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THESIS

DEVELOPMENT OF A WEB-BASED PLATFORM FOR COGNITIVE TRAINING

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Abstract

In this thesis, a web-based platform for cognitive training was developed, as a tool for a) the training of cognitive functionality of high-risk individuals or individual facing early Mild Cognitive Impairment (eMCI), and b) the support of clinical professionals' examining eMCI individuals. The cognitive training platform was developed on Moodle, a Learning Management System (LMS), which is based on Social Constructivist Pedagogy. Towards this scope, a series of interactive, specialized exercises were designed as described by Dr Foteini Kounti, cognitive psychologist and co-founder of The Greek Association of Alzheimer's Disease and Related Disorders[1], [1][2][3][4] [2].

Mild Cognitive Impairment (MCI) is described as the intermediate stage of cognitive impairment [2], which concerns a group of individuals who may or may not be at high risk for developing dementia[5][6]. Early Mild Cognitive Impairment (eMCI) describes the earliest and mildest symptomatic phase of Mild Cognitive Impairment (MCI). In these early stages, abnormal brain functional capabilities have already occurred in the form of subtle changes in the life of the individual [7][8]. The early and accurate detection and intervention of eMCI is of high importance for the individual's health[8]. However, the pathology of eMCI remains mostly unknown[8], which can be challenging to the clinical diagnosis[8]. To this end, more work needs to be done on applications related to eMCI.

The cognitive training platform include training exercises which are focusing on activities of daily living, with each one to be consist of three difficulty levels. Each level consists of nine specialized exercises focused on eMCI individuals, some of which include some sub-exercises, all of which are developed using vivid interactive contents. The platform also offers consistency in workflow among the exercises, as well as detailed descriptions to avoid misunderstanding. At the end of each exercise and while users have acted on what they were asked to do, they receive the appropriate feedback. All the exercises, of each level, are evaluated concluding to an overall level score. Users also have the ability to access their grades and have a detailed view of their scores on

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[1] Source: http://www.brainsinaction.co.uk/international-recognition-for-pioneering-dementia-specialists-brains-in-action/

[2] http://www.encephalos.gr/full/47-1-04g.htm

each exercise. Finally, the platform has been developed with a simple look and feel, while it contains a wide range of user-friendly interactive content.

Περίληψη

Στην παρούσα πτυχιακή, αναπτύχθηκε μια διαδικτυακή πλατφόρμα για την εκπαίδευση γνωστικών λειτουργιών, ως εργαλείο α) για την εκπαίδευση της γνωστικής λειτουργικότητας των ατόμων υψηλού κινδύνου ή των ατόμων που πάσχουν από πρώιμη ήπια γνωστική εξασθένηση και β) για την υποστήριξη των ειδικών στην διαδικασία της εξέτασης ατόμων με πρώιμη ήπια γνωστική εξασθένηση . Η πλατφόρμα γνωστικής εκπαίδευσης αναπτύχθηκε στο Moodle, ένα Σύστημα Διαχείρισης Μάθησης, το οποίο βασίζεται στις παιδαγωγικές αρχές της θεωρία μάθησης του Κοινωνικού Κονστρουκτιβισμού. Για τον σκοπό αυτό, σχεδιάστηκαν μια σειρά από διαδραστικές, εξειδικευμένες ασκήσεις όπως περιεγράφηκαν από την Δρ. Φωτεινή Κουντή, γνωστικό ψυχολόγο και συνιδρυτή της Ελληνικής Εταιρείας Νόσου Αλτσχάιμερ και Σχετικών Διαταραχών[3], [1][2][3][4] [4].

Η ήπια γνωστική εξασθένηση περιγράφεται ως το ενδιάμεσο στάδιο της γνωστικής εξασθένησης [2], η οποία αφορά μια ομάδα ατόμων που μπορεί να είναι σε υψηλό κίνδυνο για την ανάπτυξη άνοιας ή και όχι [5][6]. Η πρώιμη ήπια γνωστική εξασθένηση περιγράφει το πρώιμο και ήπιο συμπωματικό στάδιο της ηπίας γνωστικής εξασθένησης. Σε αυτά τα πρώιμα στάδια, αφύσικες λειτουργικές ικανότητες του εγκεφάