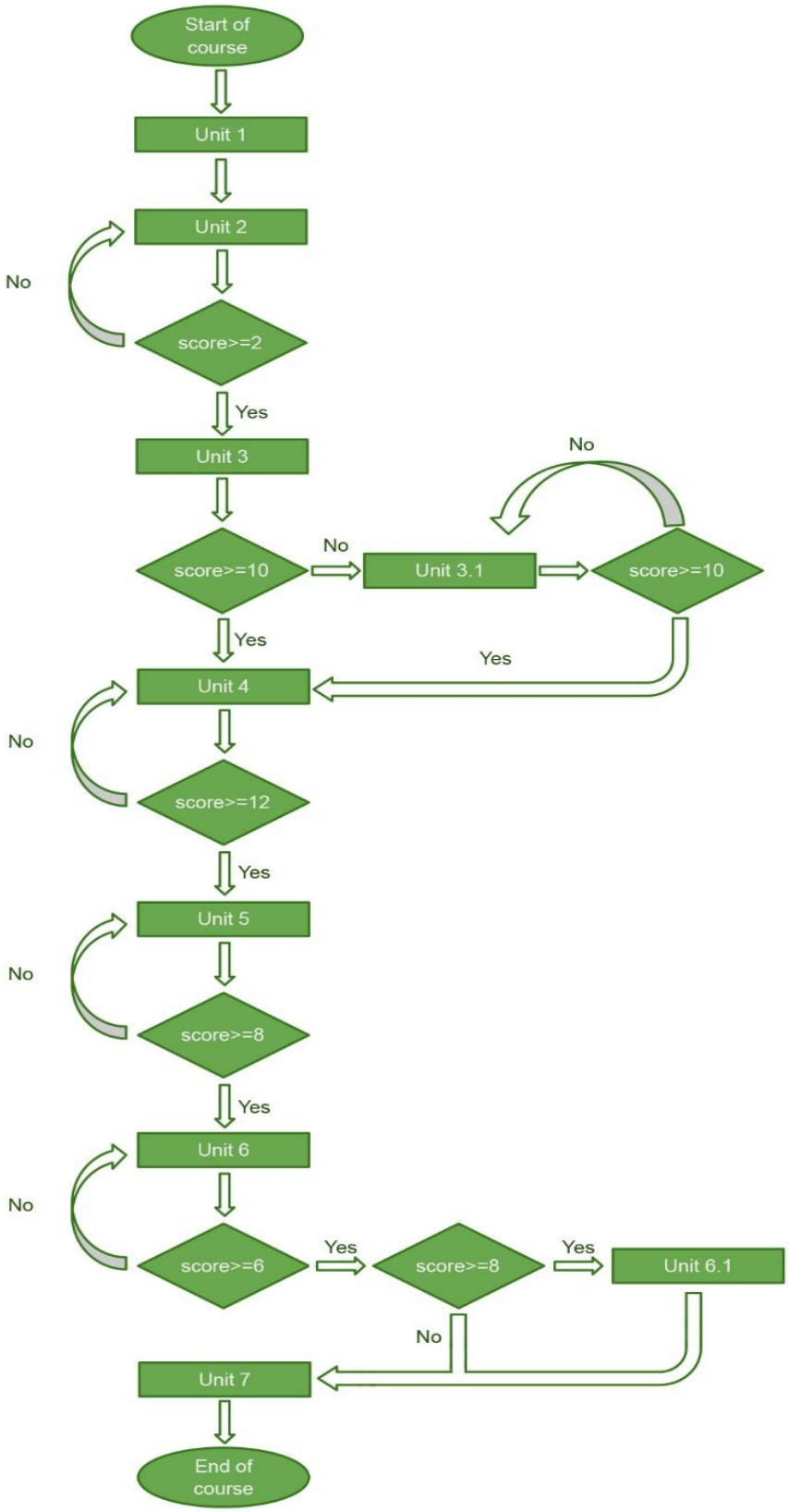

Figure 8.1 Educational paths

Chapter 9 - The Website

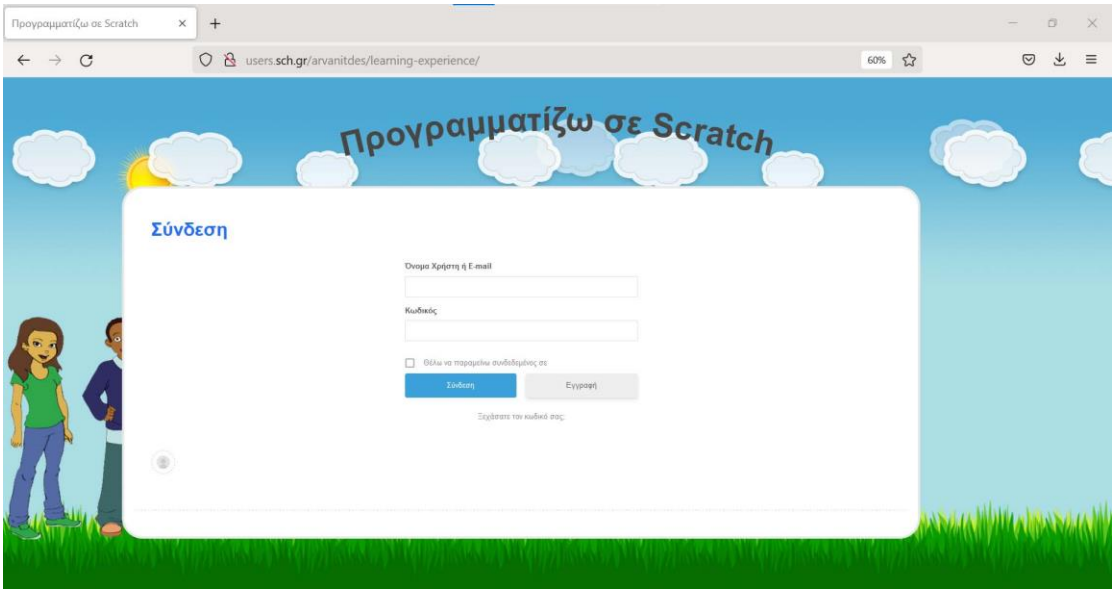

Figure 9.1 Login Screen

The content of the Website is accessible only to logged in users, as we see in Figure 9.1. Someone visiting the page has the opportunity to log in or register on the page. There are two categories of users on the website: students and teachers. Depending on the role, each user has access to a different environment, with different functions and capabilities. The student environment is designed to provide the student with access to the educational game and functions that facilitate the educational process. The teacher environment is designed to provide the teacher with tools for monitoring student progress and statistics that help draw conclusions about the educational process.

9.1 Student's environment

The student's environment is designed to create a pleasant feeling for the student. We use vivid colors, images and large fonts for the texts. When the student logs in, he sees the student's Control Panel (Figure 9.2). The screen is divided into three areas:

1. **Main area.** It is located in the center of the screen, where the game unfolds.
2. **Menu bar.** It is located at the top right of the screen and contains options with which the student controls his navigation.

3. **Info area.** Located at the top left of the screen and contains information about the student's points, badges and energy.

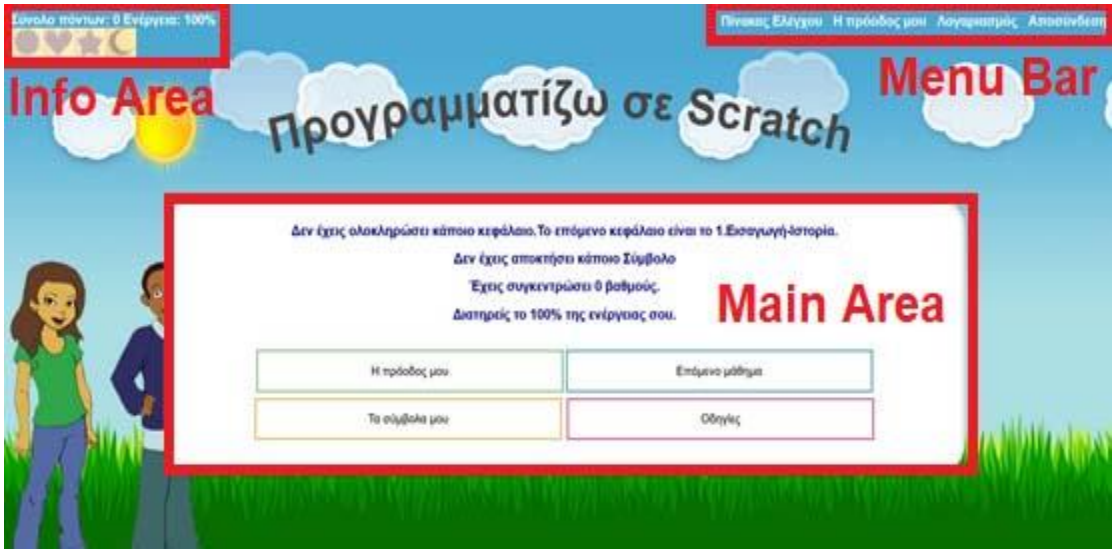

Figure 9.2 Student's Control Panel

9.1.1 Control Panel

After a student logs in, he is transferred to the Control Panel. The Control Panel provides information to the student about his status. It informs him about the last unit he has completed and which is the next unit he will attend. In addition, it gives him information about the badges he has acquired, the points he has accumulated and his remaining energy.

The Control Panel presents to the student all the available options. There are four buttons that link to the other available functions. More specifically the buttons are:

- My progress
- Next lesson
- My badges
- Instructions

9.1.2 My progress

With the "My progress" function, the student sees a map of the path that will follow. Here, are displayed all the units that the student will attend. For each unit, the following information is displayed:

- Name of the unit.
- Status. The status can be completed or pending. It also shows the next unit.
- Score. The points that the student has collected are displayed as well as the maximum score of the unit. In case the student repeats a unit, he maintains the highest grade he has obtained.
- Views. Shows how many times the student has attended each unit.

For better presentation of the data, we use green color for the units that are successfully completed and a pale gray color for the units that the student has not yet attended. For the next unit, we use orange. The completed sections and the next section are links that lead to the corresponding units. Pending units, on the other hand, do not contain a link.

Figure 9.3 My Progress

9.1.3 My badges

This webpage provides the student with detailed information about the badges of the game. For each badge, the student can see its name and the requirements for obtaining it. In addition, the student is informed about which badges he has already acquired, as well as how much is left to acquire the rest.

Figure 9.4 My Badges

9.1.4 Instructions

With "Instructions", the student receives brief information on how to navigate through the game. Specifically, he is given instructions for using the courses that use Course Presentation Content Type and Interactive Video Content type.

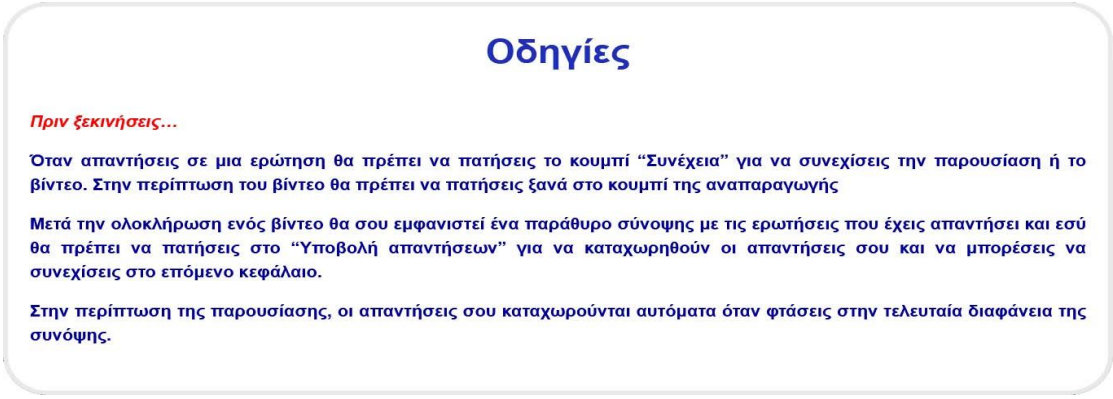

Figure 9.5 Instructions

9.1.5 Account

Through "Account", the student can modify his personal data, i.e. name, surname and email. Here, he can also change his password. This function has a purely managerial character and is not related to the other functions of the student. For this, we chose this function not to be

included in the Control Panel, as it removes vital space. It also does not offer anything in the course of the game and unnecessarily distracts part of the students' attention. For all the above, this function was placed only in the menu bar, in the upper right area of the screen.

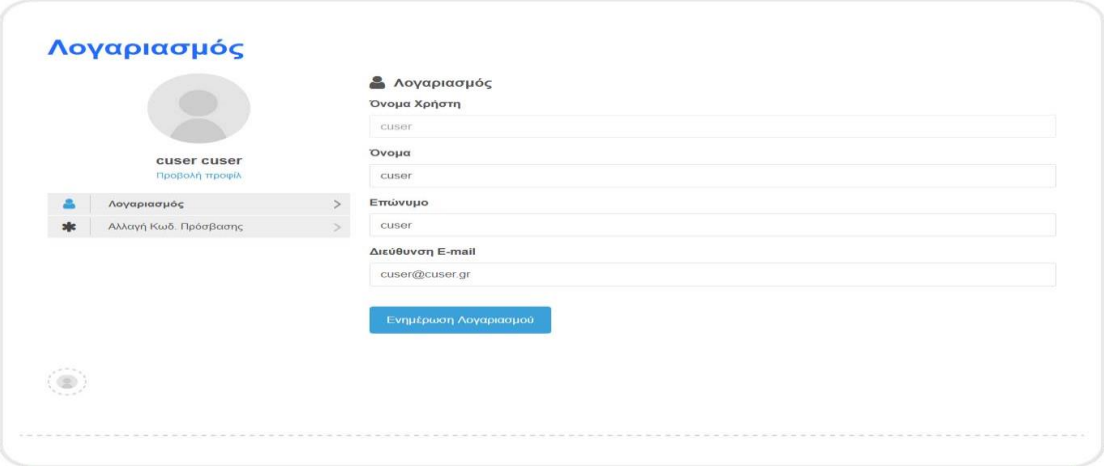

Figure 9.6 Account

9.2 Teacher’s environment

The teacher's environment follows the template we used for the student’s environment. It consists of two areas, the Main Area and the Menu Bar. The data accessed by the teacher is displayed in the Main Area. The Menu Bar is located in the upper right area, contains the necessary links that facilitate its navigation.

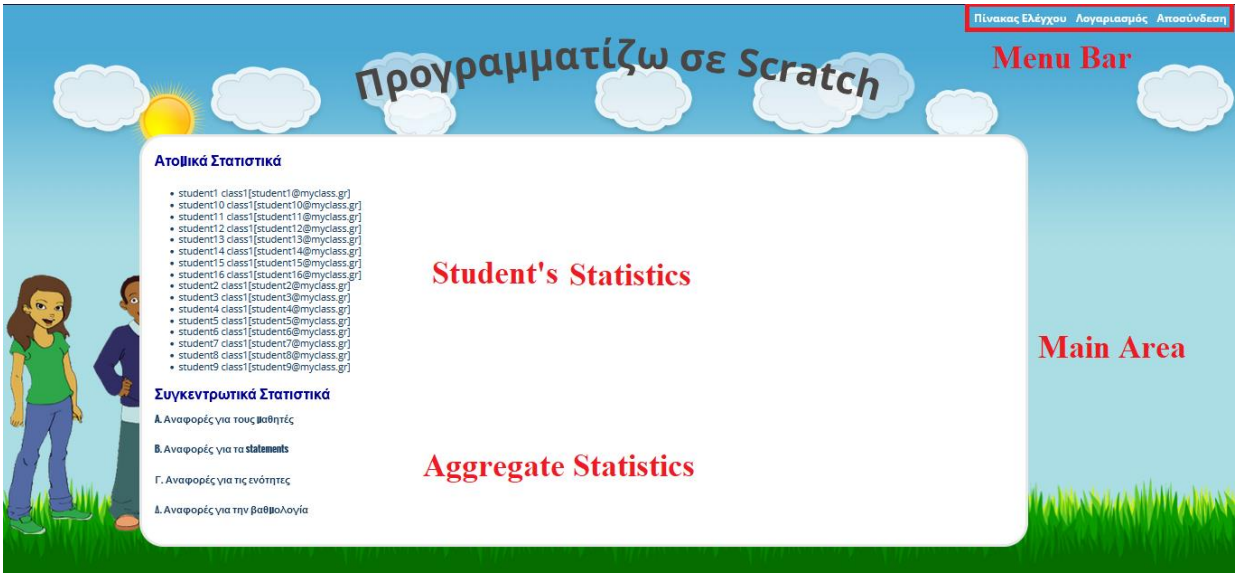

Figure 9.7 Teacher's environment

9.2.1. Control Panel

The Control Panel is the first screen the teacher sees when connected. The Control Panel contains grouped all the data created by the students' activities. In order to view the data, it is necessary for the system to communicate with the LRS and retrieve the necessary data. The Main area where the data is displayed is divided into two parts, the area of **Student's Statistics** and the area of **Aggregate Statistics**.

9.2.2 Student's statistics

In the Student's Statistics area, there is a list of all students, who have created an account on the website. The name of each student is a link that leads to a page that displays detailed information about the student's progress. To retrieve student data, the website asks from the LRS, all xAPI statements created by the student's activity. The xAPI statements are subject to the appropriate processing that extract the student's status. The information presented to the teacher, is the student's performance in each unit:

- The status of the Unit, which can be completed or pending. It also shows the next unit
- The student's score and the maximum score of the unit
- How many times the student has attended each unit

Η πρόοδος του μαθητή student1 class1

Ενότητα	Κατάσταση	Βαθμοί	Προβολές	
1.Εισαγωγή-Ιστορία	Ολοκληρώθηκε	1/1	1	✓
2.Καλώς ήρθατε!	Ολοκληρώθηκε	3/3	1	✓
3.Γνωριμία με το περιβάλλον	Ολοκληρώθηκε	14/14	1	✓
4.Αλλαγή ενδυμασίας – Δημιουργία Animation	Ολοκληρώθηκε	17/17	1	✓
5.Κίνηση	Ολοκληρώθηκε	9/11	1	✓
6.Διάλογοι	Ολοκληρώθηκε	9/9	1	✓
6.1 Τι συμβαίνει στον βυθό της θάλασσας; (bonus)	Ολοκληρώθηκε	-	1	✓
7.Η απελευθέρωση!!!	Ολοκληρώθηκε	-	1	✓

Figure 9.8 Student's progress

9.2.3 Aggregate Statistics

Aggregate statistics provide information on students' overall performance. To export and present this data we used the capabilities of LRS and utilized the tools at its disposal. All data processing took place in the Learning Locker environment. In Learning Locker, we quered xAPI statements and we created the corresponding graphs with the results of the queries. These graphs were integrated into dashboards and then these dashborards became shared. We embed the shareable links in our Website and displayed them in the teacher's environment.

Aggregate Statistics are divided into four categories:

A. **Reports for the students.** The data contained in Reports for the students provide information on the overall performance of students in all units. The information provided is as follows:
   - Number of participants. Displays the total number of students.
   - Number of users completed the course. Displays the number of students who successfully completed the course.
   - Students' answers. Displays the total number of correct and incorrect answers of each student.

Figure 9.9 Reports for the students

B. **Reports for the statements.** These reports focus on the xAPI statements. The information provided is as follows:

- Number of statements per student.
- Number of statements per verb.
- Number of statements for each activity.

Figure 9.10 Reports for the statements.

C. **Reports for the units.** Here we can see the statistics about successful completion of each unit. We keep unit 3.1 and unit 6.1 in separate boards, because these are the extra units that a student may attend. The information provided is as follows:

- Number of students completed each unit
- Number of students that completed Unit 3.1
- Number of students that completed Unit 6.1

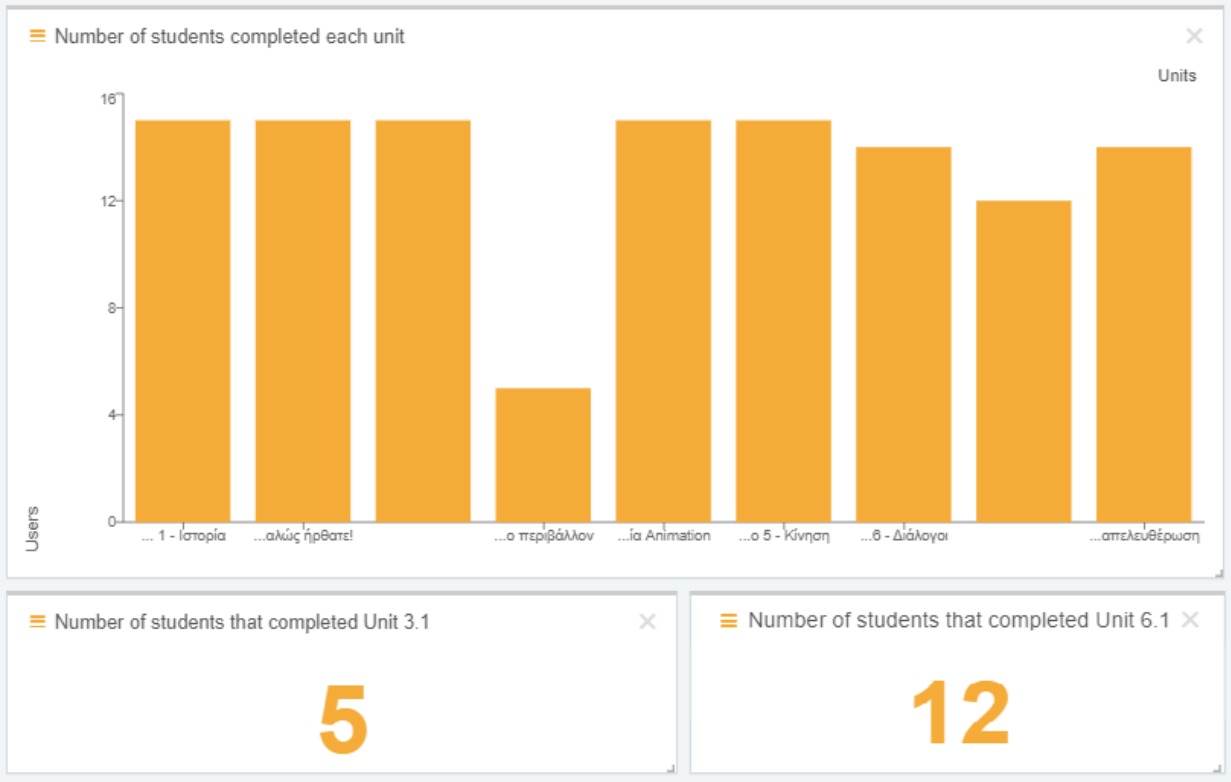

Figure 9.11 Reports for the units

D. **Reports for the score.** The information provided is as follows:

- Total score per student
- Average score per student
- Average score per unit
- Distribution of score

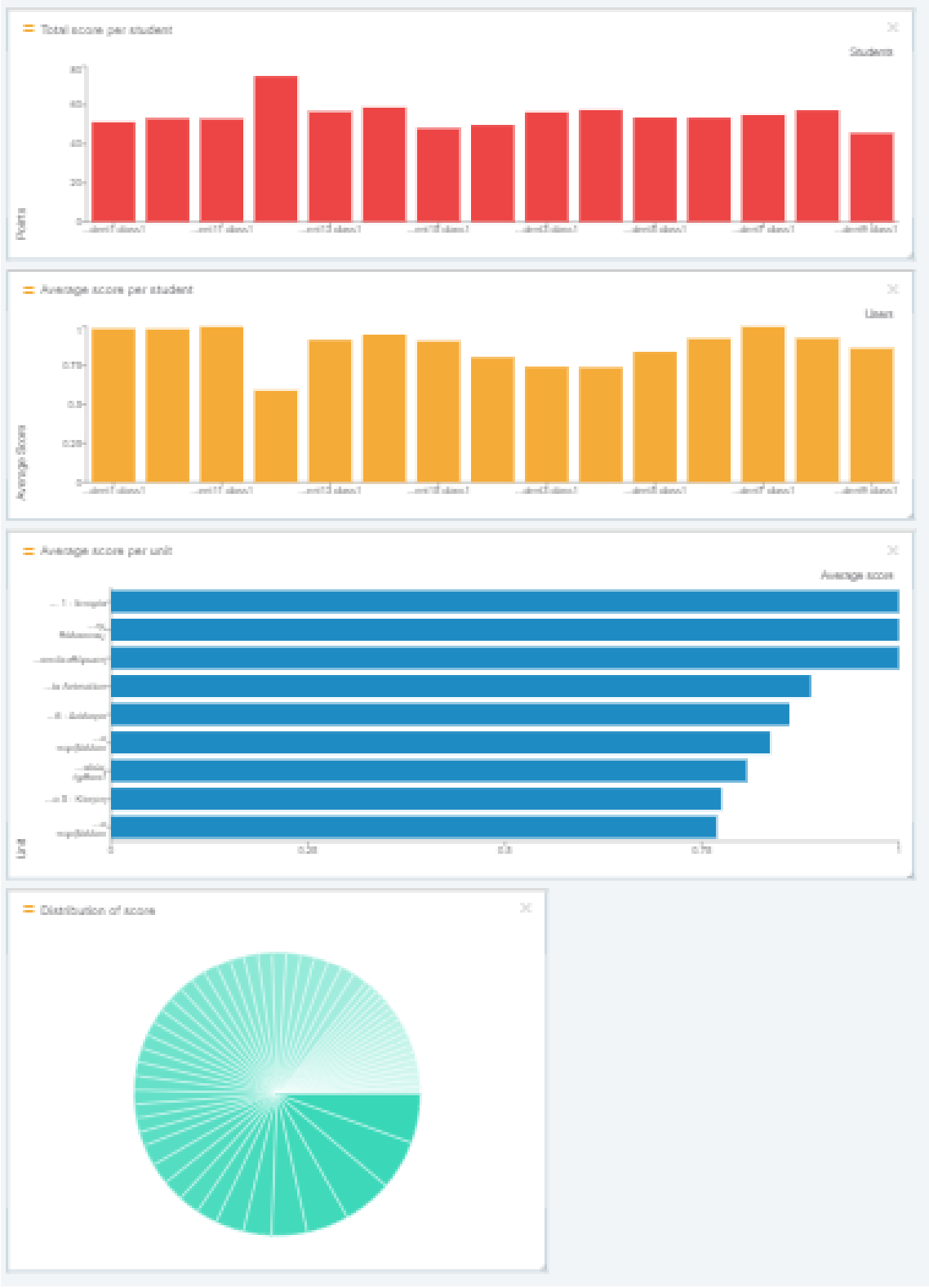

Figure 9.12 Reports for the score

9.2.4 Account

Through "Account", the teacher can modify his personal data, i.e. name, surname and email. Here, he can also change his password. This function has a purely managerial character and is not related to the other functions of the teacher.

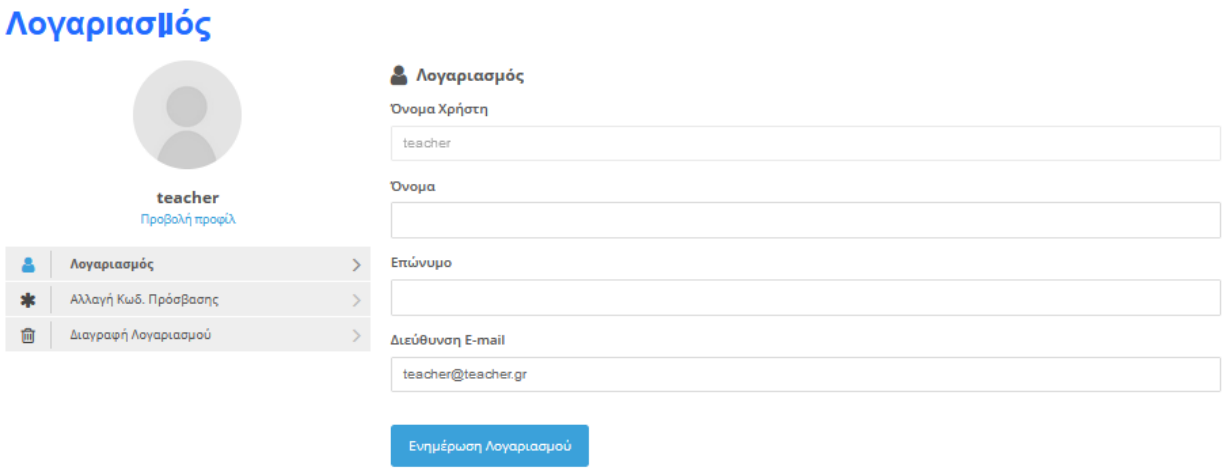

Figure 9.13 Teacher's account

Chapter 10 - Evaluation

The pandemic brought great disruption to the educational process. Students often had to be absent from school, either due to illness or because they came into close contact with a case of covid-19. This situation made our research difficult, as we could not be sure that we would have a stable sample of students to participate in the research. For this reason, we selected our sample by using Convenience Sampling. As Etikan, Musa, & Alkassim (2016) highlight in their article, Convenience Sampling is a non-probabilistic sampling method where subjects are selected at a non-random way where they are geographically proximate, accessible, available and willing to participate at a given time in a study. For our case, the subjects that participated in our study, were easily accessible to us and the available data that were utilized in it had no further requirements (Bhardwaj, 2019).

At this point, it should be emphasized that all necessary checks were performed before the system was put into operation. Initially, the educational material was developed on the Website and the code that will be executed there. In addition, having at our disposal the organization in Learning Locker, we created an experimental store and a client there. After the communication between the website and the LRS was established, the first statements began to be sent.

Subsequently, a team of case studies was created and implemented and the necessary tests took place. This process resulted in some errors in the way the statuses were sent from the site to the LRS, which were corrected. When the necessary improvements were made to the operation of the system and the verification for its proper operation was made, the system was put to use.

10.1 Evaluation from the learning system

Fifteen students of the fifth grade of Elementary School participated in our study and all the required data were collected through our learning system. They were given a unique username and password and the necessary instructions for using the system. The results obtained from its use are presented in the reports that follow and come from the Dashboards provided by Learning Locker as described in a previous chapter.

In our case, four reports have been created regarding our evaluation: for the students, for the statements, for the units and for the score. In addition, the statistics of each student were particularly useful.

10.1.1 Report for the students

In order to have a complete picture of the students' (Actors) progress, a Dashboard was created which contained the following visualizations:

A. Number of students that participated:

Figure 10.1 Number of participants

In this visualization, we have visualized the unique number of the Actors that generated the statements in our learning system.

B. Number of students that completed the course

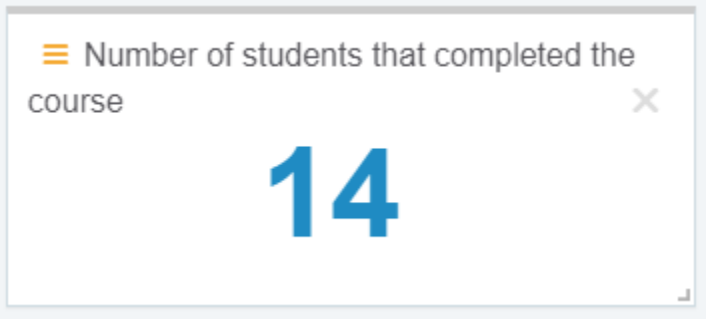

Figure 10.2 Number of students that completed the course

In this visualization, we have visualized the number of the Actors that have completed the activity 7.1 which is the last one of our learning environment. If the completion is true then the actor is obtained in this number.

C. Students' answers

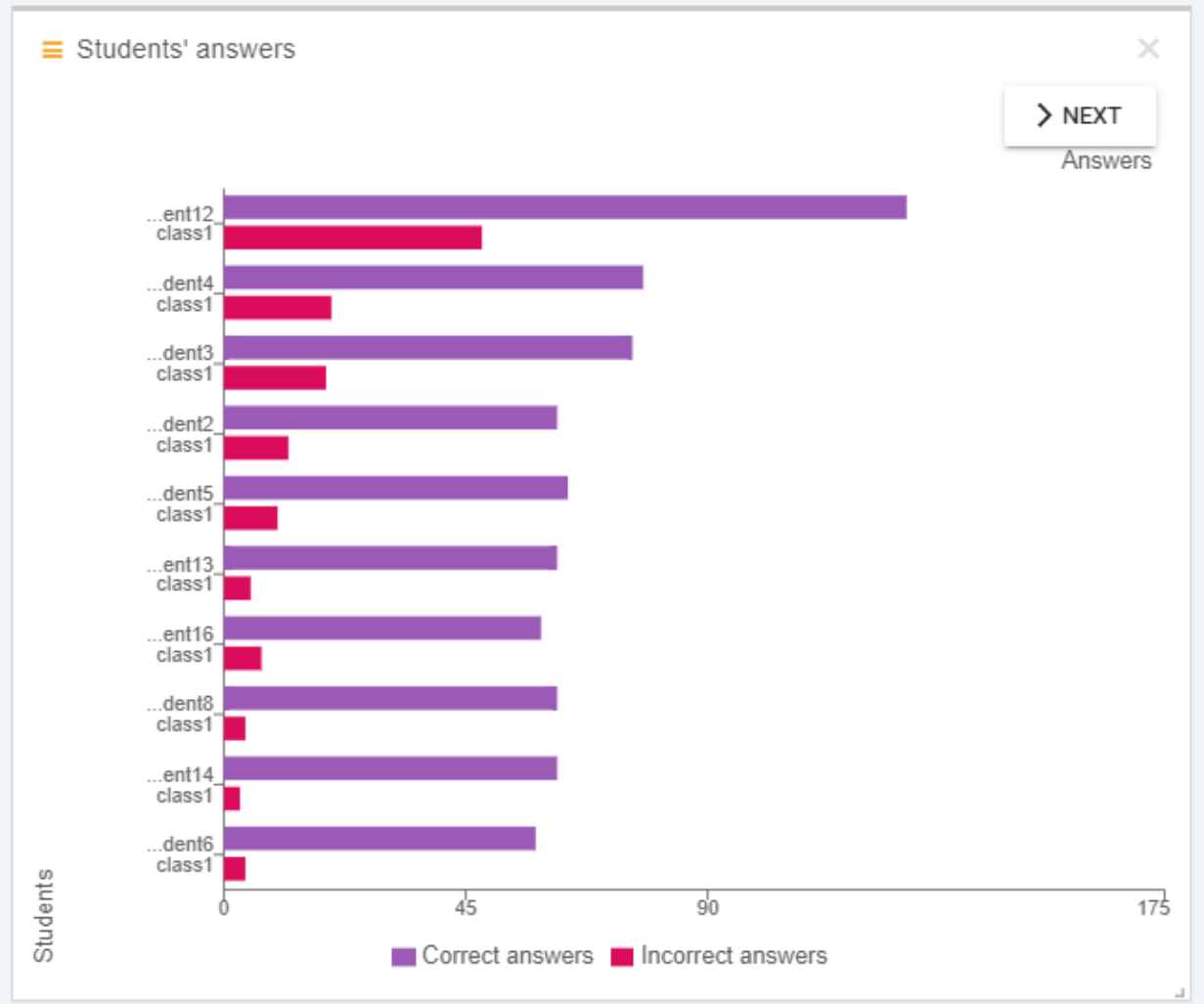

Figure 10.3 Students' answers

This bar graph illustrates the number of correct and incorrect answers given by the Actors when accessing the units of our learning system. The number of the answers in each category has to do with how many units each Actor completed and whether he enjoyed units 3.1 and 6.1, which contain additional activities to be answered. This leads to an increase in the number of activities that have been answered.

10.1.2 Report for the statements

In this report we have a Dashboard with visualizations regarding the Statements that have been sent to the LRS.

A. Number of statements per student

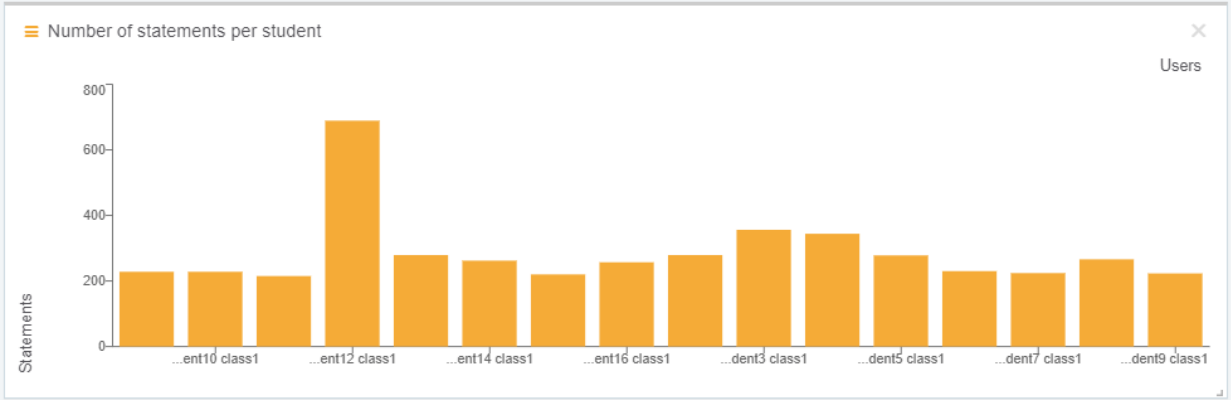

Figure 10.4 Number of statements per student

In this column chart we have visualized the total unique number of statements that each Actor produced.

B. Number of statements per verb

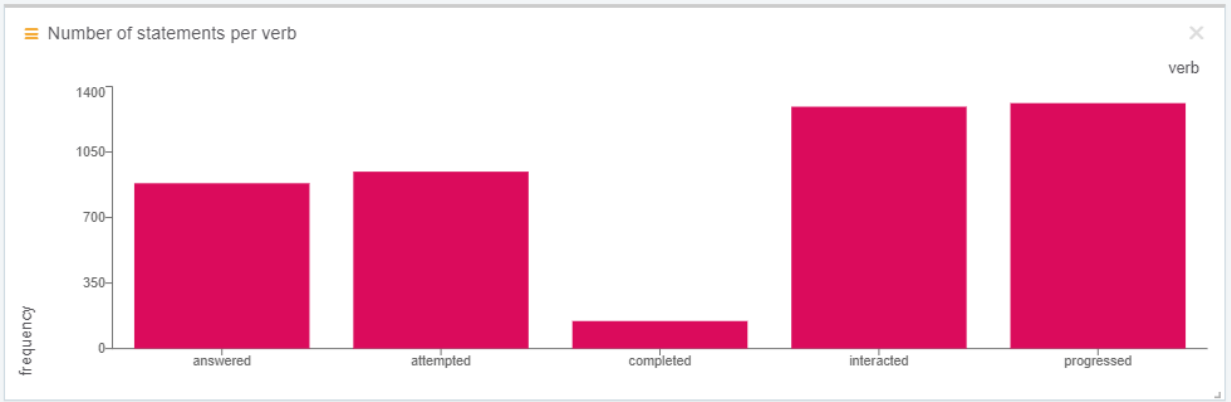

Figure 10.5 Number of statements per verb

In this column chart, the total unique number of statements that is produced for each verb by our H5P activities is depicted.

C. Number of statements for each activity

The following column chart illustrates the total unique number of statements that is produced by each H5P activity.

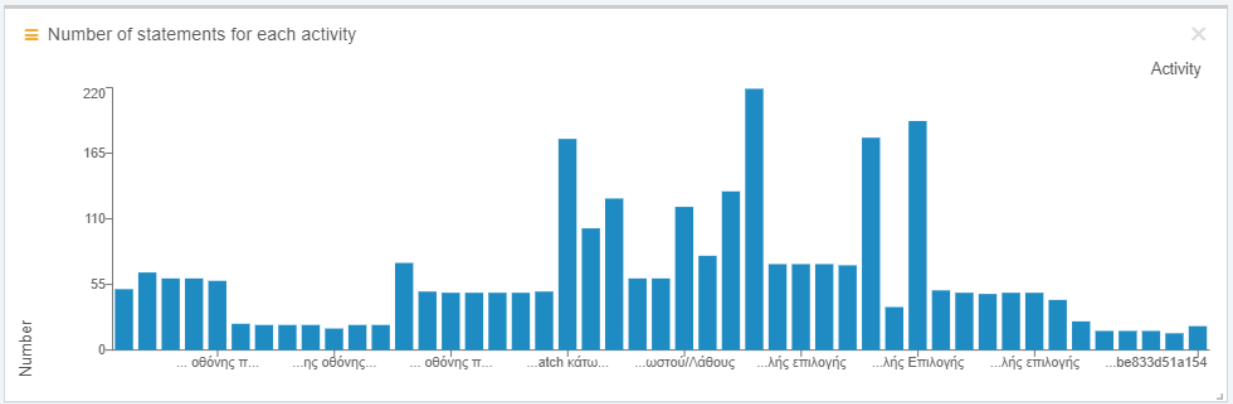

Figure 10.6 Number of statements for each activity

10.1.3 Report for the units

Regarding the visualization of the information related to the units of our educational environment, the following graphs emerge:

A. Number of students that completed each unit

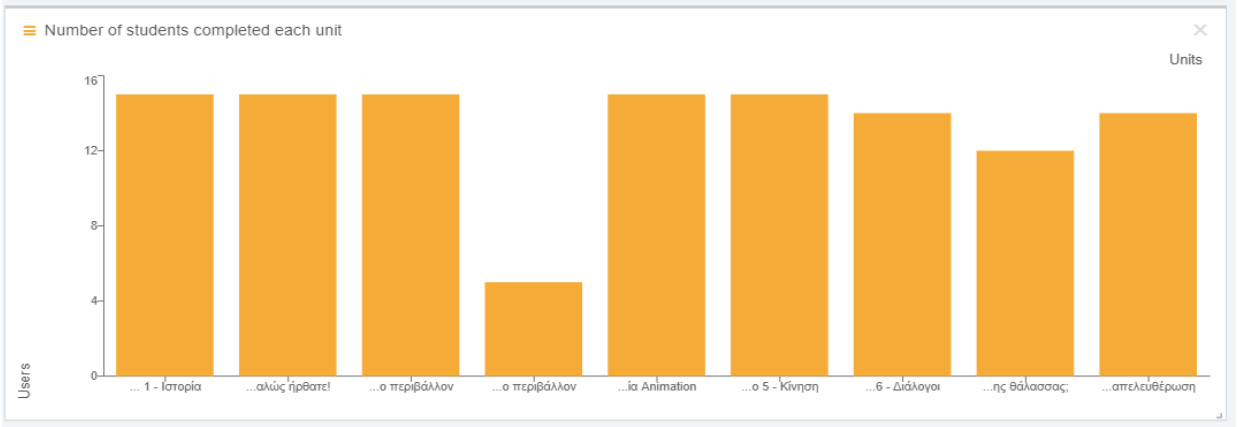

Figure 10.7 Number of students that completed each unit

In this column chart the total unique number of the Actors that have completed the following units are presented:

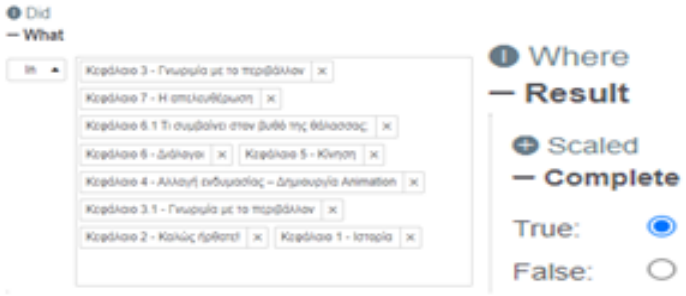

Figure 10.8 Queries for the visualization

B. Number of students that completed Unit 3.1

In the following count chart we present with a number, the unique number of students that have completed Unit 3.1.

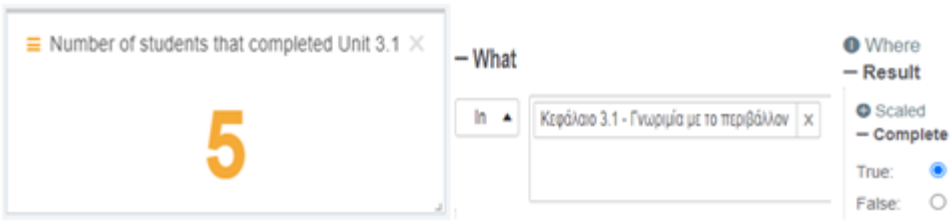

Figure 10.9 Number of students that completed Unit 3.1

C. Number of students that completed Unit 6.1

The third visualization depicts number, the unique number of students that have completed Unit 6.1.

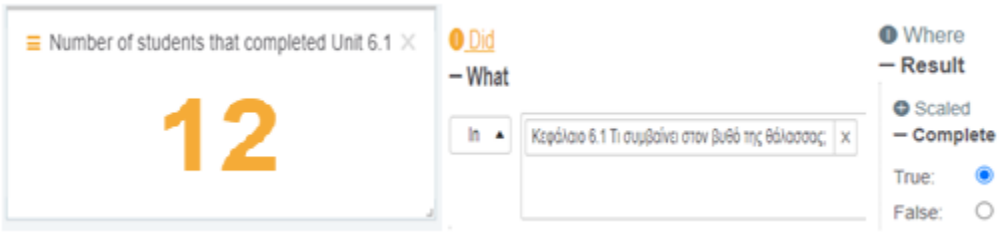

Figure 10.10 Number of students that completed Unit 6.1

10.1.4 Report for the score

In the fourth report, we present visualizations that are related with the scores that have been achieved during the access to the educational activities.

A. Total score per student

This column chart visualize the sum of the scaled results that students achieved in the learning system.

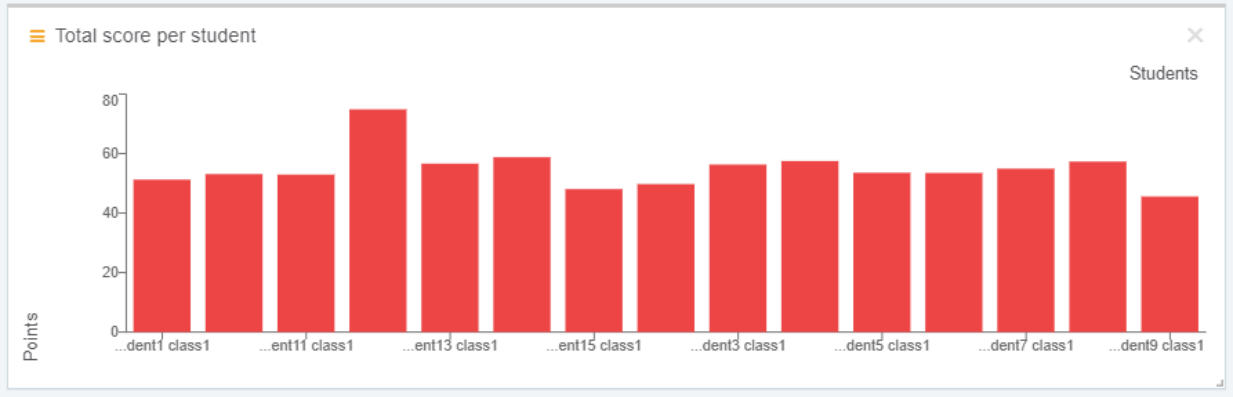

Figure 10.11 Total score per student

B. Average score per student

The graph below that is a column chart, depicts the average of the scaled results for the students:

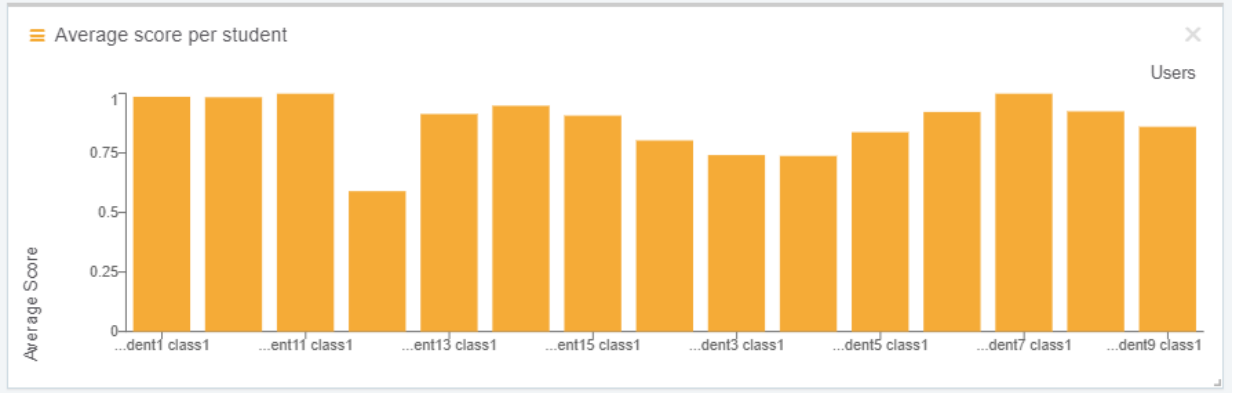

Figure 10.12 Average score per student

C. Average score per activity

The average score per activity graph visualizes the average of the scaled results for each unit:

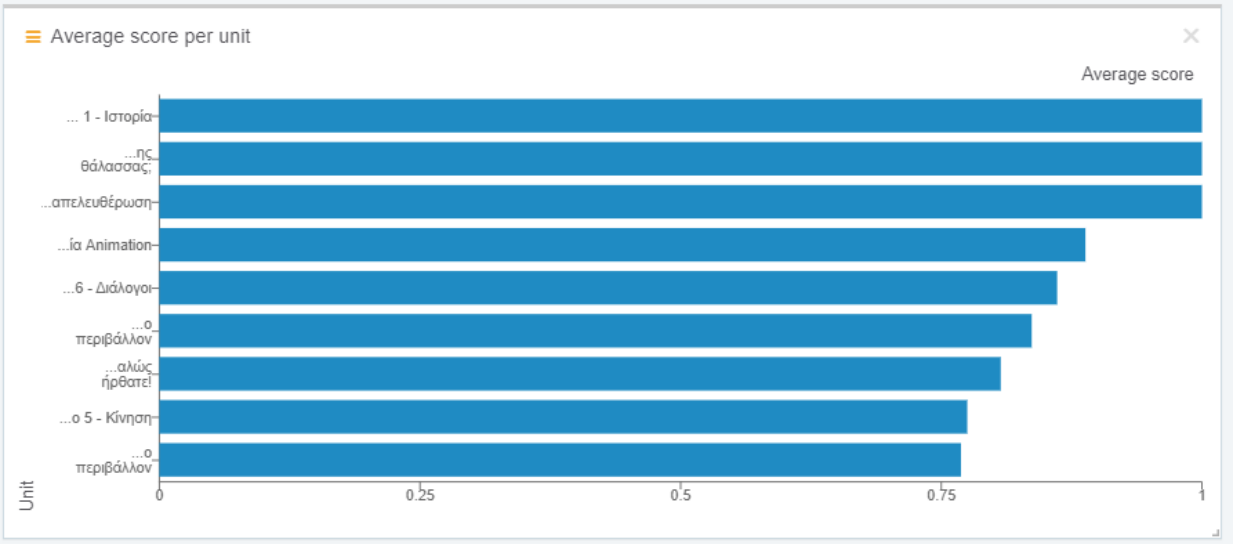

Figure 10.13 Average score per activity

D. Distribution of score per activity

In the last graph that is a pie chart, the total unique number of each activity is presented:

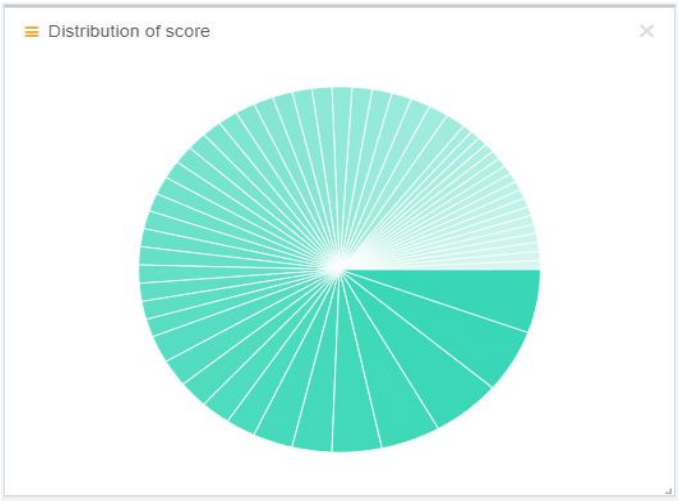

Figure 10.14 Distribution of score per activity

10.1.5 Students' statistics

The statistics of each student provide the teacher with the opportunity to have an image of the course that the student followed. From these, we can focus on the special needs of each student and make the necessary interventions. At the same time, with these statistics we form a better picture of the educational process, as they cover the gaps that aggregate statistics have. These data are available for each student through the teacher's Dashboard. For a better presentation, we have gathered them in the table below.

	Unit1		Unit2		Unit3		Unit3.1		Unit4		Unit5		Unit6		Unit6.1		Unit7		
Students	Score	Views	Score	Views	Score	Views	Score	Views	Score	Views	Score	Views	Score	Views	Score	Views	Score	Views	
Student1	1	1	3	1	14	1	-	-	17	1	9	1	9	1	-	1	-	1	53
Student2	1	1	3	1	12	1	-	-	16	1	8	2	8	1	-	1	-	1	48
Student3	1	1	3	2	6	1	12	1	16	1	10	2	8	1	-	1	-	1	50
Student4	1	1	2	1	9	1	12	1	12	1	11	2	6	2	-	-	-	1	44
Student5	1	1	2	1	11	1	-	-	17	1	11	1	8	2	-	1	-	1	50
Student6	1	1	3	2	14	1	-	-	15	1	11	1	9	1	-	1	-	1	53
Student7	1	2	3	1	14	1	-	-	17	1	11	1	9	1	-	1	-	1	55
Student8	1	1	2	1	13	1	-	-	17	3	11	1	7	1	-	-	-	1	51
Student9	1	1	3	1	13	1	-	-	15	1	9	1	9	1	-	1	-	1	50
Student10	1	1	3	1	14	1	-	-	17	1	9	1	9	1	-	1	-	1	53
Student11	1	1	3	1	14	1	-	-	17	1	11	1	9	1	-	1	-	1	55
Student12	1	1	3	3	8	1	12	3	17	4	6	4	-	-	-	-	-	-	39
Student13	1	1	3	1	8	1	14	1	17	1	10	1	8	1	-	1	-	1	53
Student14	1	1	3	1	9	1	14	1	17	1	11	1	8	1	-	1	-	1	54
Student15	1	1	3	1	14	1	-	-	17	1	8	1	8	1	-	1	-	1	51

Table 10.1 Students' statistics

10.2 Evaluation from students' questionnaire

All fifteen participating students completed the questionnaire. The questionnaire was short and consisted of twelve questions. The purpose of the questionnaire was to capture the students' opinions about the educational environment and the educational material. The questions we used were closed-ended which could be answered with yes or no and linear scale

questions in the Likert scale model where they were rated from 1 to 5. The feedback we got from this questionnaire added additional data to evaluate the self regulated learning approach we used and its effectiveness in this age group.

10.2.1. Description of the questionnaire

The questions given to the students were short and presented in a single section. The questions were intended to investigate the following issues:

1. **The students' previous knowledge**. For this issue, the students were asked the following question, which they could answer with yes or no:
    - *"Did you know scratch before participating in this educational game?"*

2. **The game experience.** To draw conclusions about the game, we investigated the ease of adaptation to the game, its duration, the game elements and the overall impression it left on the students.

   Initially, we investigated the usability of the learning system. The students were asked to complete the following two questions, about how they adapted to the game environment:
    - *"Did you like the game environment?"*
    - *"Did you adapt easily to the game environment?"*

   In the first question, the students filled in a linear scale from one (not at all) to five (very much), to rate the learning system. In the second question, the students rated the ease of adapting to the learning system by filling in a linear scale from one (very difficult) to five (very easy).

   Continuing the investigation on this particular topic, we indirectly confirmed their answers by asking them if they needed extra help during the game. This was achieved with the following two questions, which were asked in different parts of the questionnaire:
    - *"Did you need your teacher's help when playing the game?"*
    - *"In addition to the in-game instructions, did you need additional instructions?"*

These questions were answered with yes or no.

Regarding the duration and the game elements of the game, we used the following questions respectively:

- *"How satisfied are you with the overall duration of the game?"*
- *"How satisfied are you with the game elements (points, badges) that the game had?"*

The students rated the duration and the game elements of the game by filling in a linear scale from one (very dissatisfied) to five (very satisfied).

For the general evaluation of the game, we asked the students to rate their overall experience from the game, with the following question:

- *"How do you rate your overall experience with the game?"*

The question was answered by completing a linear scale from one (not good at all) to five (very good).

3. **The learning content**. Students were asked to complete the following two questions to rate the ease and interest of the educational content:
   - *"How easy was the learning content presented to you?"*
   - *"How interesting was the learning content presented to you?"*

   Students completed a linear scale from one to five for each question. For the degree of ease, the scaling was from one (very difficult) to five (very easy), while for the degree of interest the scaling was from one (not at all interesting) to five (very interesting).

4. **The learning results.** In this question, we asked the students to self-evaluate the knowledge they have acquired. The question was simple and could be answered with yes or no. The results of the question may have been influenced by the general self-confidence of the students, but it does not cease to be a basic indicator of the outcome of the lesson. The question asked to the students was:
   - *"Do you think you are capable of creating your own programs in Scratch?"*

5. **The general impression formed by the students about the educational games.** With this question, we attempted to investigate the overall impression left on the students by the teaching approach we used, through the learning system we created. By asking students whether they were interested in participating in similar educational games, we can draw a general conclusion about the effectiveness of our project. We asked the following question, which could be answered with yes or no:
    - *"Would you like to participate in similar educational games for learning other courses or programs?"*

10.2.2. Results of the questionnaire

1. **"Did you know scratch before participating in this educational game?"**

Of the 15 students, 12 students (80%) did not know Scratch before this course, while 3 students (20%) had seen it before.

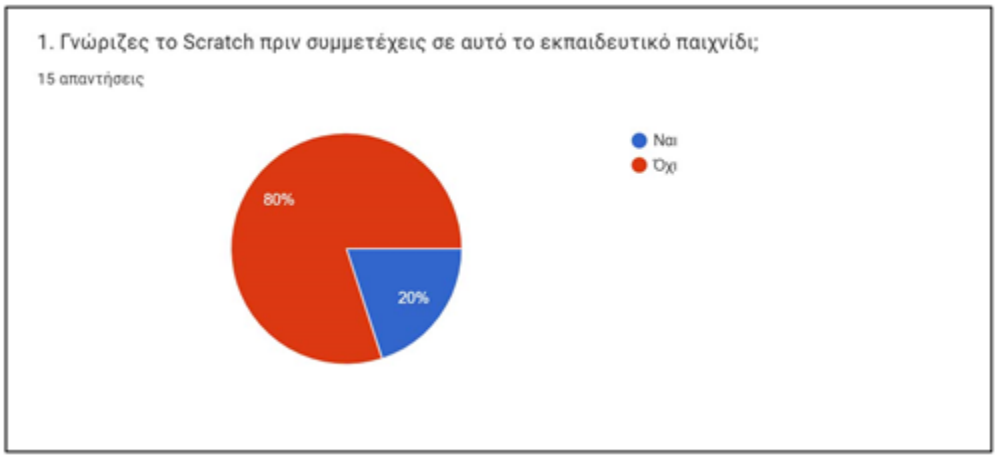

Figure 10.15 Results of question 1

2. **"Did you like the game environment?"**

About the game environment 12 students (80%) answered that they liked it very much, 2 students (13,3%) answered that they liked it and 1 student (6,7%) stated neutral.

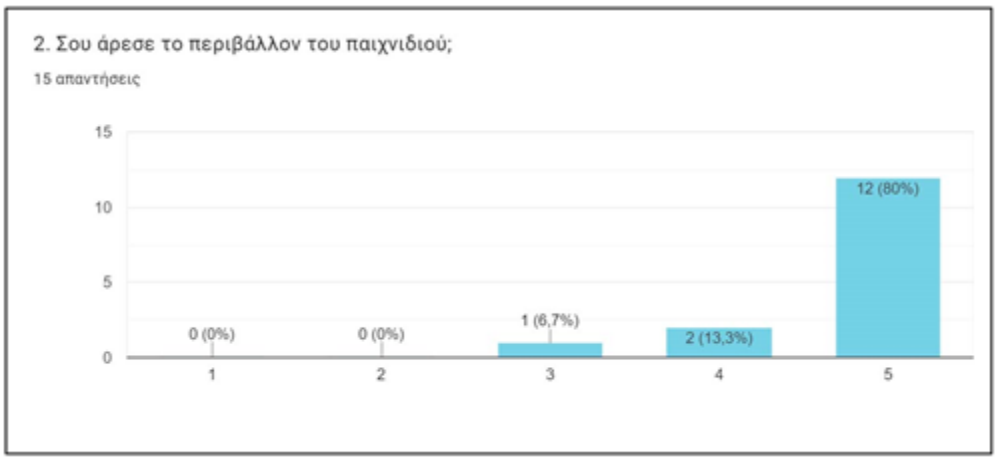

Figure 10.16 Results of question 2

3. "Did you adapt easily to the game environment?"

About the game adaptation 12 students (80%) answered that they adapted very easily, 2 students (13,3%) answered that they adapted easily and 1 student (6,7%) stated neutral.

Figure 10.17 Results of question 3

4. "How easy was the learning content presented to you?"

In this question, 12 students (80%) answered that learning the content was very easy, 2 students (13,3%) answered that it was easy and 1 student (6,7%) stated neutral.

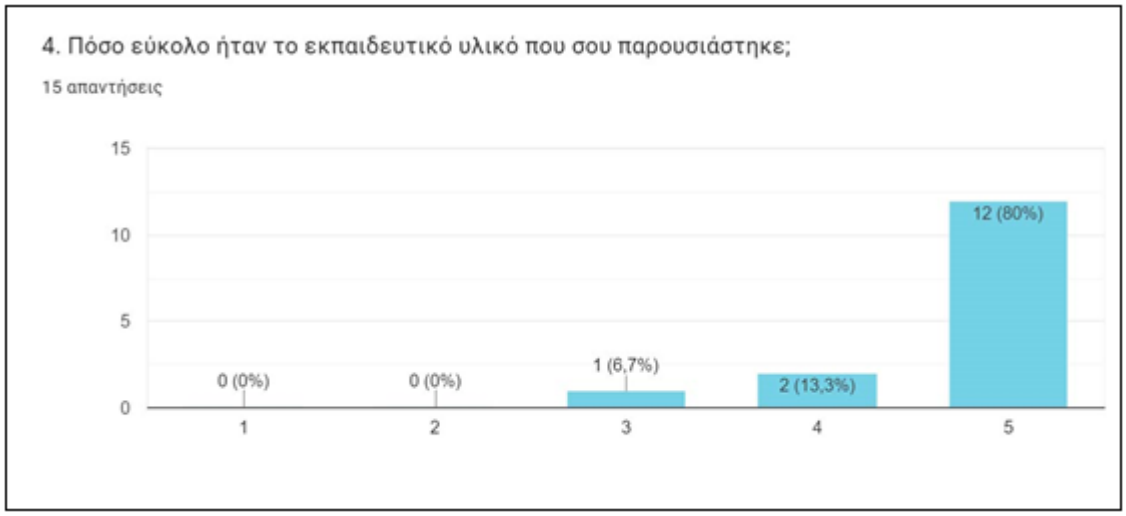

Figure 10.18 Results of question 4

5. "Did you need your teacher's help when playing the game?"

14 students (93,3%) answered that they didn't need their teacher's help, while 1 student (6,7%) answered that he needed help.

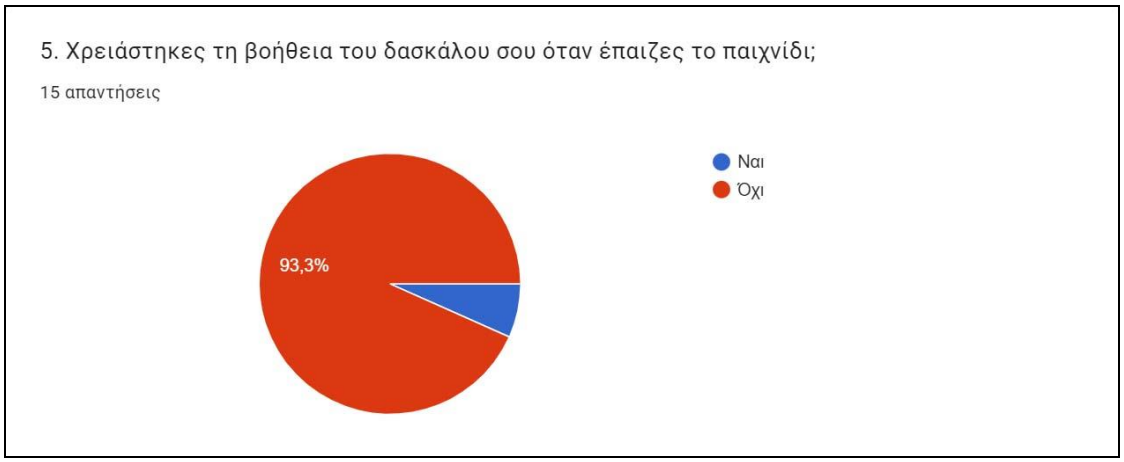

Figure 10.19 Results of question 5

6. "How interesting was the learning content presented to you?"

About the learning content 11 students (73,3%) answered that learning the content was very interesting, 3 students (20%) answered that it was interesting and 1 student (6,7%) stated neutral.

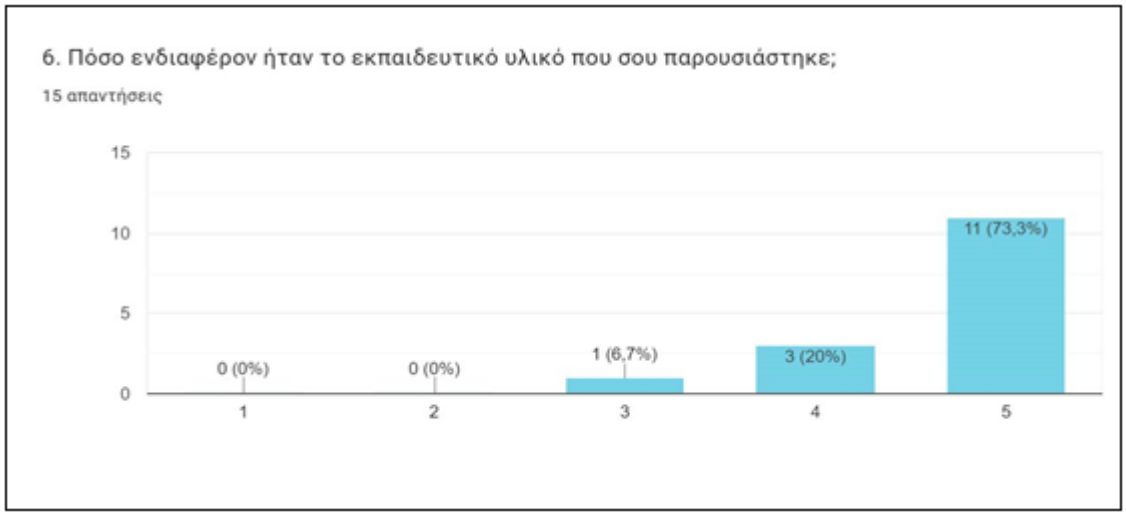

Figure 10.20 Results of question 6

7. "How satisfied are you with the overall duration of the game?"

About the game's duration 13 students (86,7%) answered that they were very satisfied, 1 student (6,7%) answered that he was satisfied and 1 student (6,7%) stated neutral.

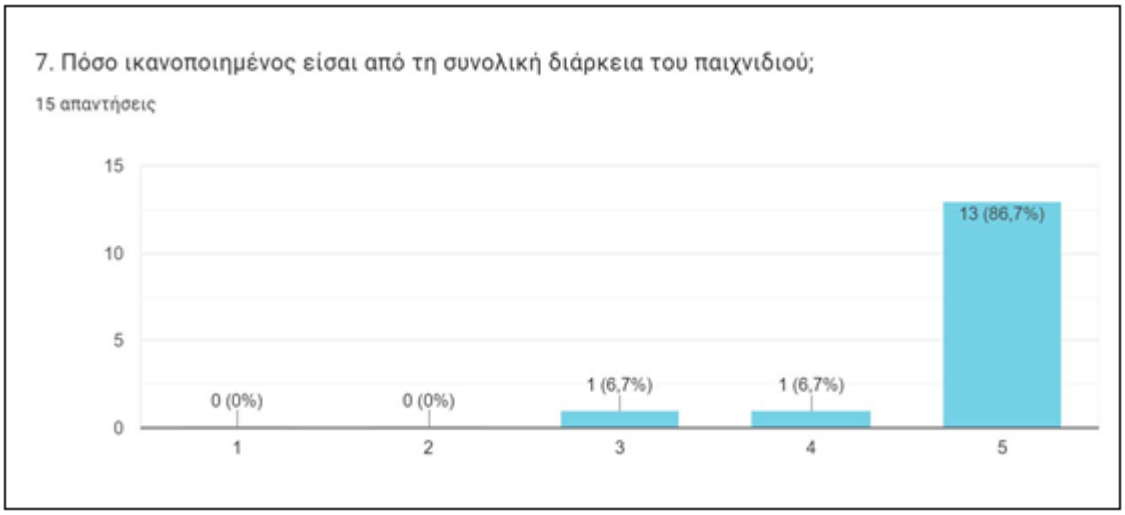

Figure 10.21 Results of question 7

8. "In addition to the in-game instructions, did you need additional instructions?"

14 students (93,3%) answered that they didn't need any additional instructions, while 1 student (6,7%) answered that he needed extra help.

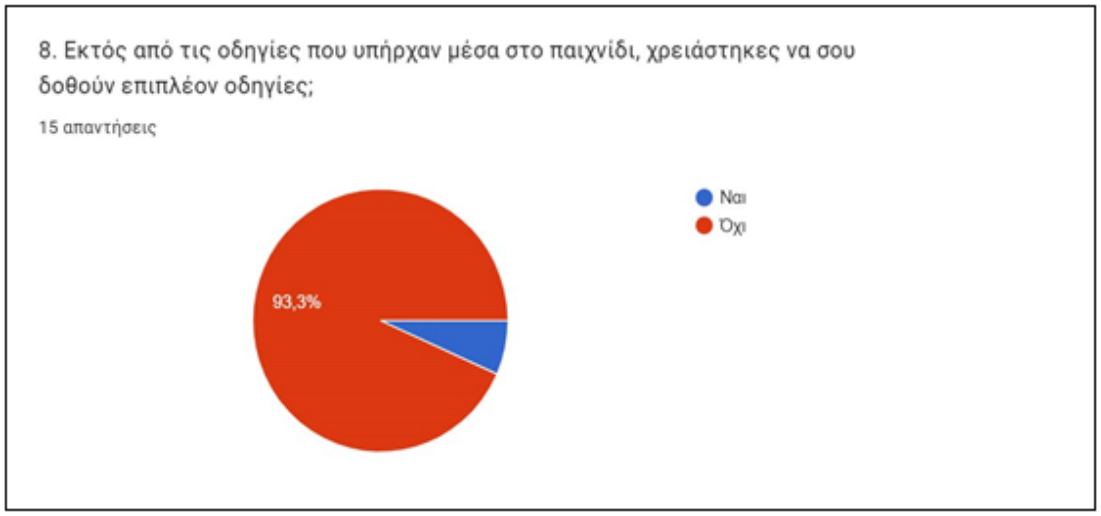

Figure 10.22 Results of question 8

9. **"How satisfied are you with the game elements (points, badges) that the game had?"**

About the game elements 14 students (93,3%) answered that they were very satisfied and 1 student (6,7%) answered that he was satisfied.

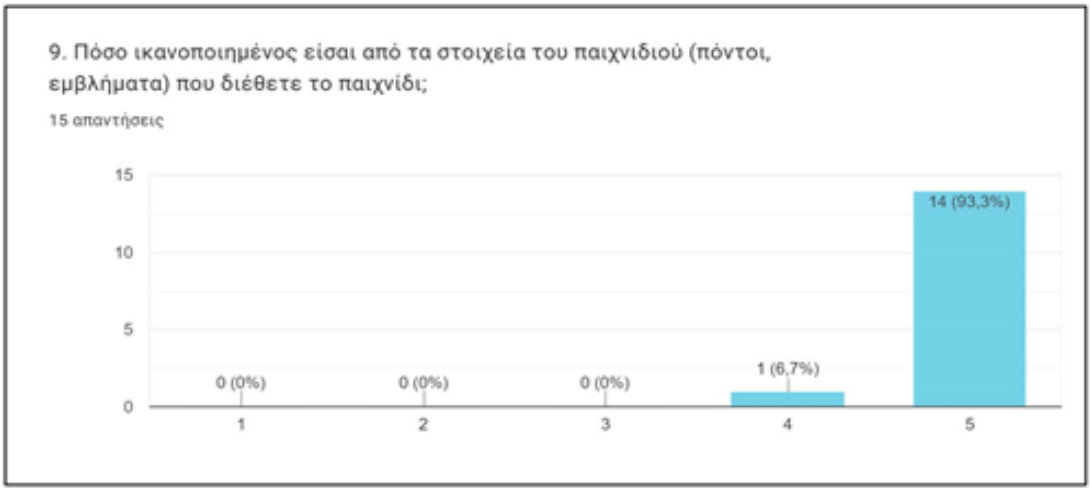

Figure 10.23 Results of question 9

10. **"How do you rate your overall experience with the game?"**

About the overall game experience, 12 students (80%) answered that the game experience was very good, 2 students (13,3%) answered that it was good and 1 student (6,7%) stated neutral.

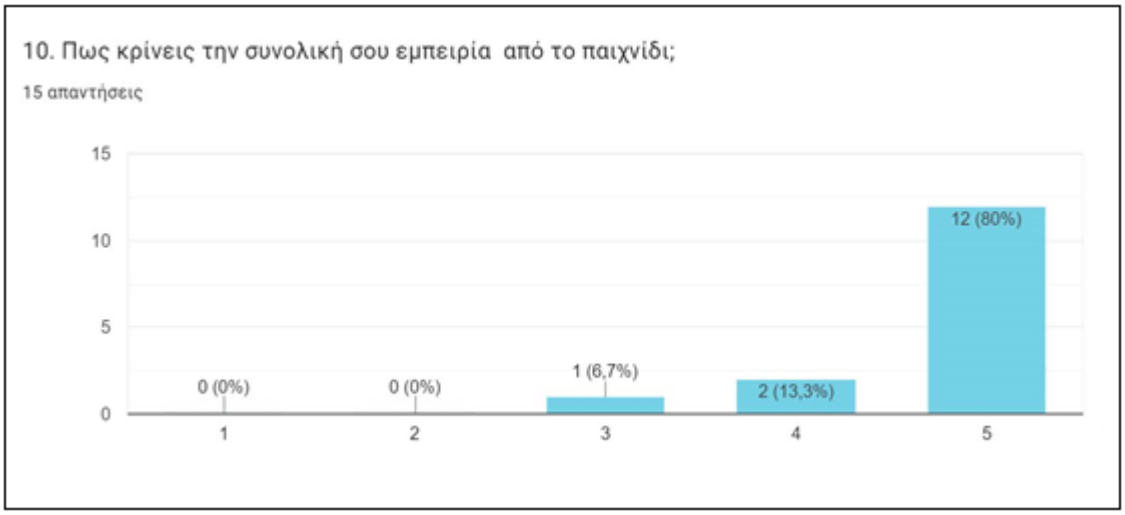

Figure 10.24 Results of question 10

11. "Do you think you are capable of creating your own programs in Scratch?"

About their capability of creating program elements 14 students (93,3%) answered positive and 1 student (6,7%) answered negative.

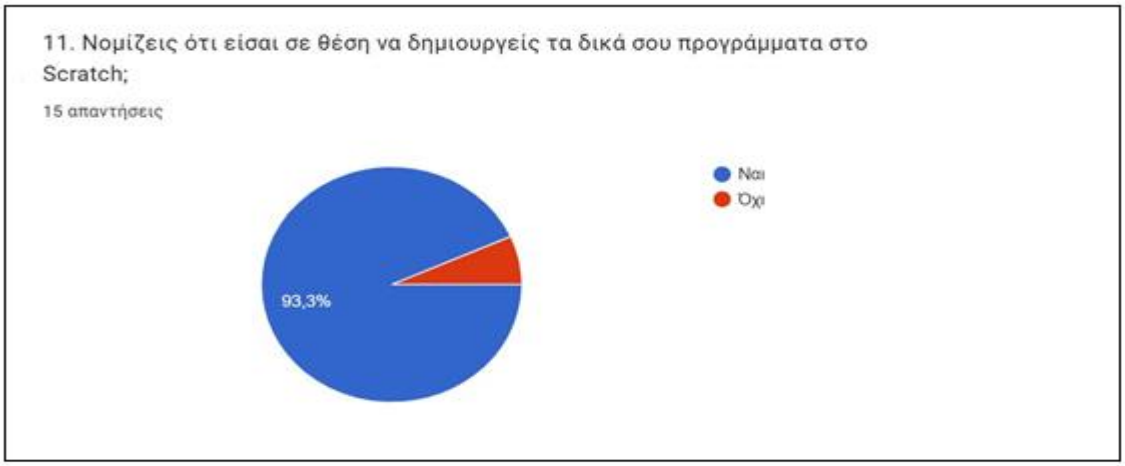

Figure 10.25 Results of question 11

12. **“Would you like to participate in similar educational games for learning other courses or programs?”**

Regarding their desire to participate in other similar educational games for learning other courses or programs, all students responded positively.

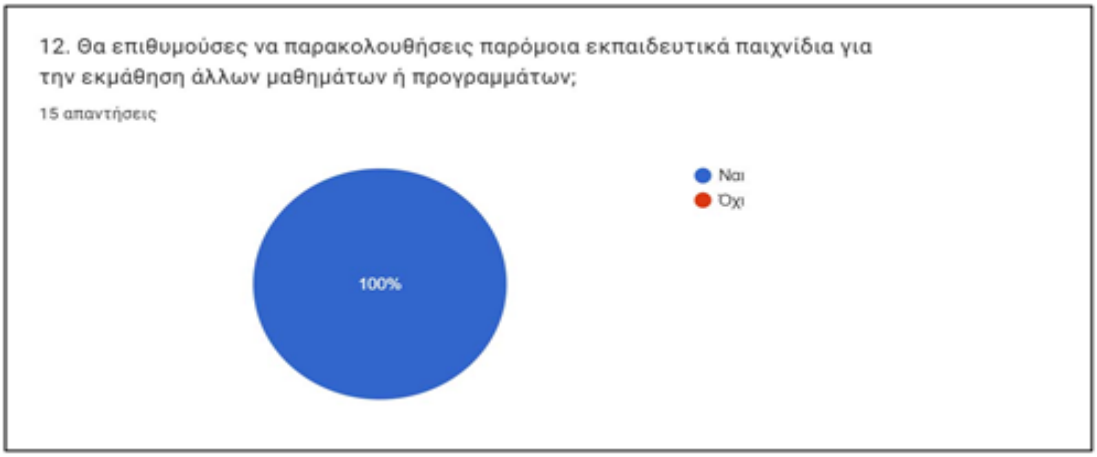

Figure 10.26 Results of question 12

10.3 Results from the evaluations

The reports created by the LRS and the student’s statistics provided by our Website, give us useful information to evaluate the educational material presented to the students. Moreover, they provide us with an overview of student response. These results are of particular interest if we examine them in conjunction with the questionnaires filled in by the students evaluating their experience from the educational game.

The learning environment and the educational game were user friendly. To evaluate them, we examined the students' opinion regarding the adaptation to the game, its duration, the game elements and the overall impression. Additionally, based on the activities’ results, we examined whether the students were able to participate, to complete the course and whether they needed additional help.

The students stated that they were pleased with the educational game and that they adapted easily. All students were able to navigate the Website and participate in the game. The vast majority of students successfully completed the game. Out of the 15 students, only 1 did

not complete the course as he ran out of energy. Only one student needed additional instruction beyond what the system provided, to continue his course.

To evaluate the learning content, we examined the students' opinion regarding its degree of difficulty and the interest it caused to the students. To draw conclusions based on student results, we examined the aggregated student statistics combined with student's statistics.

The majority of students found the learning content interesting and easy. In particular, 80% found it very interesting and very easy, 13.3% found it interesting and easy, and 6.7% found it of moderate difficulty and interest.

The performance of the students was quite satisfactory. The maximum score a student could get was 55 points. Two students excelled (55/55) and ten students scored between 50 and 54. One student scored 48 points and another scored 42 points. The student who did not complete the course due to energy exhaustion scored 39 points.

Total score	55	54	53	51	50	48	42	39
Number of students	2	1	4	2	3	1	1	1

Table 10.2 Students' total score

An additional item of interest is the number of times a student attended a unit. Seven of the fifteen students (46,6%) completed the course without having to repeat a unit. Of the remaining 7 students who completed the course, 4 students repeated a unit 1 additional time, while 2 students repeated 2 units 1 additional time and 1 student repeated the same unit 2 times.

It is also interesting to examine which units students were required to repeat. As we see in Table 10.3, the most repeated unit was Unit5. This data motivates us to look at the units with the most views to see if some interventions are needed. Another element we notice is that there were additional views in units 1 and 2. These units are purely introductory and the learning content presented is of low difficulty. These additional views may indicate some difficulties in adapting to the educational environment that the students faced.

Unit	Times repeated
Unit 1	1
Unit 2	2
Unit 4	2
Unit 5	3
Unit 6	2

Table 10.3 Unit views

An additional issue that needs investigation is the evaluation of the content types we used to present the learning content and their effectiveness for students. For the learning content we present, we use two content types, the Interactive Video and the Course Presentation. In this matter, we can draw a conclusion by comparing the scores of the students who attended unit 3 and unit 3.1. In unit 3, we present the educational material through the Interactive Video. In case a student does not achieve the objective of the unit, he proceeds to unit 3.1 where he attends the same educational material through Course Presentation. The activities he is asked to participate in are the same in both units. Of the 15 students, 5 had to additionally attend unit 3.1. The results of the students improved significantly and in fact, 2 of them achieved an excellent performance.

Finally, the system demonstrated the required adaptivity. Out of 15 students, 5 had to be reinforced at some point in the course. In addition, 12 students showed increased performance and therefore were assigned an additional unit, unit 6.1, to cover their increased educational needs. We note that three students who needed reinforcement while attending unit 3.1, then their performance raised and were rewarded by attending unit 6.1.

Chapter 11 - Discussion

The evolution of technology has provided new tools that assist learning. The educational process is in a continuous process of transformation, readjusting its form, means and goals. The various forms of e-learning that have emerged adopt new teaching models and attempt to cultivate new skills that did not exist or were not a priority in traditional teaching models (Engelbrecht, 2003; Valverde-Berrocoso, Garrido-Arroyo, Burgos-Videla, & Morales-Cevallos, 2020).

The new situations that have been formed due to the COVID-19 pandemic, led to the rapid implementation of distance learning. During the pandemic, distance learning has mainly relied on replacing the in-school classroom with the online classroom. Students and teachers were connected to the online classrooms through video conferencing software. This solution was necessary due to the special conditions that prevailed, but faced many problems in its implementation. There were many technical problems, and lack of familiarity with the technical means, by teachers, parents and students.

At the same time, in addition to synchronous distance learning, asynchronous education platforms were also used. In my opinion, this approach, once the initial implementation difficulties were overcome, was more effective. Students could process the learning material at their own pace, yielding better results. Furthermore, in cases where asynchronous education worked effectively, it helped synchronous education work better. The students processed the educational material through the asynchronous learning platform and used the synchronous education to speak with the teacher and solve questions and problems.

Based on what we experienced when implementing distance education, I believe that one of the biggest problems we faced was that our educational system has not methodically incorporated e-learning teaching approaches. This results in a lack of appropriate educational materials for primary and secondary education, designed for e-learning. Motivated by this, we researched innovative forms of teaching, which are better suited to e-learning. At the same time, we looked for tools to help us evaluate the effectiveness of a learning approach. In this area, e-learning has the advantage over traditional learning that the educational process can generate data, which can be collected and analyzed with Learning Analytics. With Learning

Analytics we have an insight into how the student interacts with the educational material, and we can better analyze the way students learn.

A particularly powerful Learning Analytics specification for tracking learning experience is xAPI. XAPI have piqued the interest of researchers who have conducted many studies on this subject. Many learning systems have been developed that aim to capture and record the learning experience of students. Nehiri & Aknin, (2020) propose an architecture to track students' data information from different e-learning systems. Panagiotakis, Papadokostaki, Vassilakis, & Malamos (2019) developed an adaptive learning system that is independent of a LMS using xAPI. Michailidi, E., Skordas, I., Papatsimouli, M., Lazaridis, L., Michailidis, H., Tavoultzidou, S., & Fragulis (2021) in their article present a web platform for learning the Greek language. Sun et al. (2020) propose a ubiquitous learning system that is based in xAPI.

In the above studies as well as in many others, no relevant research has been conducted on e-learning systems that in combination with the xAPI specification are adaptive, foster self-regulated learning and use game elements. In our thesis, we attempt to fill this gap.

Therefore, we developed a learning system where students of the fifth grade of Elementary School are first exposed to programming through the Scratch graphical programming environment. In this way, students develop Computational Thinking skills that are necessary to meet the demands of the 21st century.

For our system, we tried to leverage solutions that facilitate its development. In this context, we used WordPress to develop the website and the TinCanJS library to manage the communication with the LRS. These tools accelerated the development process by providing basic functionality. An average user can easily create a website with WordPress. However, in the case of developing a system like ours, the development process requires a lot of time and specialized knowledge.

Regarding the installation of Learning Locker, we cannot make any particular comment as we used ready-made infrastructure. However, from the research we did while studying Learning Locker, it was clear that developing the system is not a process that can be implemented by a novice user. On the other hand, managing Learning Locker as a user of an organization is a process that an average user can handle satisfactorily.

For the creation of the educational content, we did not face any problem. The H5P environment is user-friendly, providing several facilities for authoring. In addition, the portability of the learning content helped us a lot during the development of the system. For faster development of the learning content, we created the material in a local installation of the system and finally uploaded it to its final location. The only limitation was that the coverage of the xAPI is limited to a small number of content types.

Making an overall assessment of the system development process, we conclude that it is a process that cannot be implemented by the average teacher. The part of developing and interconnecting the nodes of our ecosystem requires specialized computing resources and technical support. In contrast, the process of developing educational materials can be easily implemented by the average teacher. Therefore, for a solution like the one we propose to thrive, it is necessary to have a central infrastructure with corresponding technical support. Teachers should only be able to create or upload learning materials and then be able to access the results of student interaction. Despite the difficulties encountered during the development and implementation of the system, we succeeded and created an environment that does everything it was designed to do.

In our system, students in their own way and pace completed the chapters included in the game by setting goals and developing self-regulation skills. At the same time, they were given a strong incentive to continue the game. They had to face challenges by answering consolidation questions and collecting points from correct answers. So, depending on the score they had accumulated and the chapters they had successfully completed, they were rewarded with badges.

In addition to the above, students who failed to complete a specific chapter were given the opportunity to repeat it with a different presentation format, while students who achieved a high score in another chapter were given an additional chapter as a reward.

After completing the research and processing the xAPI statements sent and stored in the LRS, we conclude that our system is innovative in its category. This is because it combines the learning of a new programming environment with game elements, adapted to the results achieved by the students, with the flexibility of space and time as well as the possibility of self-regulation on the part of the students.

Regarding the evaluation of the results obtained from the processing of the xAPI statements stored in the LRS, we conclude that the system has fulfilled its purpose. After receiving the necessary instructions, the students connected to the educational environment and participated in the game. The largest percentage of students successfully completed the educational game and a large percentage of them achieved very high scores. The system responded to the special needs of the students and provided the required adaptivity by adjusting their course within the game.

From the evaluation that took place after the use of the learning system by the students, it emerged that most of them found the environment attractive, offering a very good overall experience with a minimal degree of difficulty. The largest percentage of students, completing the educational game, felt capable of creating their own programs in Scratch. All students responded that they would like to participate in similar educational games to learn other subjects or programs. In conclusion, we would say that the environment had a positive response from the students.

As is obvious, however, the small scale of the research does not allow us to proceed to generalizations regarding the use and acceptance of the environment. It would be interesting to extend the research to a larger number of samples and to test other factors as well.

This work is a first approach to the development of an adaptive learning system addressed to Primary School students for learning Scratch 3. After the use of this system by the students, it would be interesting to be used by IT teachers who teach the specific subject in Primary School, to be followed by research on the application of self-regulated learning at this level of education.

Additionally, as the system we developed is autonomous and does not depend on other learning environments, an interesting approach would be to integrate the specific system into already existing learning environments for example Learning Management Systems (LMSs).The system could be accessible through a SSO (Single Sign On Service) from an access point. The users of the system after entering the service will have access to various applications and to our system. Another solution could be LTI (Learning Tools Interoperability) specification where students with one login will have access to an LMS and to external systems like ours.

Chapter 12 - Conclusions

The development of technology in the field of Information and Communication Technology could not leave education unaffected. Many new technologies are constantly coming to the forefront with the aim of enhancing the effectiveness of the educational process. Educational organizations use these technologies to make valuable inferences about how and what students learn, and to provide engaging learning experiences for students.

E-learning both synchronous and asynchronous, has come into our lives to stay. It can be used as either an auxiliary tool in the educational process but it can also be used as a main tool in the learning process. In both cases, however, they should focus on the student and his learning style, while also taking into account his special characteristics.

Learning Analytics is one of the tools used to record and analyze how the student behaves during the learning process so that we can draw valuable conclusions from this process. A specification commonly used in recent times to support this process is the xAPI Specification whose features were analyzed above.

Considering all these, we designed and developed a learning system where each student at his own pace follows and completes the chapters contained therein. The concept of this system has some unique features since it combines self-regulated learning, adaptivity and gamification. At the same time, the system promotes the development of Computational Thinking skills through programming learning with the Scratch programming environment in Primary School.

After the use of the system by a group of fifth grade students, the recording and analysis of the results, we noticed that almost all of the students managed to complete the game, achieving satisfactory results. This leads us to conclude that the development of a learning environment that combines all the aforementioned features has successfully fulfilled the purpose for which it was created. To support the learning of a new subject while giving an engaging learning experience to students and valuable insights to teachers regarding the learning process.

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Appendix A - Learning Content

A.1 Unit 1. Introduction-History

A.1.1 Overview

For the first unit we used the Interactive Video Content type of H5P. This Content Type is based on a video that is enriched with interactive elements. H5P supports both uploading video to the site and embedding video from external video sources such as YouTube, Vimeo etc. All the videos we use in our game, are embedded from YouTube. In this way we achieve better video performance with less burden on our web host. The video is then enriched with interactive elements, which provide the student with the opportunity to interact.

The video that introduces the story is short, so as not to tire the students and lasts less than 2 minutes. It contains images that present the story and is accompanied by background music. The narration consists of frames with texts that appear between the frames of the images. The story attempts to achieve a gentle escalation of emotions. The background music creates an atmosphere of agony, while the images start with happy colors which gradually become more gray when our heroes encounter problems. But at the same time, in order to avoid creating negative emotions in the students, we chose in all the pictures our heroes to be all smiling.

A.1.2 Educational goals

The goal of this section is to prepare the student psychologically in order to mobilize his attention and activate his interest through the presentation of the story that frames the game. Thus, he will be able to receive new knowledge.

Figure A.1 Unit 1. Introduction-History

A.1.3 Activities - Interactive elements

At the end of the unit, the student encounters the first question, which is multiple choice. This question is intended to confirm that the student has understood the purpose of the game and to introduce him smoothly to the question answering process.

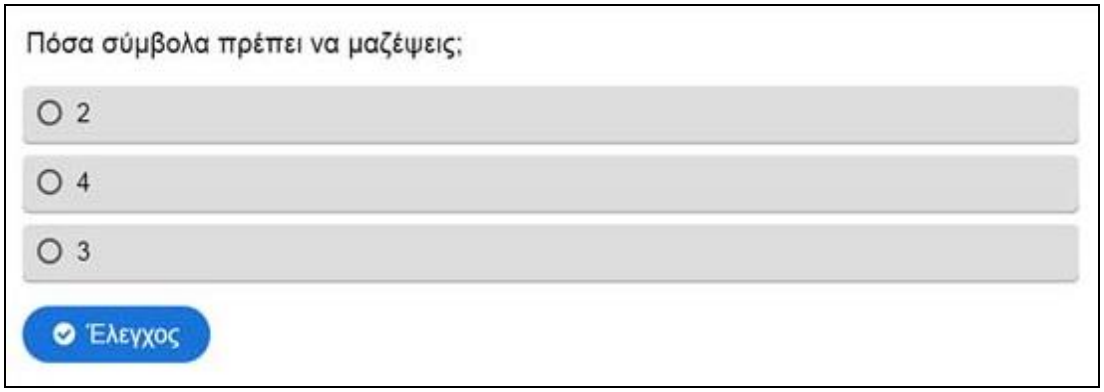


Figure A.2 Unit 1 - Activity 1

If the student answers correctly, he will collect his first grade. In case of an incorrect answer, the relevant message is displayed and the video returns to the point where the answer to the question is presented. When he answers correctly, he proceeds to the next unit.

A.2 Unit 2. Welcome!

A.2.1 Overview

Unit 2 introduces the student to Scratch. The student makes his first contact with Scratch and acquires some basic knowledge to understand the nature of Scratch and its use.

For this unit, we also used the Interactive Video Content type of H5P. The video we use is also short of one minute and thirty-five seconds and the student has to answer three comprehension questions. In order for the student to proceed to the next unit, he must collect a specific grade limit, as described before.

In the video presentation, we use two narrators, a boy and a girl. The narrators are in the form of comic characters and the narrated texts appear in text bubbles. In addition, we use screenshots from the Scratch environment that help us better present the information given to us by the narrators. Video attempts to create a fun learning system. The background music is a happy melody, the colors of the images are vivid, pleasant and the images of the narrators are smiling children.

Figure A.3 Unit 2. Welcome!

A.2.2 Educational goals

The Educational goals of the unit are for the student to understand:

- what is a program,

- what is Scratch,
- what he can do with Scratch,
- how he can download the program, and
- how he can work with Scratch.

A.2.3 Activities - Interactive elements

While watching the video, the student is asked to answer three comprehension questions. The questions are multiple choice and their degree of difficulty is low. The questions aim on the one hand to keep the student's attention undiminished and on the other hand to help him consolidate key elements of the presentation. The questions in this section are shown in Figure A.4, Figure A.5 and Figure A.6.

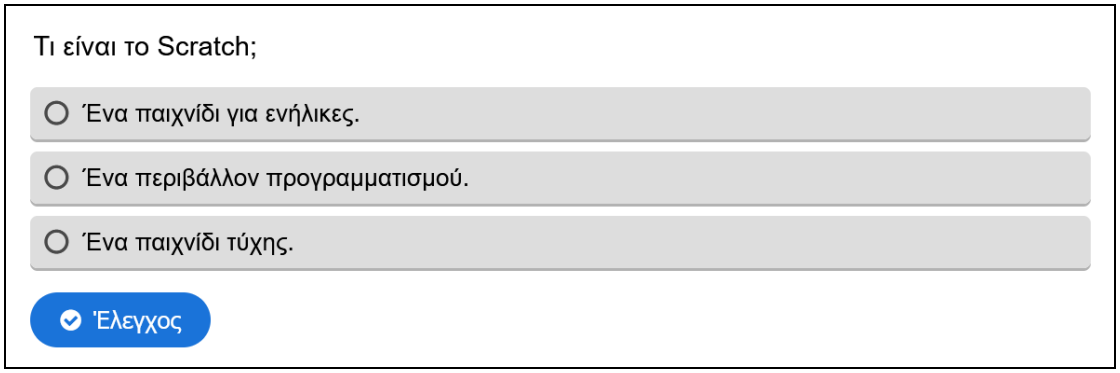


Figure A.4 Unit 2 - Activity 1

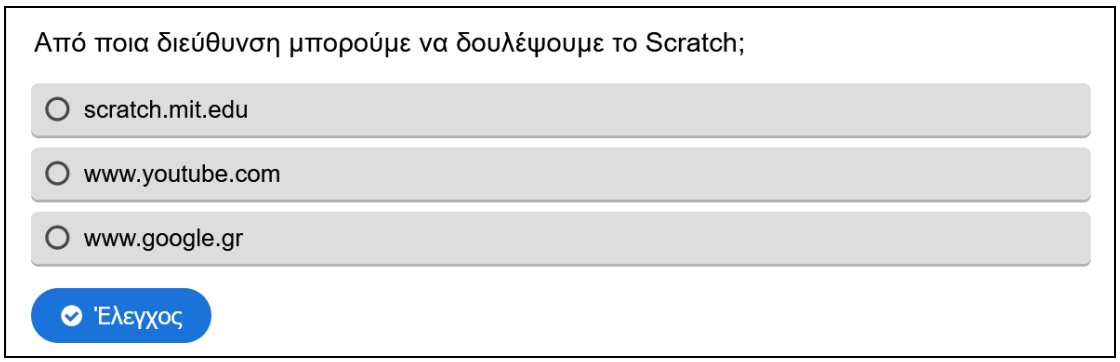


Figure A.5 Unit 2 - Activity 2

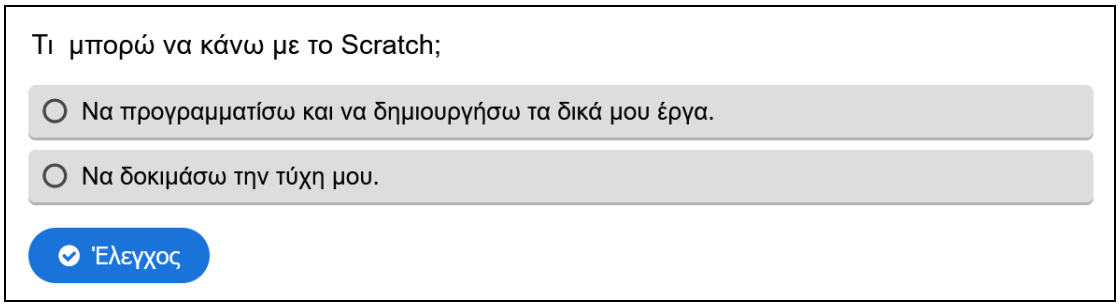


Figure A.6 Unit 2 - Activity 3

A.3 Unit 3. Introduction to the environment

A.3.1 Overview

In this unit, the student is introduced to the Scratch environment. For the presentation we use an interactive video. The teacher, who through a screen capture presents and explains the Scratch environment, does the narration. In addition, the teacher demonstrates the process by which he completes some basic actions. The interactive video lasts eight minutes and fifty-four seconds. In between, students engage in eight comprehension activities. In case, the student does not gather the required points to continue to the next unit, he attends an additional unit, which will help him to understand the educational subject better.

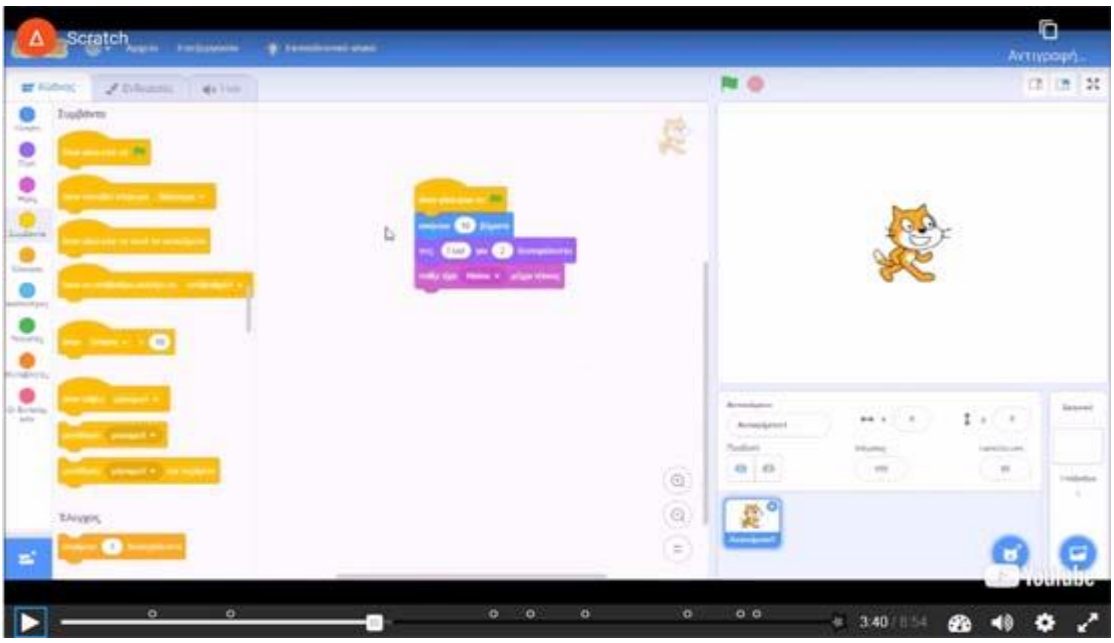


Figure A.7 Unit 3. Introduction to the environment

A.3.2 Educational goals

The Educational goals of the unit are for the student to:

- identify areas of the Scratch interface,
- distinguish command groups and the commands in each of them,
- manage commands, objects and backgrounds, and
- execute a program.

A.3.3 Activities - Interactive elements

In this unit, the student engages in activities that simulate the Scratch environment, giving the student the feeling that he is working in the program work environment. The main goal is to familiarize the student with the Scratch environment, so that he can easily locate and identify the areas of which the environment is composed. This is accomplished by asking the student to locate the areas we are asking for, and then dragging and dropping tabs with the names of the areas in place of each area.

The student participates in eight activities with content type drag and drop. The first seven activities are of low difficulty, as they are introduced immediately after the presentation of the topic they are dealing with. The last activity is of increased difficulty, as it is a summary of the whole unit. In the following figures, we see the activities of this unit.

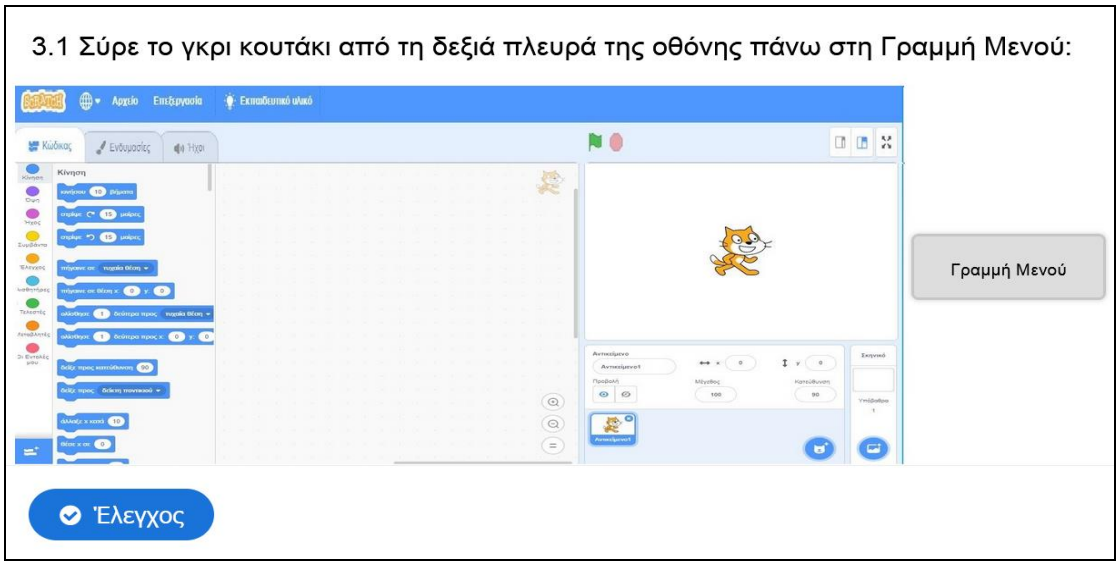


Figure A. 8 Unit 3 - Activity 1

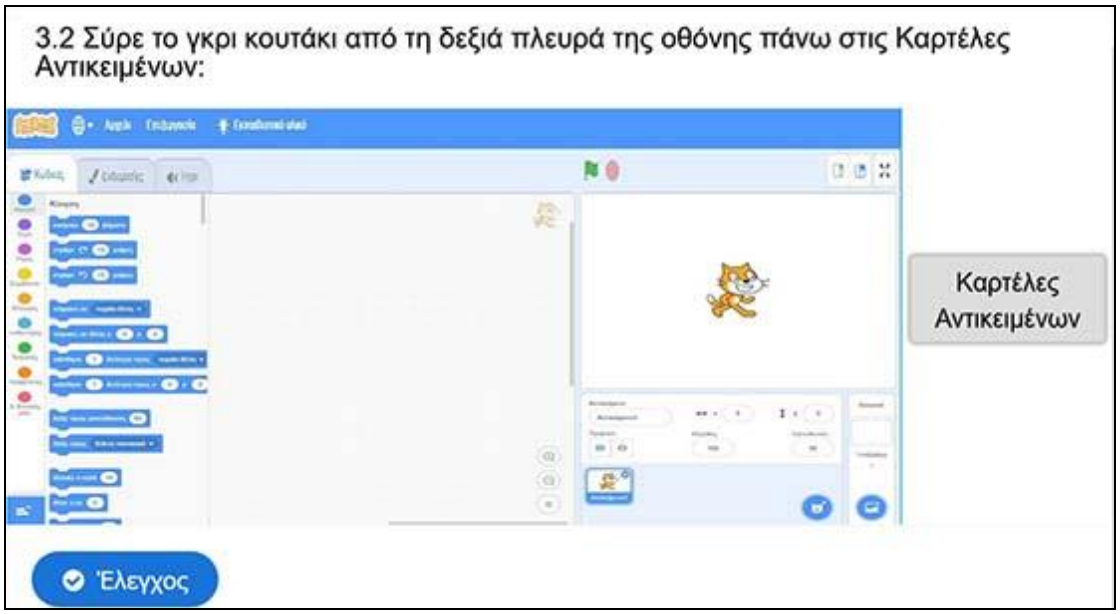


Figure A.9 Unit 3 - Activity 2

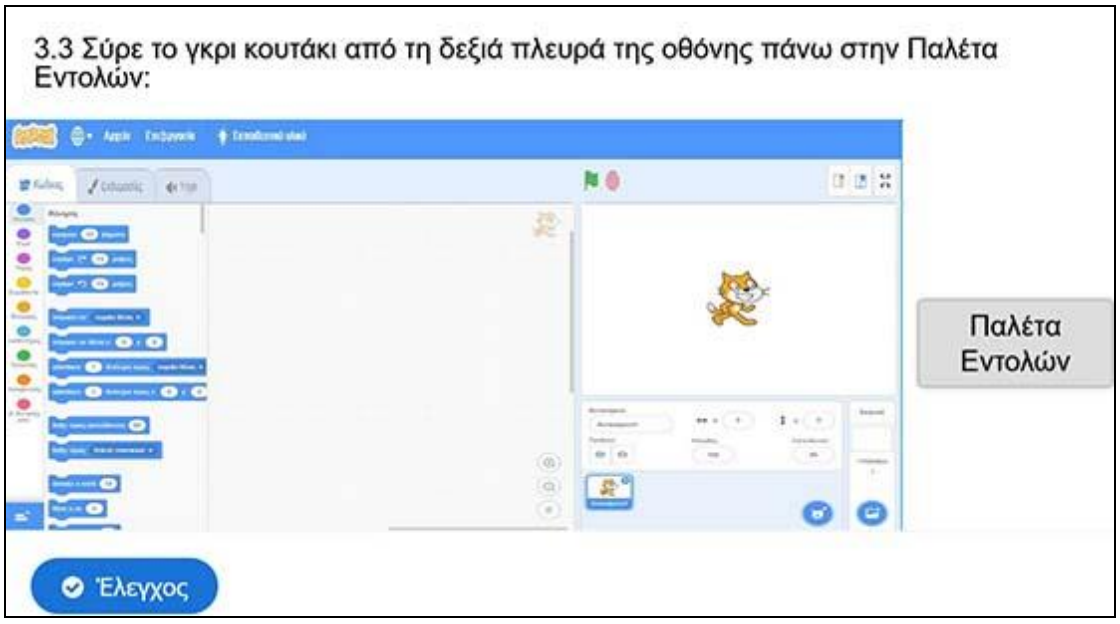


Figure A.10 Unit 3 - Activity 3

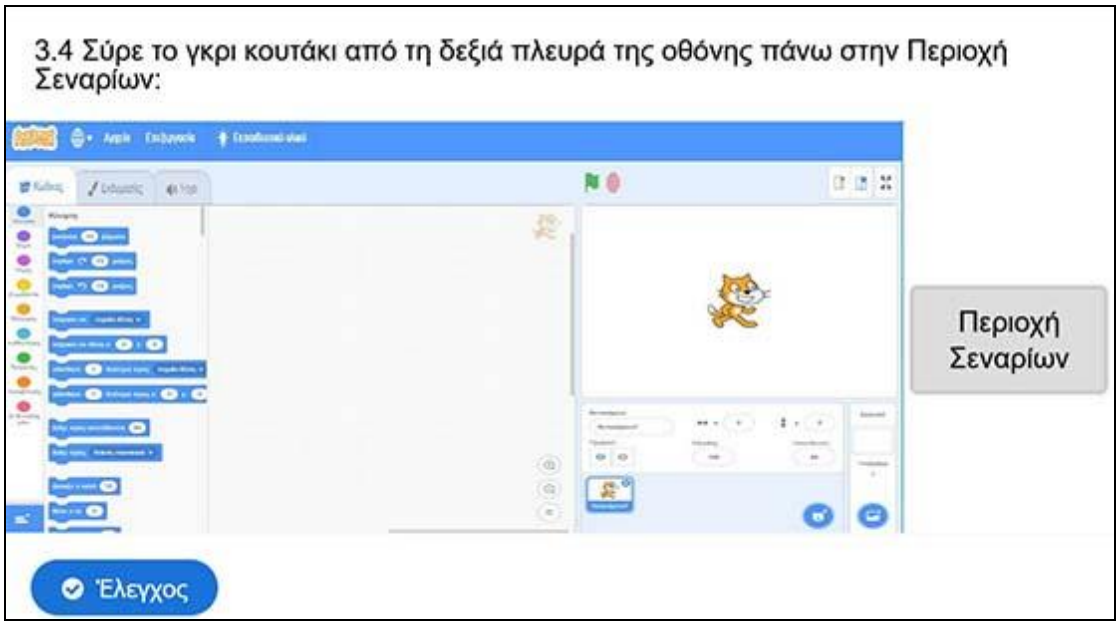


Figure A.11 Unit 3 - Activity 4

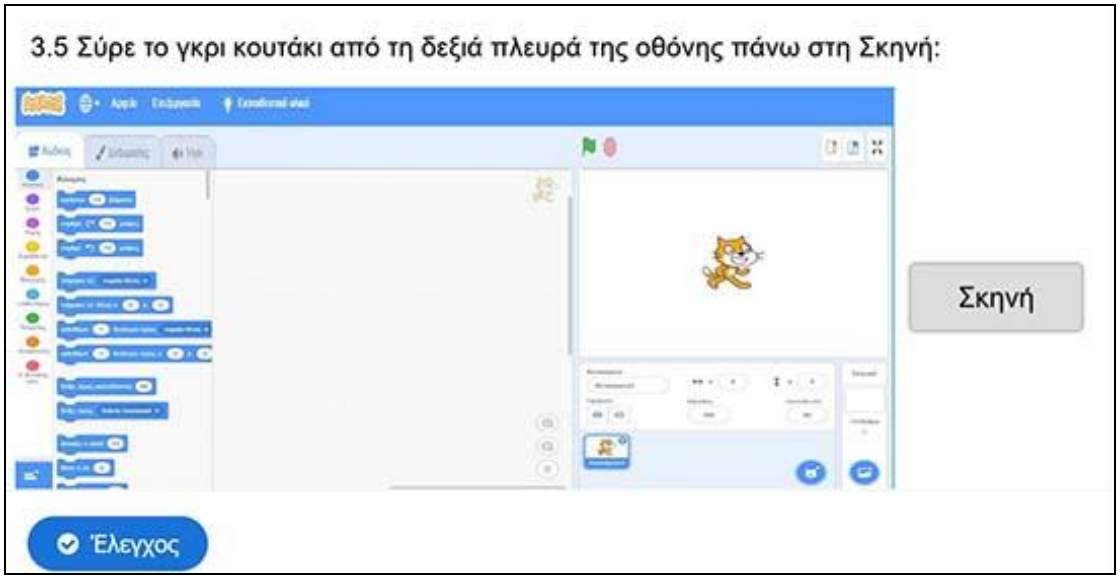


Figure A.12 Unit 3 - Activity 5

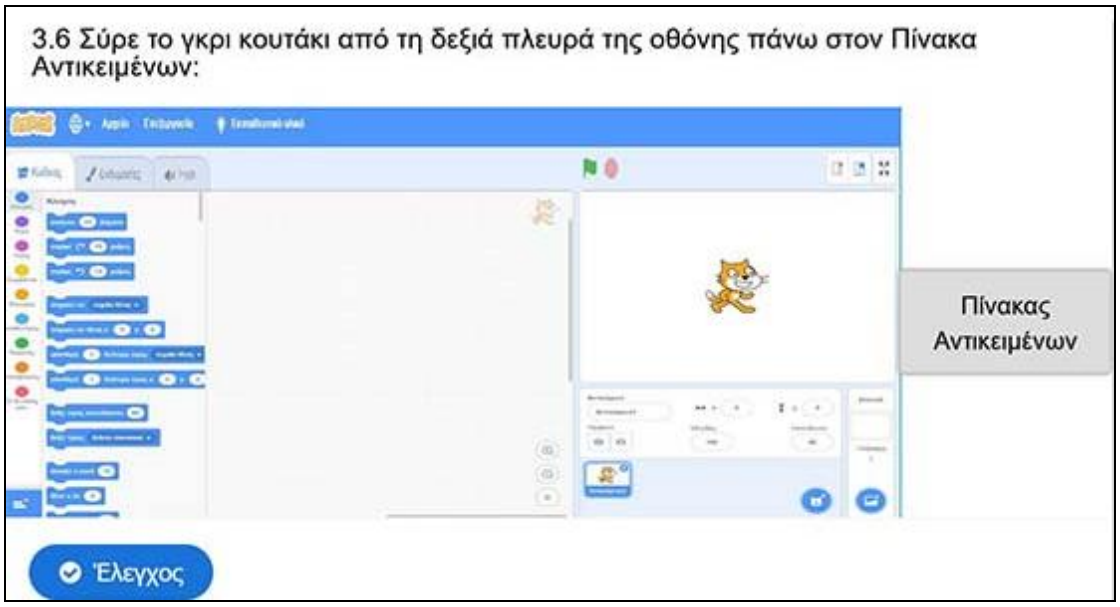


Figure A.13 Unit 3 - Activity 6

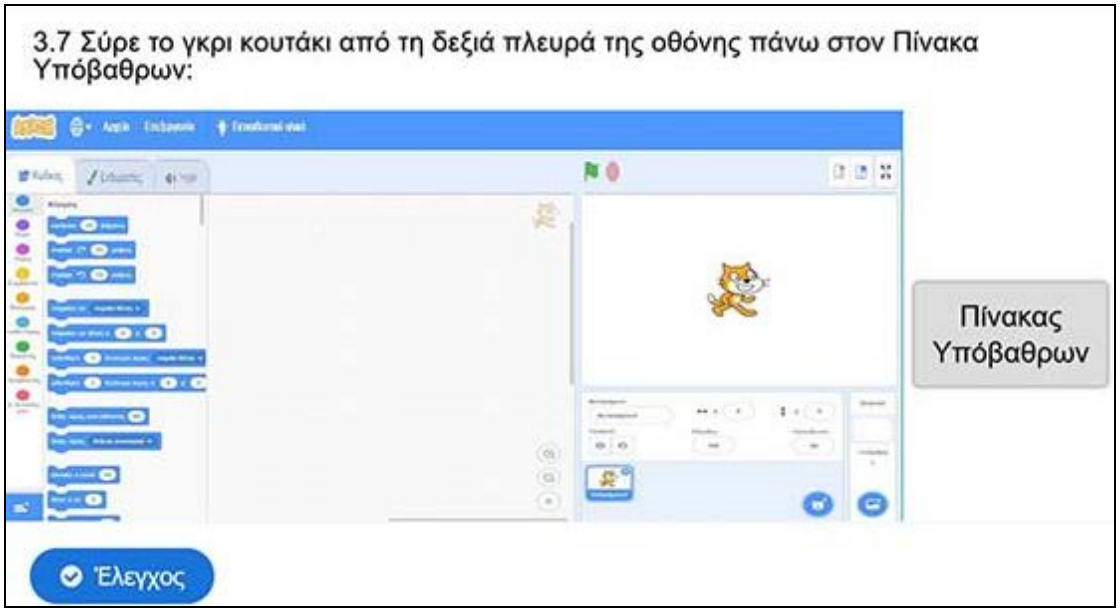


Figure A.14 Unit 3 - Activity 7

Figure A. 15 Unit 3 - Activity 8

A.4 Unit 3.1 Introduction to the environment (extra)

A.4.1. Overview

This unit aims to help students understand better the subject matter of the previous unit. This unit only appears to students whose performance in the previous section was not satisfactory. Our Educational goals are the same as in the previous section, but we apply a different teaching approach, in order to achieve a better result. To achieve this, we chose to use the Course Presentation Content Type of H5P.

Course Presentation is a more static presentation tool. The section consists of a series of slides. The student moves on the slides with his mouse or the arrow keys on his keyboard, whenever he feels ready to change the slide. Among the slides, the student is asked to answer comprehension questions.

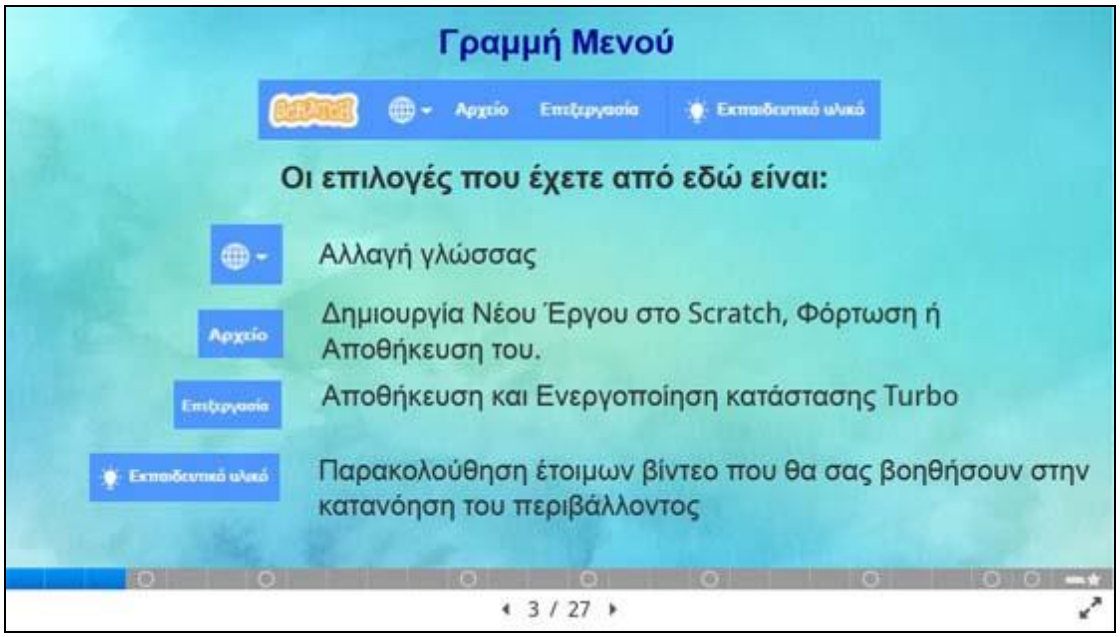


Figure A.16 Unit 3.1 Introduction to the environment (extra)

The unit consists of twenty-seven slides. Sixteen of them present the educational material to the student. The educational objects presented are the same as presented in the previous unit, but the information is presented in the form of text and image. There is no narration or background sound in the presentation. In addition, eight slides contain comprehension exercises and the last slide is the summary of the unit presenting the student's score in the exercises. This unit is supportive of the previous one, thus for student assessment, we use the same comprehension exercises we used in the previous unit. In this way, we will be able to conclude whether the different teaching approach works for the particular student. If the student does not reach the minimum point limit to continue to the next unit, he repeats the current unit.

The Educational goals and the Activities - Interactive elements of this unit are the same as those of the previous unit.

A.5 Unit 4. Change costumes – Create Animation

A.5.1. Overview

In unit 4, the student begins to delve deeper into Scratch. In this unit, we present to the student the change of costumes and the creation of animation. We use a detailed example, where we present step by step the actions he needs to follow. The student monitors the steps required to write and execute a program in Scratch. After this, he is instructed to do one task on his own in his actual environment. After completing the task, he returns to the environment and answers the questions for understanding the unit. If he fails to collect the minimum score, he repeats the current unit.

The student attends a presentation of twenty-four slides created with the H5P Course Presentation Content Type. Fifteen of them present the educational material, eight slides contain comprehension exercises and the last slide is the summary of the unit. There is no narration or background sound in the presentation and the information is provided to the student in the form of text and image.

A.5.2. Educational goals

The Educational goals of the unit are for the student to:

- understand what animation is and how it is implemented,
- change costumes on an object,
- insert a delay in executing program commands,
- insert into the project one of the available backgrounds,
- insert sounds to his work, and
- create his own animation.

A.5.3. Activities - Interactive elements

In this unit, we use additional interactive elements and resources for the needs of the presentation of the educational material.

The student participates in eight activities. The first two activities (Figure A.17 and Figure A.18) are comprehension questions with drag and drop, drag the words questions' types. After this, the student is assigned his first project in Scratch (Figure A.19). The student is invited to visit the Scratch page and create a project, using the knowledge he has acquired so

far. He will then perform the remaining six activities, answering comprehension questions (Figure A.20 - Figure A.25). In comprehension questions we use various types of content, such as single choice questions, multiple choice questions, true / false and drag and drop. The last activity involves a program creation simulation, asking students to put the commands of a program in the correct order.

In the following figures we see the activities of this unit:

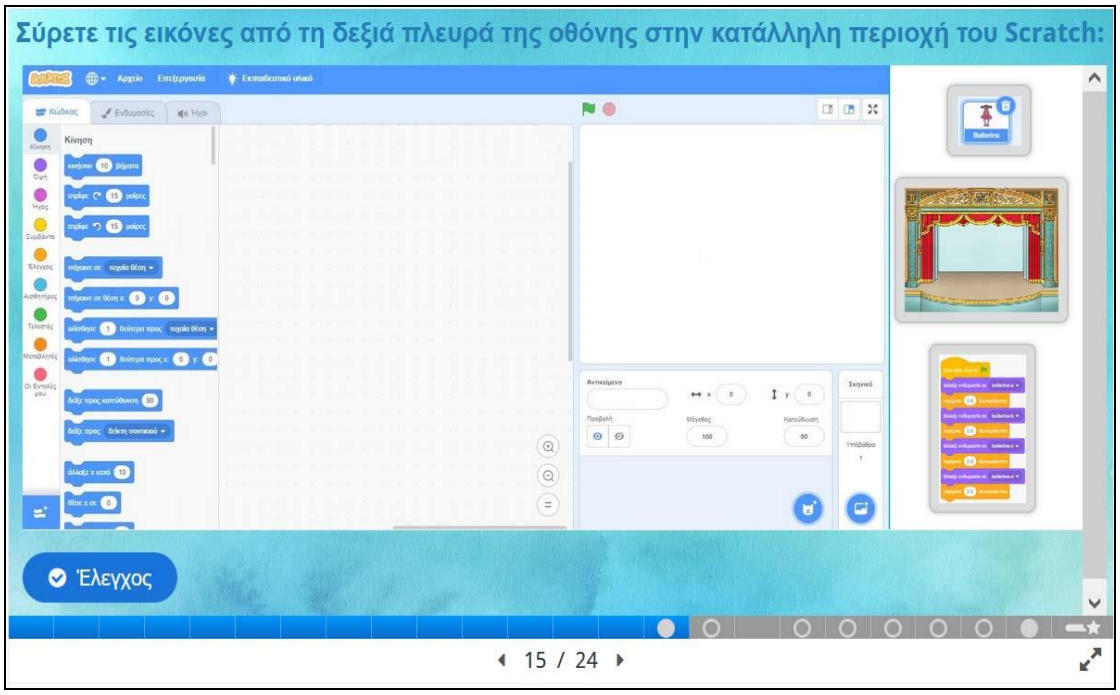


Figure A.17 Unit 4 - Activity 1

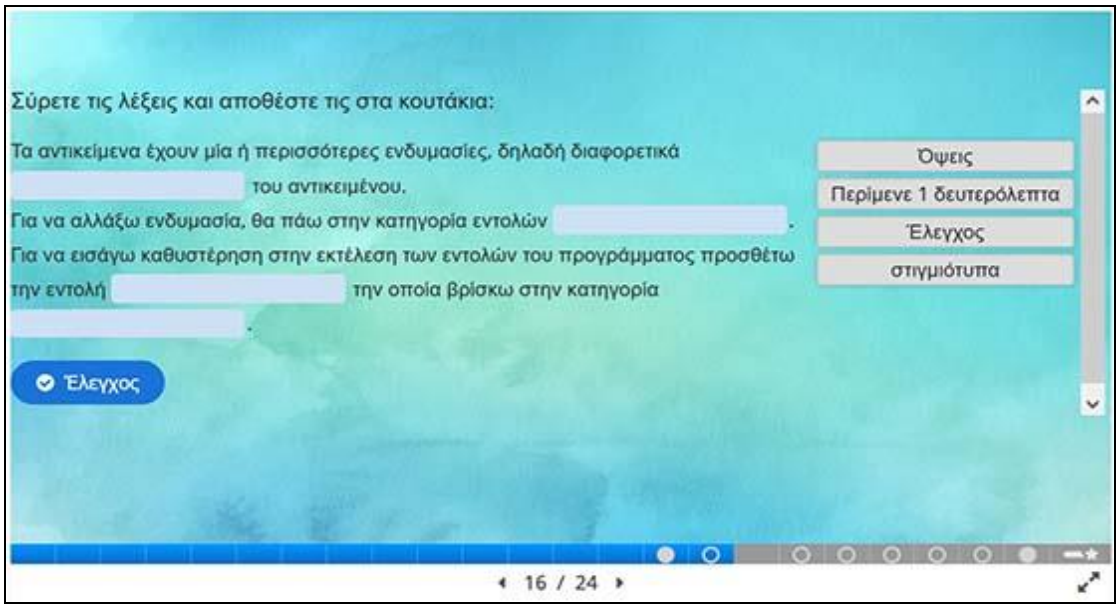


Figure A.18 Unit 4 - Activity 2

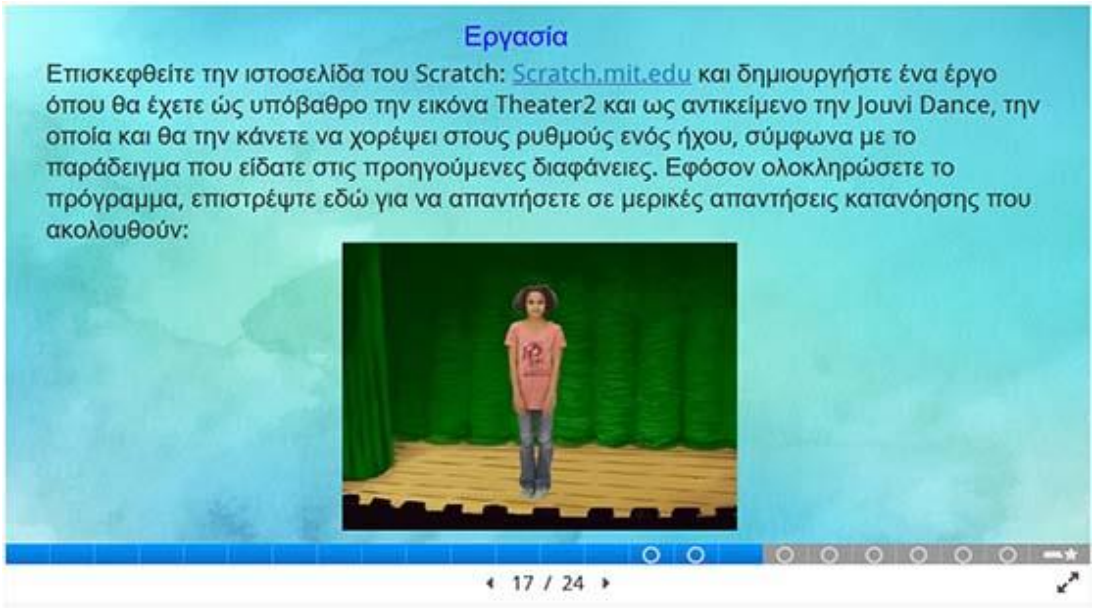


Figure A.19 Unit 4 – Project

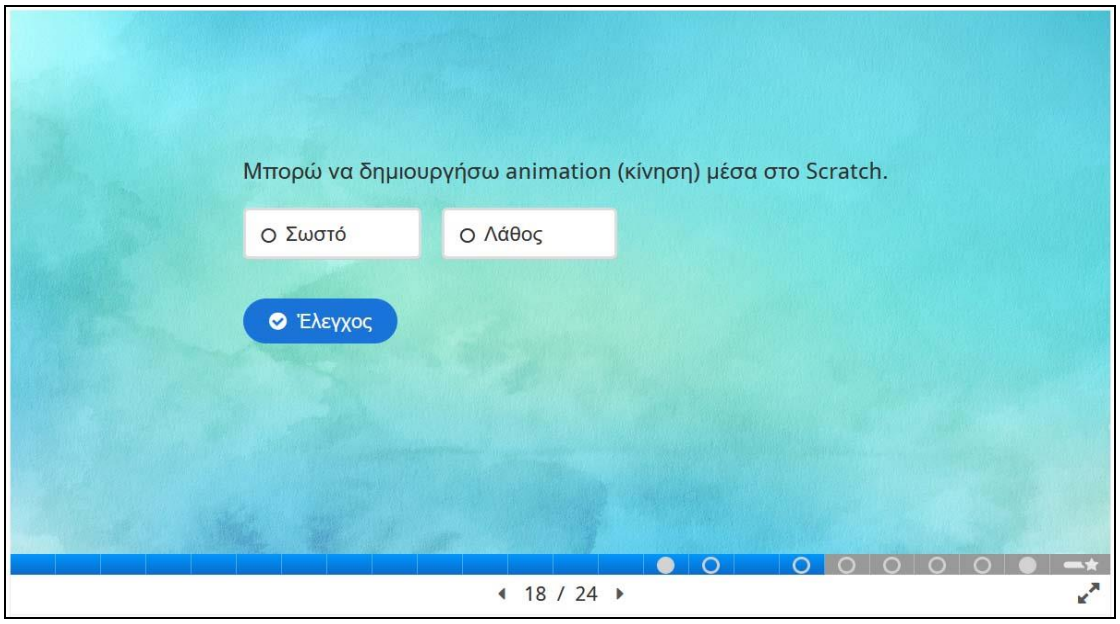


Figure A.20 Unit 4 - Activity 3

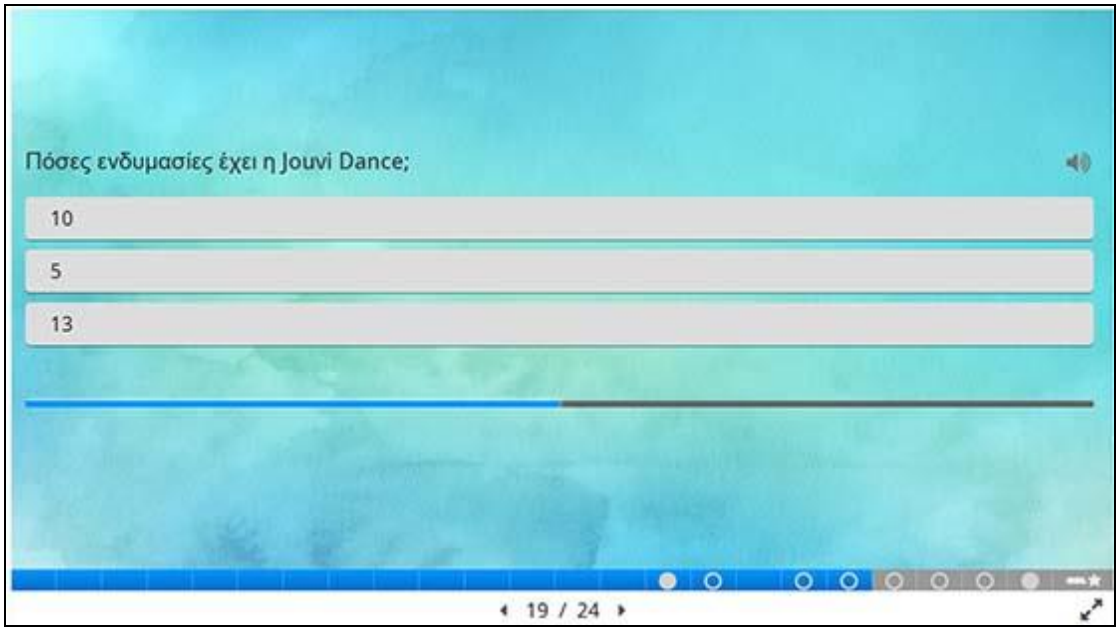


Figure A.21 Unit 4 - Activity 4

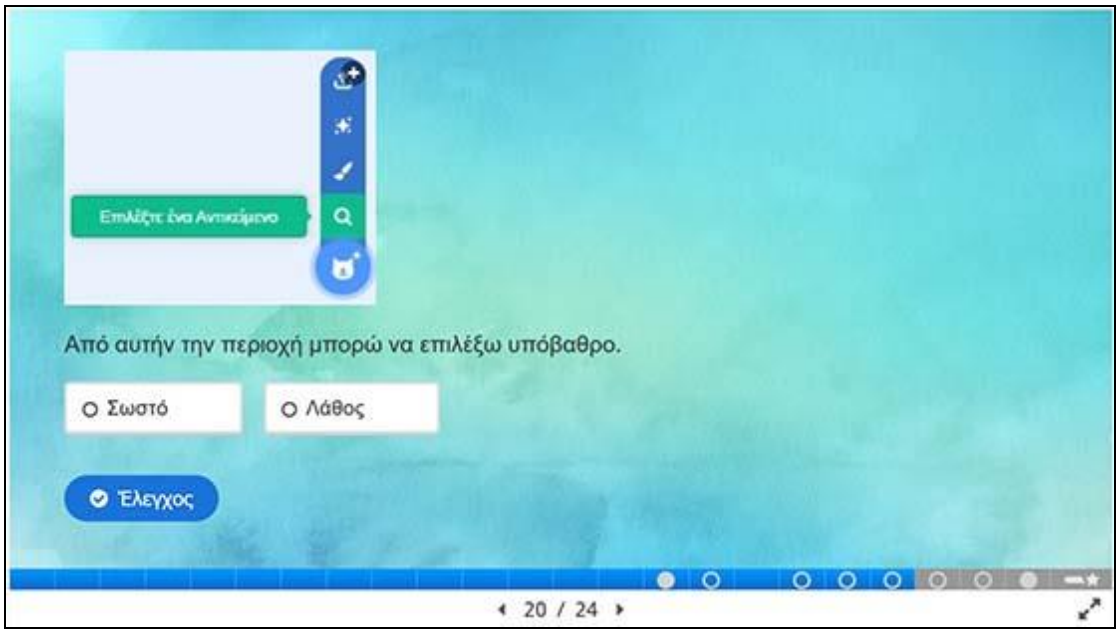


Figure A.22 Unit 4 - Activity 5

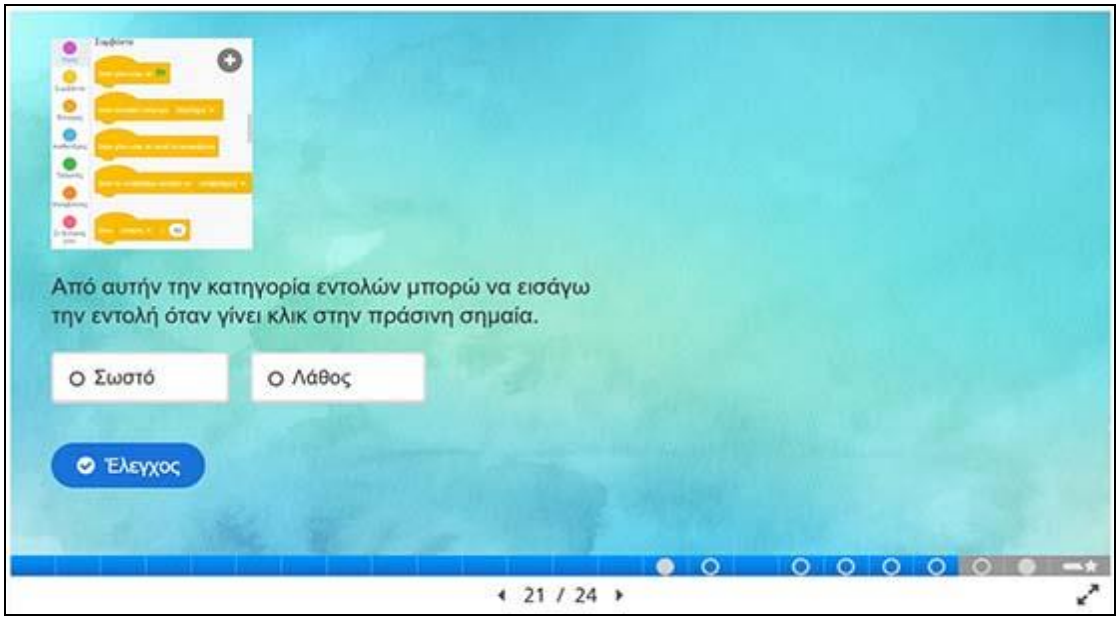


Figure A.23 Unit 4 - Activity 6

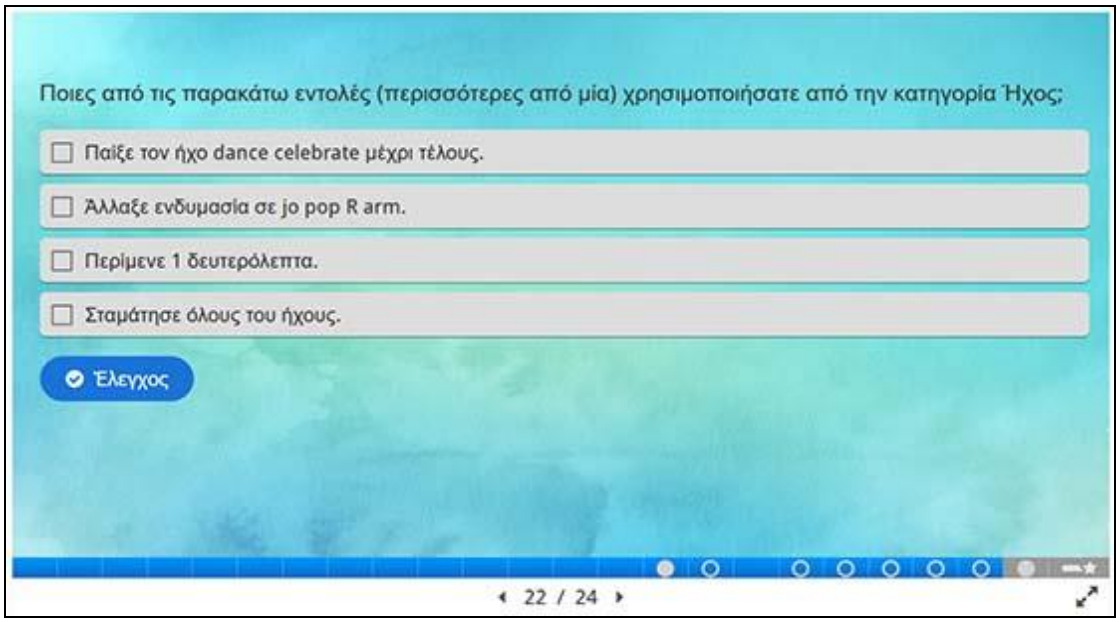


Figure A.24 Unit 4 - Activity 7

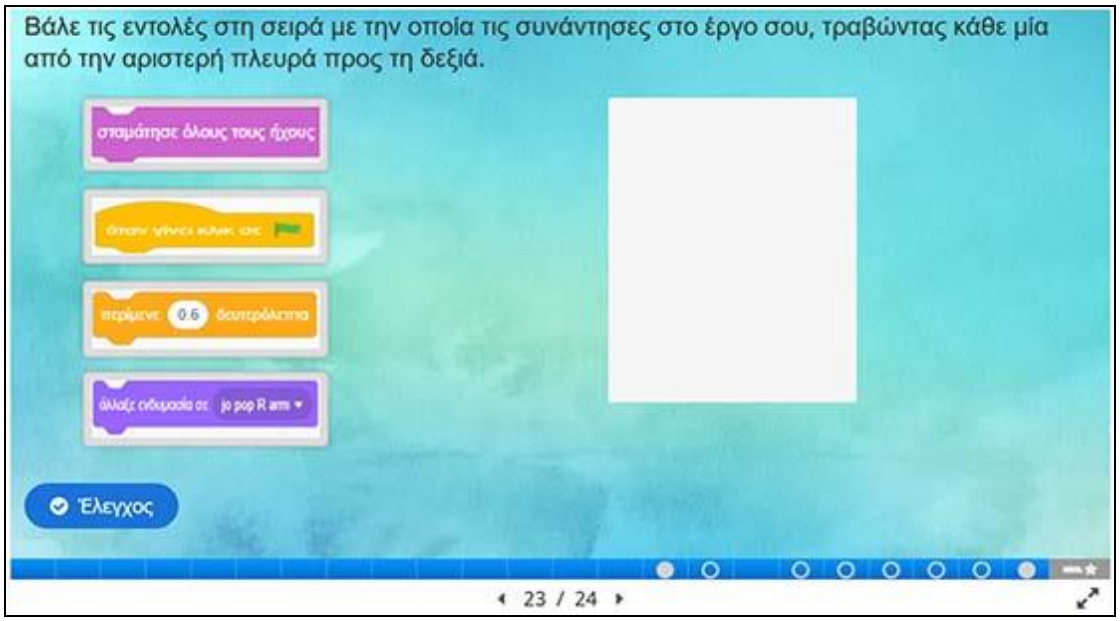


Figure A.25 Unit 4 - Activity 8

A.6 Unit 5. Motion

A.6.1 Overview

In the previous unit, we saw how we can create animation by changing costumes. In this unit, we will continue with changing costumes but additionally we will use commands from the Motion Group.

The teaching approach we use is the same as the previous unit. We present the educational object with detailed instructions. We assign to the student a task that he has to do in the real environment of Scratch. Finally, we ask him comprehension questions. If he fails to collect the minimum score, he repeats the current unit.

This unit is implemented using the Course Presentation Content Type of H5P, and contains seventeen slides. Eight of them present the educational material, the eight slides contain comprehension exercises and the last slide is the summary of the unit. There is no narration or background sound in the presentation and the information is provided to the student in the form of text and image.

A.6.2 Educational goals

The Educational goals of the unit are for the student to:

- identify motion commands,
- select the appropriate motion command according to the requirements of a project,
- combine motion commands with change costumes commands to create animation, and
- create his own animation.

A.6.3 Activities - Interactive elements

The interactive elements of this unit do not differ from the previous units.

The student participates in eight activities. After the first three activities (Figure A.26 - Figure A. 28) which are comprehension and multiple choice questions, the student is assigned a project in Scratch (Figure A.34). The student is invited to visit the Scratch site and create a project, using the knowledge he has acquired so far. He will then perform the remaining five activities, answering comprehension questions (Figure A.29 - Figure A.33). In comprehension

questions we use various types of questions, such as true / false questions, single choice set and drag and drop. The last activity involves a program creation simulation, asking students to put the commands of a program in the correct order.

In the following figures we see the activities of this section:

Figure A.26 Unit 5 - Activity 1

Figure A.27 Unit 5 - Activity 2

Figure A. 28 Unit 5 - Activity 3

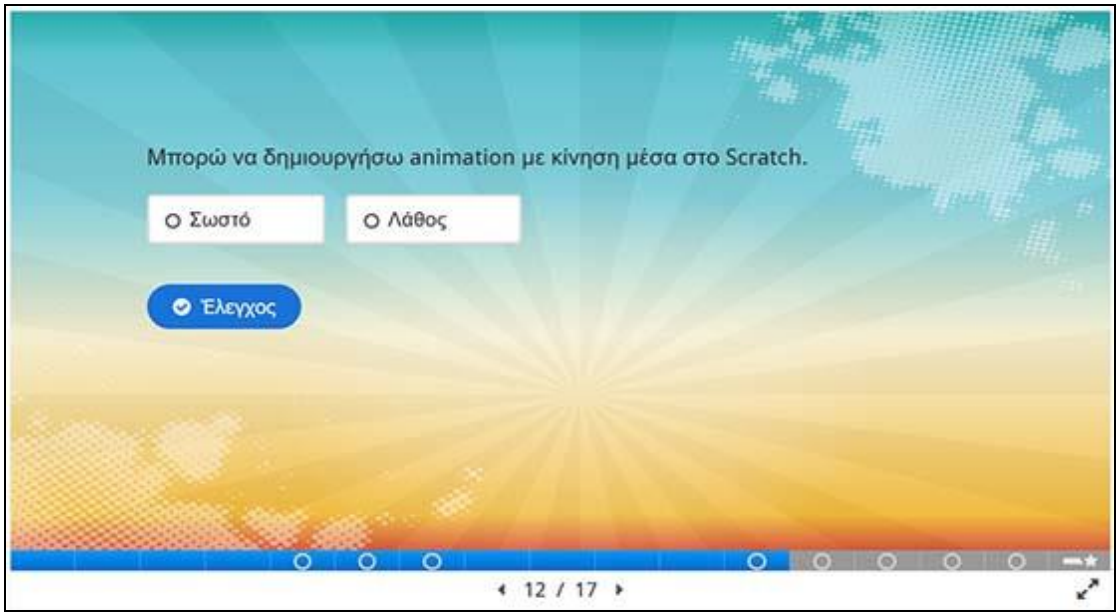


Figure A.29 Unit 5 - Activity 4

Figure A.30 Unit 5 - Activity 5

Figure A.31 Unit 5 - Activity 6

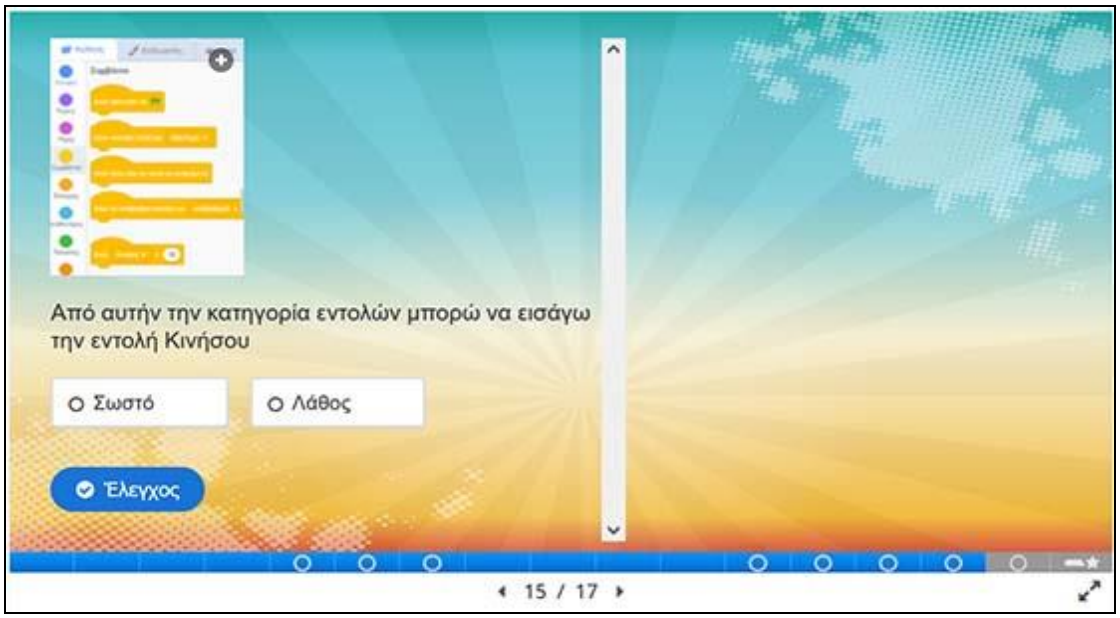


Figure A.32 Unit 5 - Activity 7

Figure A.33 Unit 5 - Activity 8

Figure A.34 Unit 5 – Project

A.7 Unit 6. Looks

A.7.1 Overview

In this unit, we will continue learning additional commands, which increase the functionality of our projects. The educational object that we will examine is the dialogues, how we will make our heroes speak and have dialogues.

Our teaching approach is the same as in the previous units. We present to the student the educational object with detailed instructions. We assign him a task that he has to do in the real environment of Scratch. Finally, we ask him comprehensive questions. Essentially, it is the last unit that the student will be introduced to new educational subjects, as the next unit is the end of the game. If he fails to collect the minimum score, he repeats the current unit. However, if the student achieves a very high performance, he is rewarded by offering him an extra unit to attend. Otherwise, the student continues to the last unit.

This unit is implemented using the Course Presentation Content Type of H5P, and contains seventeen slides. Seven of them are used to present the educational material, while the

next ten slides contain comprehension exercises. There is no narration or background sound in the presentation and the information is provided to the student in the form of text and image.

A.7.2 Educational goals

The Educational goals of the unit are for the student to:

- identify speech and dialogue commands,
- distinguish speech and dialogue commands,
- apply speech commands to their objects, and
- create dialogues between the objects of a project.

A.7.3 Activities - Interactive elements

The interactive elements of this unit do not differ from the previous units. The student participates in nine activities. After the first four activities (Figure A.35 - Figure A.38) which are multiple choice comprehension questions, the student is assigned a task in Scratch (Figure A.39). The student is invited to visit the Scratch page and create a project, using the knowledge he has acquired so far. He will then perform the remaining five activities, answering comprehension questions (Figure A.40 - Figure A. 44). In comprehension questions, we use the True / False and Single Choice Set question's types.

In the following figures we see the activities of this unit:

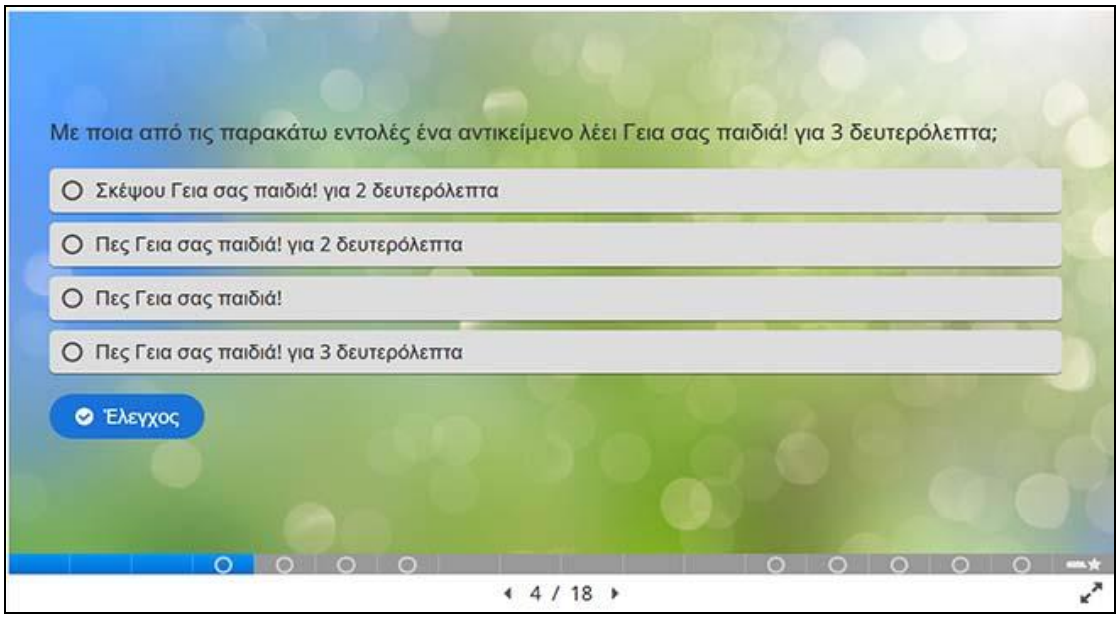


Figure A.35 Unit 6 - Activity 1

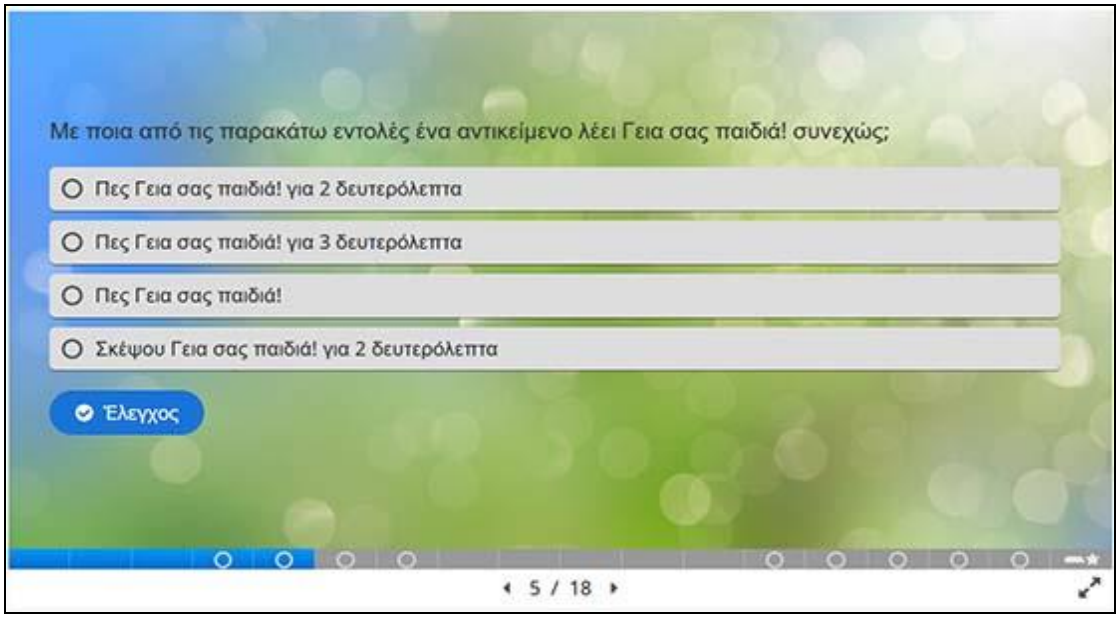


Figure A.36 Unit 6 - Activity 2

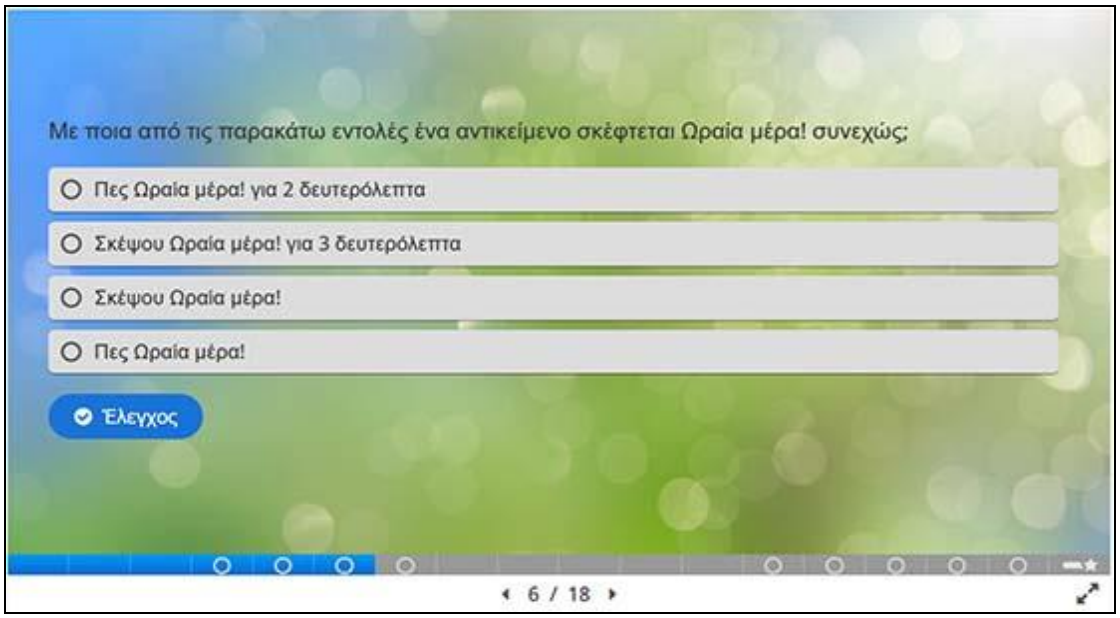


Figure A.37 Unit 6 - Activity 3

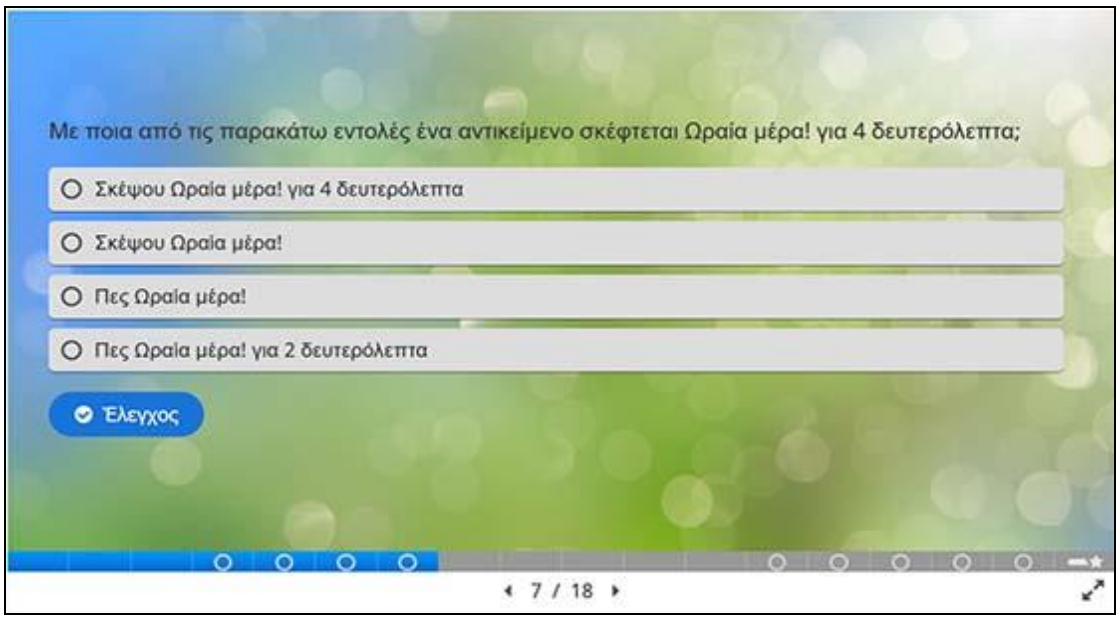


Figure A.38 Unit 6 - Activity 4

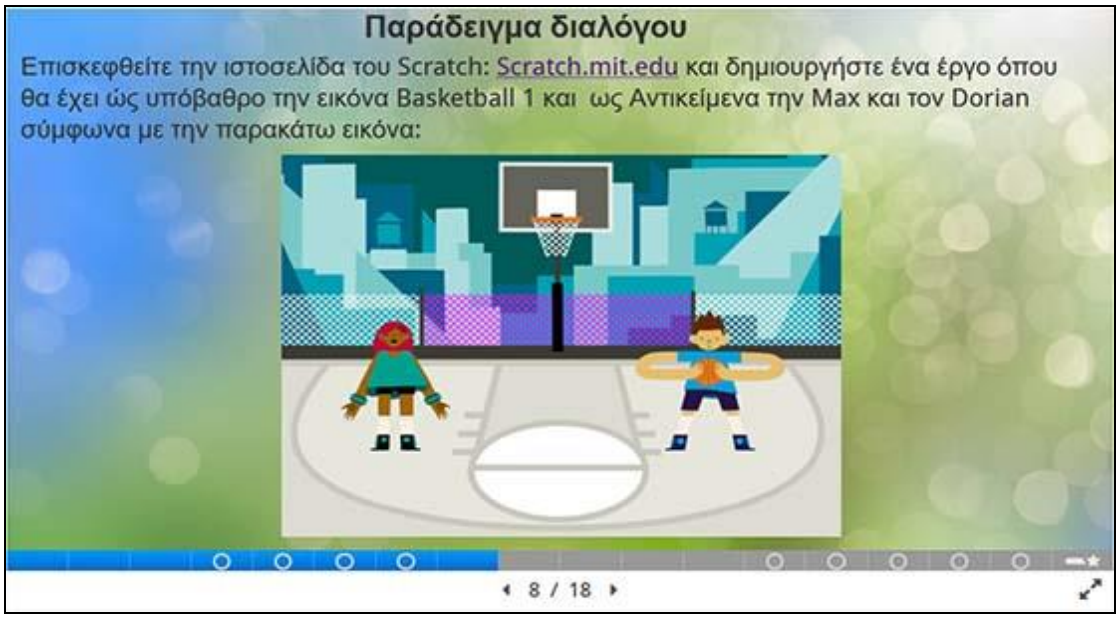


Figure A.39 Unit 6 - Project

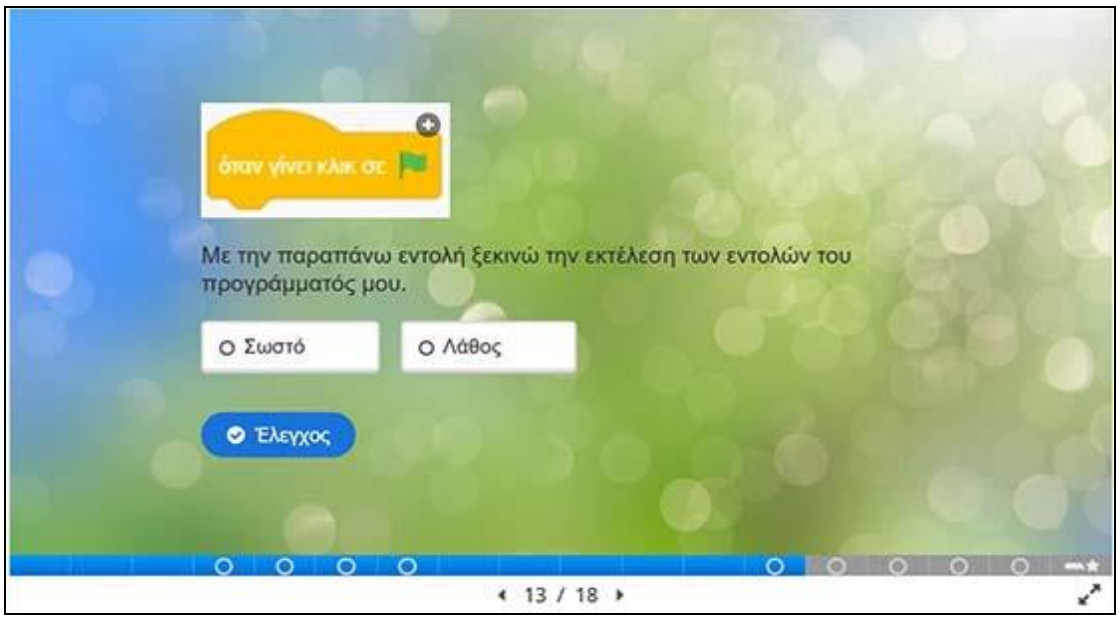


Figure A.40 Unit 6 - Activity 5

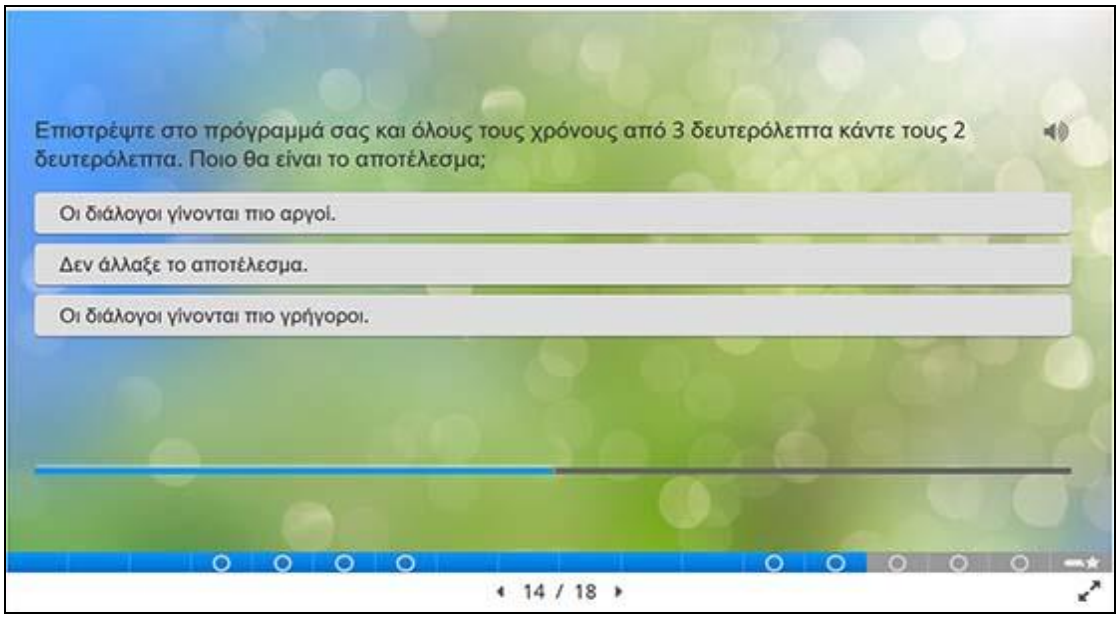


Figure A.41 Unit 6 - Activity 6

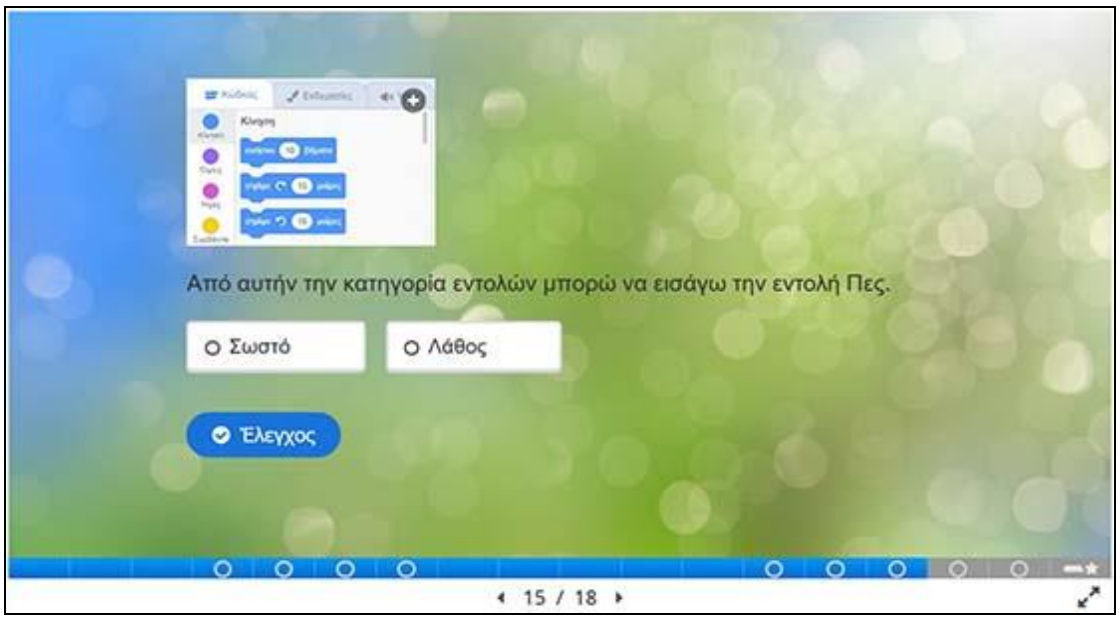


Figure A.42 Unit 6 - Activity 7

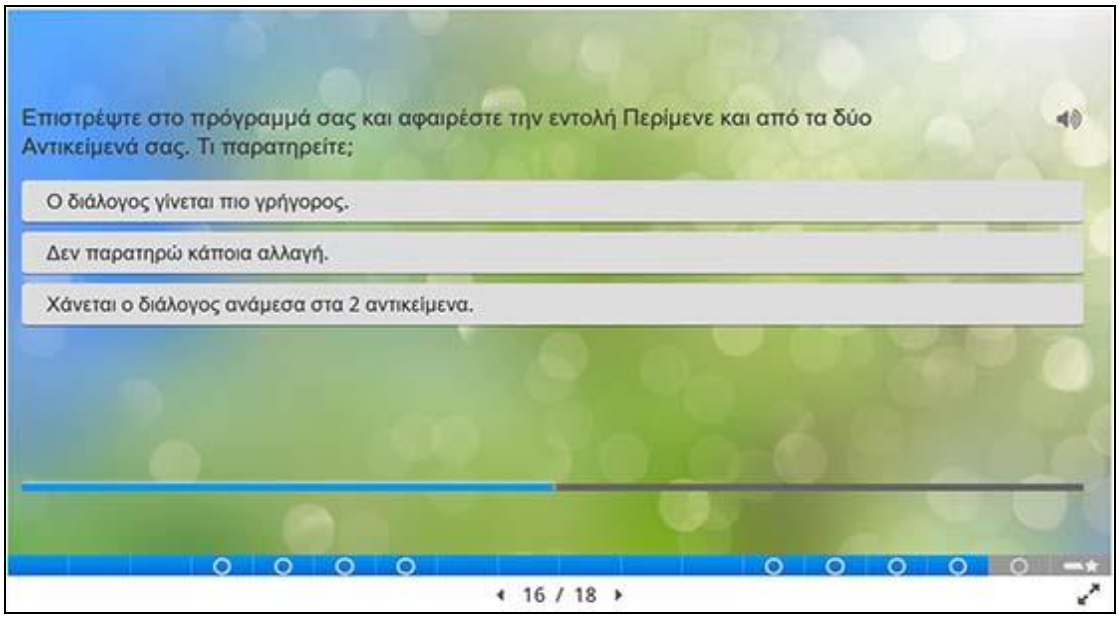


Figure A.43 Unit 6 - Activity 8

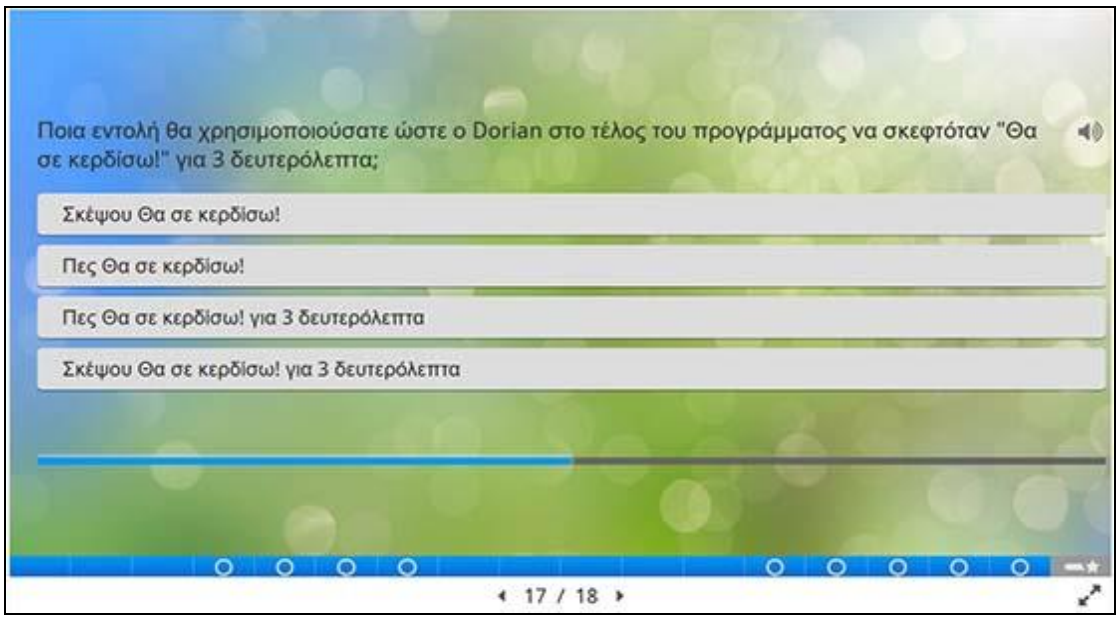


Figure A. 44 Unit 6 - Activity 9

A.8 Unit 6.1 What is happening at the bottom of the sea. (bonus)

A.8.1 Overview

This unit is a reward to the students who achieved a very high score in the previous unit. The unit is implemented using the Course Presentation Content Type of H5P and has only two slides. The student will implement this additional activity in the Scratch environment. Essentially, this work is the trigger for students to develop their creativity. We give students some basic elements to use in their work, such as backgrounds and objects, and ask them to create their own story by animating the objects.

The purpose of the activity is on the one hand to be an additional motivation for the students the reward it offers and on the other hand to provide them with an additional activity for practice. This activity does not offer anything extra to the student's score. By reaching this section, the student has already fulfilled the objectives of the game and has completed it successfully. After this unit, the student continues to the last unit, which is the end of the game.

Figure A.45 Unit 6.1 What is happening at the bottom of the sea

A.9 Unit 7. The liberation!!!

A.9.1 Overview

This is the last unit of the game. The student, reaching this section, has successfully completed all the units of the game and has collected the four badges required to achieve the purpose of the game and free Elli.

For this unit we used the Interactive Video Content Type of H5P. We present a video of forty-one seconds, which shows the end of the story. The student receives information through texts that appear in the video and is informed that he managed to achieve the goal and release Elli. Elli has now returned to her home (Figure A.46).

When the student completes the unit, he is redirected to the page where he will be able to download his successful completion award (Figure A.47).

Figure A.46 Elli at home

Figure A.47 The award

Appendix B - Technical Implementation

In this appendix, we present in more detail the implementation of the communication between the Website and the LRS. We start this analysis with paragraph B.1 where we present the session variables we use in the website. These variables are of particular importance, as they are the temporary copy of the LRS data on the website. Then we present one by one the cases where there is communication between the website and the LRS and analyze them by quoting excerpts of code.

B.1 Session Variables

The session variables we use for the student's activity on the Website are the following:

- **[nextLesson].** The next lesson that the student should attend.
- **[totalScore].** The total score achieved by the student in all activities.
- **[energy].** The total energy that the student has at his disposal.
- **[badges].** The badges acquired by the player.
- **[lessons].** Information about each lesson and the student's activity. For each lesson the following basic information is stored:
    - **[status].** The unit's status, which can be completed or pending.
    - **[timesCompleted].** The student can attend a chapter more than once. Here we store how many times he has completed it.
    - **[name].** The unit's name.
    - **[score].** Here are stored the scores that the student achieves in each unit but also in each separate activity of the unit. In case the student repeats a unit, the highest score he has achieved is counted. For each activity a record is created with the activity id and two subrecords where the score achieved and the maximum score that can be achieved in each activity is stored. Respectively, a record is created (lessonTotal) with two subrecords where the total score achieved and the maximum total score that can be achieved in each chapter are stored.
        - **[lessonTotal] ["lessonScore"].** The unit's score.
        - **[lessonTotal]["lessonMaxScore"].** The unit's maximum score.
        - **[*activityid*] ["activityScore"].** The score of the activity with id *activityid*.
        - **[*activityid*]["activityMaxScore"].** The maximum score of the activity with id *activityid*.

- **[activity].** For each xAPI statement a separate subrecord is created where the type of action and the timestamp performed are stored.
  - **["verb"].** The verb of the xAPI statement is stored which identifies the action taken.
  - **["date"].** The statement's timestamp.

B.2 Actions taken during a student's connection

Initially the student is led to the Control Panel to be informed about his status. To display the content to the student, we contact the LRS, submitting the appropriate query to retrieve its activity so far.

The retrieved xAPI statements are then stored in session variables and kept on the Website throughout the student's connection. A dynamic table is created for each training module, and with proper processing, each statement is saved in the corresponding record. At the same time, checks are performed to determine the course followed by the student and to determine his status, which is stored in the corresponding variables. Then, based on the information we now have, we show the student the appropriate messages for his status and the option buttons to start his activity.

B.2.1 Displaying Control Panel

The Control Panel is divided into two areas (Figure B.1), in the Status Area and in the Buttons' Area. In Figure B.2 we see the code of the Control Panel.

Figure B.1 Student's Control Panel

In Figure B.2 we see a code snippet of the student's Control Panel. In the status area *(lines 35-62)* depending on the student's situation, one of the following messages is displayed to the student:

- Successful completion of the course. In addition, the score he achieved and the link for downloading his award are displayed.
- Exhaustion of energy.
- Current status. Shows how many chapters it has completed, what the next chapter is, the badges, the score and the energy.

The following buttons appear in the buttons' area *(lines 63-77)*:

- My progress. Links to the page with the student's detailed progress.
- Next Lesson. Links to the next lesson.
- My badges. Links to the page where it shows the badges that the student has acquired and how much is left to obtain the rest.
- Instructions. Links to the page with instructions for the course.

If the student has completed the course, either successfully or due to energy depletion, the Next Lesson button does not appear.

For each message and button, we create the corresponding html division. Starting the execution of the Control Panel, all divisions are set not to appear *(lines 9-13)*. In order to present the appropriate message and the appropriate buttons to the students, we check the values of the session variables. When the student logs in, these values have not been updated so we call the JavaScript init_func function which, as we will see in B.2.2 Submit a query to the LRS to retrieve the xAPI Statementscommunicates with the LRS and retrieves the student's xAPI statements. The xAPI Statements are processed as we will see in section B.2.3 Processing xAPI Statements. Then, depending on the student's situation, we display the division needed with jquery.

```php
function controlPanel($reqUser){
    $email = $reqUser;
    $imgurl=get_stylesheet_directory_uri()."/img/ajax-loader.gif";

    if (!isset($_SESSION['lessons']))
    {
        $successdisplay="style=\"display: none;\"";
        $energydisplay="style=\"display: none;\"";
        $runningdisplay="style=\"display: none;\"";
        $buttonsdisplay="style=\"display: none;\"";
        echo "  <script type=\"text/javascript\">initfunc('".$email."');</script>
        <div id=\"loading\">
            <p style=\"text-align:center\">Παρακαλούμε περιμένετε για την ενημέρωση των δεδομένων σας...</p>
            <p style=\"text-align:center\"><img src=$imgurl> </p>
        </div>

        <div id=\"loaded\">
            <p style=\"text-align:center\">Η ενημέρωση ολοκληρώθηκε</p>
        </div>";
    } else {
        if (($_SESSION['nextLesson'] == "gameover") && ($_SESSION['energy'] > 0))
            $successdisplay="style=\"display: block;\"";
        else if ($_SESSION['energy'] <= 0)
            $energydisplay="style=\"display: block;\"";
        else
            $runningdisplay="style=\"display: block;\"";

        $buttonsdisplay="style=\"display: block;\"";
    }
    $completedLessons = getCompletedLesson();
    echo "<div id=\"statusArea\" style=\"display: block;\">";
        echo "<div id=\"success\" ".$successdisplay.">";
            echo "Συγχαρητήρια!!!<br> Ολοκλήρωσες με επιτυχία την αποστολή και απελευθέρωσες την Έλλη<br>";
            echo "Απέκτησες τα 4 Σύμβολα συγκεντρώνοντας " .$_SESSION['totalScore']." βαθμούς και διατήρησες το ".
                $_SESSION['energy']."% της ενέργειας σου.<br>";
            echo "Μπορείς να κατεβάσεις το βραβείο σου πατώντας την παρακάτω εικόνα. <br>";
            echo "<a href=\"http://users.sch.gr/arvanitdes/learning-experience/wp-content/uploads/2021/07/certificate.pdf\">
                <img src=\"".get_stylesheet_directory_uri()."/img/award.png\" /></a>";
        echo "</div>";

        echo "<div id=\"outfoenergy\" ".$energydisplay.">";
            echo "Δυστυχώς δεν μπορείς να συνεχίσεις την αποστολή σου, διότι εξαντλήθηκε η ενέργεια σου.<br>";
            echo "Απέκτησες ".$_SESSION['badges']." Σύμβολα συγκεντρώνοντας " .$_SESSION['totalScore']." βαθμούς.<br>";
            echo "<img src=\"".get_stylesheet_directory_uri()."/img/outofenergy.png\" width=\"100px\" />";
        echo "</div>";

        echo "<div id=\"running\" ".$runningdisplay.">";
            if ($completedLessons == 0)
                echo "Δεν έχεις ολοκληρώσει κάποιο κεφάλαιο.";
            else
                echo "Εχεις ολοκληρώσει ".$completedLessons." κεφάλαια.<br>";
            echo "Το επόμενο κεφάλαιο είναι το ".$_SESSION['lessons'][$_SESSION['nextLesson']]['name'].".<br>";
            if ($_SESSION['badges'] > 0)
                echo "Εχεις αποκτήσει ".$_SESSION['badges']." Σύμβολα<br>";
            else
                echo "Δεν έχεις αποκτήσει κάποιο Σύμβολο<br>";
            echo "Εχεις συγκεντρώσει " .$_SESSION['totalScore']." βαθμούς.<br>";
            echo "Διατηρείς το ".$_SESSION['energy']."% της ενέργειας σου.<br>";
        echo "</div>";
    echo "</div>";

    echo "<div id=\"buttonsArea\"".$buttonsdisplay. ">
        <p style=\"text-align:center\">
        <div style=\"text-align:center\">
        <button class=\"button button1\" onclick=\"linkButton('myprogress')\">Η πρόοδος μου</button>";
    if ($_SESSION['nextLesson'] != "gameover")
        echo "<button class=\"button button2\" onclick=\"linkButton('nextLesson')\">Επόμενο μάθημα</button>";
    echo "</div>
        <div style=\"text-align:center\">
        <button class=\"button button3\" onclick=\"linkButton('mybadges')\">Τα σύμβολα μου</button>

        <button class=\"button button4\" onclick=\"linkButton('instructions')\">Οδηγίες</button>
        </div>
        </p>
    </div>";
}
```

Figure B.2 The code of student's Control Panel

B.2.2 Submit a query to the LRS to retrieve the xAPI Statements

To compile and submit the query to LRS with which we retrieve the xAPI statements from the LRS, we use TinCanJS. The code we use is shown in Figure B.3.

- For the connection to the LRS we create an LRS object *(lines 7-16)*. The parameters we use are the **endpoint** address and the credentials of the user who has access to the relevant store. The **allowFail** parameter defines the error reporting in case of failure.
- With the **queryStatements** method, we submit the query to the LRS. *(lines 22-43)*. The **queryStatements** is divided in two sections. The **params** section *(lines 24-31)* and the **callback** section *(lines 32-42).*
- In the **params** section, we define the arguments of the query. In this case, we are interested in receiving all the statements of a specific student. For this, the only parameter we use is the student's email (line 27). With his email, the student is identified uniquely in the LRS. The email is stored in the student's profile on the website, which we pass as a parameter to the function that compiles and submits the query. The limit parameter defines the number of statements we receive in each transmission *(line 30).*
- In the callback section we manage the results we receive from the LRS. In case of any problem in receiving the results, we display an error message to the user. Otherwise, once we receive the data from the LRS we use a function called **sendData** *(line 41)* to post them to PHP for further processing. In Figure B.4 we see the code sendData function.

```
function initfunc(email)
{
    // Create an LRS Object
    var lrs;
    var sr;

        try {
            lrs = new TinCan.LRS(
                {
                    endpoint: "http://nile-cls.staff.hmu.gr/data/xAPI",
                    username: "xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx",
                    password: "yyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyy",
                    allowFail: false
                }
            );
        }
        catch (ex) {
            console.log("Failed to setup LRS object: ", ex);
        }

        // Retrieving Statements
        lrs.queryStatements(
            {
                params: {
                    agent: new TinCan.Agent(
                        {
                            mbox: email
                        }
                    ),
                    limit: 1000
                },
                callback: function (err, sr) {
                    if (err !== null) {
                        console.log("Failed to query statements: " + err);
                        var base_url = window.location.origin;
                        var pathArray = window.location.pathname.split( '/' );
                        var newurl = base_url + "/" +pathArray[1] +"/connection-error/";
                        window.location.replace(newurl);
                        return;
                    }
                    sendData(sr['statements'], 0, sr['statements'].length);
                } //callback
            }//lrs.queryStatements
        ); //lrs.queryStatements
}//initfunc
```

Figure B.3 Submitting a query to LRS with TinCanJS

```
function sendData (statementsData, startStatement, endStatement) {
    jQuery(function($) {

                    if (endStatement - startStatement > 100){
                        lastStatement = startStatement+100;
                    }
                    else {
                        lastStatement = endStatement;
                    }
                    dataforsending=statementsData.slice(startStatement,lastStatement);
                    var data = {
                                'action': 'init_states_by_ajax',
                                'post_type': 'POST',
                                'datarec': JSON.stringify(dataforsending),
                                'dataType' : 'json',
                                'contentType':'application/json'
                            };

                    var base_url = window.location.origin;
                    var ajaxurl = base_url +"/wp-admin/admin-ajax.php";

                    $.post(ajaxurl, data, function(response) {
                                startStatement+=100;
                                if (startStatement < endStatement)
                                    sendData (statementsData, startStatement, endStatement);
                                else {
                                        $('#loading').hide();
                                        $('#loaded').show().delay(5000).fadeOut();
                                        location.reload();
                                }
                    });
    });  //jquery(function)
} //sendData
```

Figure B.4 sendData function

B.2.3 Processing xAPI Statements

The function **init_states_by_ajax_callback** (Figure B.5) processes the xAPI statements posted with the AJAX call. The processing is divided into two stages. In the first stage, the necessary information is extracted from xAPI statements. In the second stage, the necessary calculations are performed and the values of the session variables that determine the student's condition are stored.

More specifically, in the first stage *(lines 100-105)* we extract:

- the unit's name
- the type of action performed, ie the verb of the xAPI statement
- the timestamp
- the id of the activity
- the score achieved by the student, if the student's action was a response to an activity
- the maximum score of the activity, if the student's action was a response to an activity

In the second stage *(lines 107-124)* the following actions are performed:

- a new entry is created in the corresponding unit of the Lessons table, with the activity id, verb and timestamp *(lines 107-111)*.
- update the score of the activity or unit by calling the updateScore function. Depending on whether the score refers to the score of a unit or an activity, the corresponding field in the Lessons table is updated. In each case, if the student has repeated the unit or activity, he maintains the highest score *(line 113)*.
- in case the verb is completed, ie a unit was completed *(lines 115-123)*:
    - it is recorded how many times a student has attended this unit and if he has attended it again he reduces his energy
    - changes the status of the unit to completed
    - calls the findNextActivity function to decide which next unit to attend and updates the session variable nextLesson.
- calculates the badges the student has acquired by calling the function **getBadges** *(line 124).*

```
function init_states_by_ajax_callback() {
        $postedData = $_POST['datarec'];
        $studentActivity=json_decode( html_entity_decode( stripslashes ($postedData ) ),true );

        // Initialize Session Variables
        if (!isset($_SESSION['lessons'])){
                initializeSession();
        }
        // For each xapi statement: 1. append to the array 2. update the score 3. update the next lesson
        foreach($studentActivity as $record) {
                $varlesson =            fixLesson($record["context"]["contextActivities"]["grouping"]["0"]["definition"]["name"]["en"]);
                $varverb =              $record["verb"]["display"]["en-US"];
                $vartimestamp =         $record["timestamp"];
                $varactivitynum =       $record["target"]["definition"]["extensions"]["http://h5p.org/x-api/h5p-subContentId"];
                $varScore =             $record["result"]["score"]["raw"];
                $varMaxScore =          $record["result"]["score"]["max"];

                $newlesson =    array(
                                        'verb' => $varverb,
                                        'date' => $vartimestamp
                                );
                $_SESSION[lessons][$varlesson][activity][]=$newlesson;

                updateScore($varlesson, $record["result"]["score"], $varactivitynum, $varScore, $varMaxScore);

                if  ($varverb == "completed") {
                    if ($_SESSION['lessons'][$varlesson]['timesCompleted']>0)
                        $_SESSION['energy']-=10;
                    $_SESSION['lessons'][$varlesson]['timesCompleted']++;
                    $_SESSION['lessons'][$varlesson]['status'] = "completed";
                    findNextActivity($varlesson);
                }
            }

        getBadges();
        exit;
}
```

Figure B.5 function init_states_by_ajax_callback

B.3 Actions taken in each action of the student

For each action the student performs, while using the educational material, H5P creates the corresponding xAPI statement. To capture the xAPI statement we have implemented a Listener in JavaScript utilizing the external event dispatcher of H5P. Then with TinCanJs we send the xAPI Statement to the LRS for storage. After that, the xAPI Statement is processed to determine the new status of the student and the session variables are updated.

B.3.1 Capturing xAPI Statements

The code we use for the Listener and the communication with the LRS is shown in Figure B.6.

- For capturing the xAPI Statements, we register an event listener using the external dispatcher of H5P *(lines 3-7)*.
- When an event occurs, the xAPI Statement is saved in the variable **statement** *(line 9)*.
- For the connection to the LRS we create an LRS object *(lines 11-20)*. The parameters we use are the **endpoint** address and the credentials of the user who has access to the relevant store.

- With the **saveStatement** method, we submit the statement to the LRS. *(lines 25-183).* The **saveStatement** is divided in two parts. The statement that is forwarded to LRS and the callback section *(lines 28-181).*
- If the storage is successful, we make an AJAX call to save the xAPI statement to the session variables *(lines 38-179).* Paragraph B.3.2 Processing xAPI Statementdescribes in detail the processing performed on the xAPI statement and the calculations performed to determine the student's new condition.
- When storing the xAPI statement in session variables, we check if the xAPI statement is the result of a unit's completion (verb: completed). In this case, the appropriate message should be displayed to the student with the result he had in this unit. In addition, if the student acquired a badge at the end of the unit, a corresponding message should be displayed. Therefore, with the AJAX callback we receive these two pieces of information (lesson result, badges) and proceed to the display of the appropriate messages. The messages for the badges are displayed on lines 56-96 and the result of the lesson on lines 98-176. As the code for displaying the messages is long and does not add anything to the presentation of the research, it was not included in the code snippet shown in Figure B.6.

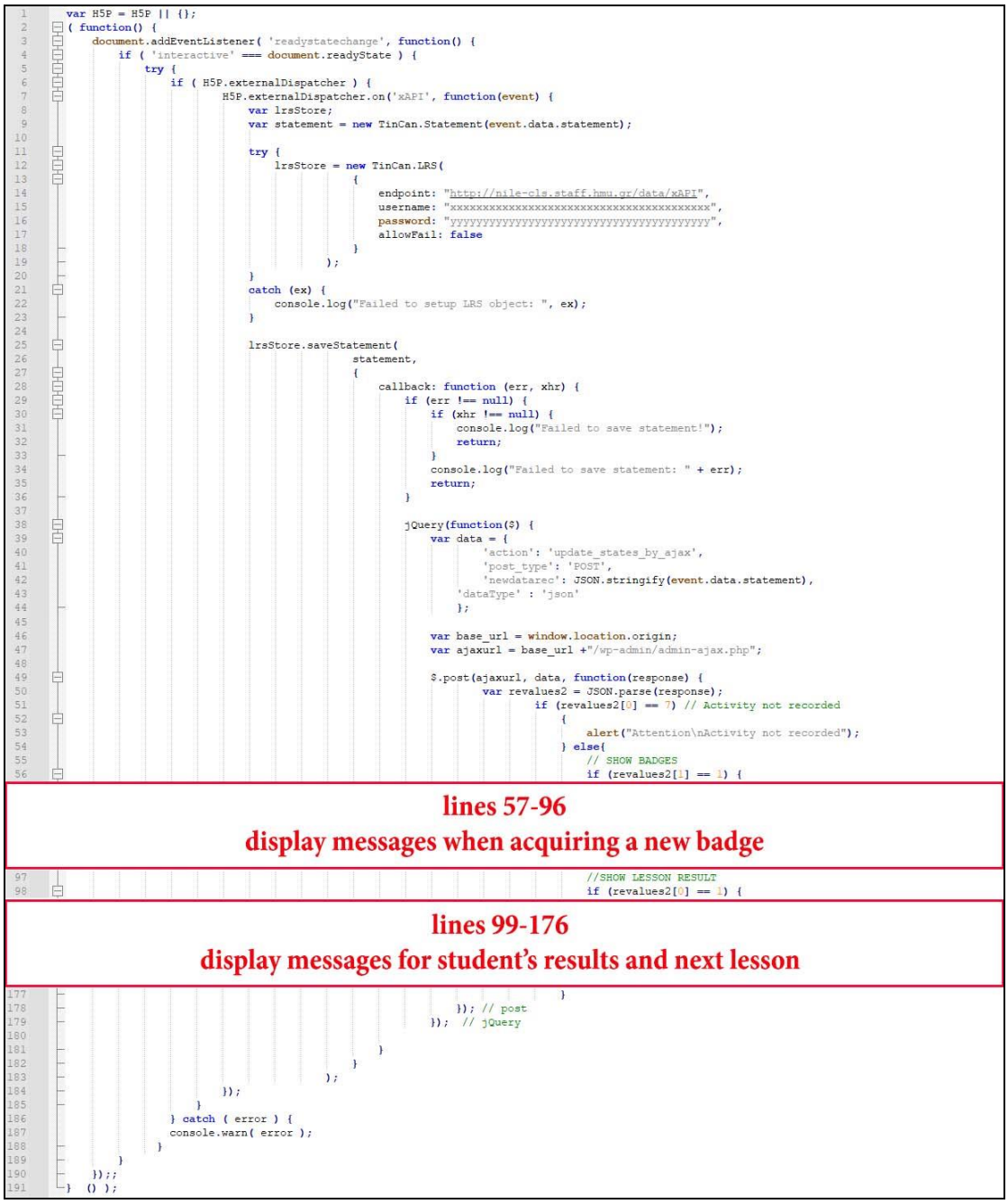


Figure B.6 The code we use for the Listener

B.3.2 Processing xAPI Statement

The function **update_states_by_ajax_callback** (Figure B.7) processes the xAPI statement posted with the AJAX call. The processing is divided into two stages. In the first stage, the necessary information is extracted from xAPI statements. In the second stage, the

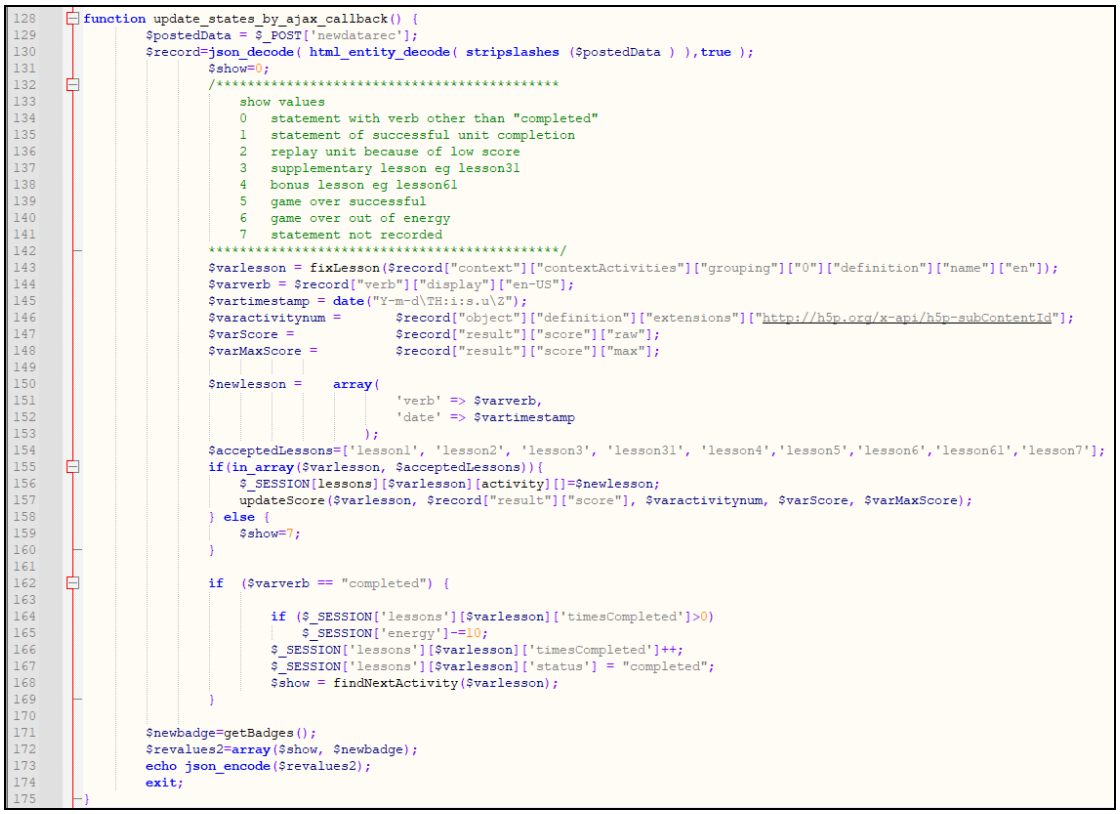
necessary calculations are performed and the values of the session variables that determine the student's condition are stored.

More specifically, in the first stage (*lines 143-148)* we extract:

- the unit's name,
- the type of action performed, ie the verb of the xAPI statement,
- the timestamp,
- the id of the activity,
- the score achieved by the student, if the student's action was a response to an activity,
- the maximum score of the activity, if the student's action was a response to an activity,
- the maximum score of the activity, if the student's action was a response to an activity.

In the second stage (*lines 150-173)* the following actions are performed:

- A new entry is created in the corresponding unit of the Lessons table, with the activity id, verb and timestamp *(lines 150-156).*
- Update the score of the activity or unit by calling the updateScore function. Depending on whether the score refers to the score of a unit or an activity, the corresponding field in the Lessons table is updated. In each case, if the student has repeated the unit or activity, he maintains the highest score *(line 157).*
- In case the verb is completed, ie a unit was completed *(lines 162-169):*
    - it is recorded how many times a student has attended this unit and if he has attended it again he reduces his energy,
    - changes the status of the unit to completed,
    - calls the findNextActivity function to decide which next unit to attend and updates the session variable nextLesson.
- Checks that the student has acquired a new badge by calling the function **getBadges** *(line 171).*
- Returns with the AJAX callback information about the messages that should be displayed to the user (lines 172-173). The first element of the returning array contains the unit's result and the second element contains the new badge.



```
function update_states_by_ajax_callback() {
        $postedData = $_POST['newdatarec'];
        $record=json_decode( html_entity_decode( stripslashes ($postedData ) ),true );
                $show=0;
                /*****************************************
                    show values
                    0   statement with verb other than "completed"
                    1   statement of successful unit completion
                    2   replay unit because of low score
                    3   supplementary lesson eg lesson31
                    4   bonus lesson eg lesson61
                    5   game over successful
                    6   game over out of energy
                    7   statement not recorded
                *****************************************/
                $varlesson = fixLesson($record["context"]["contextActivities"]["grouping"]["0"]["definition"]["name"]["en"]);
                $varverb = $record["verb"]["display"]["en-US"];
                $vartimestamp = date("Y-m-d\TH:i:s.u\Z");
                $varactivitynum =       $record["object"]["definition"]["extensions"]["http://h5p.org/x-api/h5p-subContentId"];
                $varScore =             $record["result"]["score"]["raw"];
                $varMaxScore =          $record["result"]["score"]["max"];

                $newlesson =    array(
                                        'verb' => $varverb,
                                        'date' => $vartimestamp
                                    );
                $acceptedLessons=['lesson1', 'lesson2', 'lesson3', 'lesson31', 'lesson4','lesson5','lesson6','lesson61','lesson7'];
                if(in_array($varlesson, $acceptedLessons)){
                    $_SESSION[lessons][$varlesson][activity][]=$newlesson;
                    updateScore($varlesson, $record["result"]["score"], $varactivitynum, $varScore, $varMaxScore);
                } else {
                    $show=7;
                }

                if  ($varverb == "completed") {

                    if ($_SESSION['lessons'][$varlesson]['timesCompleted']>0)
                        $_SESSION['energy']-=10;
                    $_SESSION['lessons'][$varlesson]['timesCompleted']++;
                    $_SESSION['lessons'][$varlesson]['status'] = "completed";
                    $show = findNextActivity($varlesson);
                }

        $newbadge=getBadges();
        $revalues2=array($show, $newbadge);
        echo json_encode($revalues2);
        exit;
}
```

Figure B.7 The function update_states_by_ajax_callback

B.4 Actions taken for the teachers

B.4.1 Actions taken to view a particular student's progress from the teacher's dashboard

The teacher can see the detailed progress of each student. A prerequisite for this is to update the session variables with the student's details. The procedure for retrieving and processing statements is the same as for the student, as described in paragraphs B.2.2 and B.2.3 respectively.

The student’s data that the teacher can see are displayed in paragraph 9.2.2 and the code used is shown in Figure B.8. The same code is used to view the student's progress from his Control Panel, as described in paragraph 9.1.2 .

- First, we check the level of the user (student or teacher) who displays the data *(lines 20-25)*, by examining the session variables if they are empty. In the case of the teacher, the

session variables are empty, so we search from the call parameters of the function the email of the student for whom we want to search. Then we call the controlPanel function giving it the student's email, which undertakes to retrieve the xAPI statements, edit them and update the session variables.

- In the case of the student, the retrieval and processing process has been performed during the connection, so this step is omitted.
- Then we create the divisions that display the student's progress (lines 41-107).
- In lines 41-46 we create the titles of the divisions.
- In lines 49-106 we check the units one by one and display their status. The information we display is the name of the unit, the status (completed or pending), the score and the number of views.

```php
// if the user is teacher SESSION var is empty. Get records by student's email
if (!isset($_SESSION['energy'])) {
    $reqUser = $_GET['userEmail'];
    echo $reqUser;
    controlPanel($reqUser);
}



// Customize page title
$user = wp_get_current_user();
if ( in_array( 'subscriber', (array) $user->roles ) ) {
    $pageTitle = "Η πρόοδος μου";
}
else {
    $reqUser = $_GET['userEmail'];
$aa = get_user_by( 'email', $reqUser );
$pageTitle = "Η πρόοδος του μαθητή ". $aa->first_name . ' ' . $aa->last_name;
}
?>
        <div class="lessonTitle"> <?php echo $pageTitle;?> </div>
        <div>
            <div class="headRow">
                    <div class="firstCell"> Ενότητα</div><div class="secCell"> Κατάσταση </div>
                    <div class="thirdCell">Βαθμοί </div><div class="forthCell">Επαναλήψεις </div>
                    <div class="fifthCell"> </div>
            </div>

                <?php
                foreach($_SESSION['lessons'] as $lessonNum=>$progress) {

                    if ($lessonNum == "lesson31") {
                        if ((is_null($progress['activity'])) && ($_SESSION['nextLesson']!="lesson31"))
                            continue;
                    }

                    if ($lessonNum == "lesson61") {
                        if ((is_null($progress['activity'])) && ($_SESSION['nextLesson']!="lesson61"))
                            continue;
                    }
                echo "<div class=\"dataRow\"> <h2>";
                    if (($_SESSION['energy'] <= 0) || ($_SESSION['lessons']['lesson7']['status'] == "completed"))
                        $lessonUrl = $home."/gameover";
                    else
                        $lessonUrl = $home."/".$lessonNum;
                    $linkOpenTag = "";
                    $linkCloseTag = "";
                    $statusclass = "greyclass";
                    $timestext = $progress['timesCompleted'];
                    if (is_null($progress['score']['lessonTotal']['lessonScore']) )
                        $pointstext = "-";
                    else
                        $pointstext = $progress['score']['lessonTotal']['lessonScore']."/".$progress['score']['lessonTotal']['lessonMaxScore'];

                    // enable the lesson link
                    if (($progress['status']== "completed") || ($lessonNum == $_SESSION['nextLesson'])) {
                        $linkOpenTag = "<a href=\" " . $lessonUrl . " \">";
                        $linkCloseTag = "</a>";
                    }

                    if ($progress['status']== "completed")  {
                        $imgurl=get_stylesheet_directory_uri()."/img/tick.png";
                        $statusclass = "greenclass";
                        $progresstext = "Ολοκληρώθηκε";
                    }
                    elseif ($progress['status']== "pending")    {
                        $imgurl=get_stylesheet_directory_uri()."/img/neutralGrey.png";
                        //$statusclass = "orangeclass";
                        $progresstext = "Εκκρεμεί";
                    }
                    else    {
                        $imgurl=get_stylesheet_directory_uri()."/img/cross.png";
                        //$statusclass = "redclass";
                    }

                    if ($lessonNum == $_SESSION['nextLesson']) {
                        $statusclass = "orangeclass";
                        $imgurl=get_stylesheet_directory_uri()."/img/neutral.png";
                        $progresstext = "Επόμενο κεφάλαιο";
                    }
                echo    "<div class=\"firstCell\"><span class=".$statusclass.">". $linkOpenTag .$progress['name'] . $linkCloseTag . " </span></div>
                        <div class=\"secCell\"><span class=".$statusclass.">" . $linkOpenTag .$progresstext.$linkCloseTag ."</span></div>
                        <div class=\"thirdCell\"><span class=".$statusclass.">" . $linkOpenTag .$pointstext.$linkCloseTag ."</span></div>
                        <div class=\"forthCell\"><span class=".$statusclass.">" . $linkOpenTag .$timestext.$linkCloseTag ."</span></div>
                        <div class=\"fifthCell\"><img src=\"".$imgurl ."\" /> </div>";
                echo "</h2></div>";
                }?>
        </div>
```

Figure B.8 Code to view a particular student's progress

B.4.2 Actions taken for displaying aggregate statistics from the teacher's dashboard

The aggregate statistics are displayed through the **Formatted Statistics** provided by Learning Locker. The process is very simple for the website as all the processing load has been handled by Learning Locker.

In the teacher's Control Panel, we list the available statistics (Figure B.9). Then, using the shared URL of the dashboard created in Learning Locker, we integrate it with an iframe on our page (Figure B.10).

```
47    <div class="dashboardTitles"> Συγκεντρωτικά Στατιστικά </div>
48
49    <div class="reportLabel">
50    <a href="<?php echo $home."/displaystats?stat=60fb19c754312f320d5e79f2"?>">Α. Αναφορές για τους μαθητές</a>
51    </div>
52    <br>
53
54    <div class="reportLabel">
55    <a href="<?php echo $home."/displaystats?stat=6103c9be54312f320d5e7a01"?>">Β. Αναφορές για τα statements</a>
56    </div>
57    <br>
58
59    <div class="reportLabel">
60    <a href="<?php echo $home."/displaystats?stat=60fb1d7254312f320d5e79fe"?>">Γ. Αναφορές για τις ενότητες</a>
61    </div>
62    <br>
63
64    <div class="reportLabel">
65    <a href="<?php echo $home."/displaystats?stat=629a43ff570aa9715f405ce5"?>">Δ. Αναφορές για την βαθμολογία</a>
66    </div>
```

Figure B.9 Code for aggregate statistics

```
17  $statId = $_GET['stat'];
18
19  echo "<iframe src=\"http://nile-cls.staff.hmu.gr/dashboards/".$statId."\" width=\"100%\" height=\"500\"></iframe>";
20
21  echo "<div id=\"buttonsArea\" style=\"display: block;\">
22          <p style=\"text-align:center\">
23          <div style=\"text-align:center\">
24          <button class=\"button button1\" onclick=\"linkButton('teachermainpage')\">Επιστροφή</button>";
25
26      echo "</div>
27
28          </p>
29      </div>";
```

Figure B.10 The iframe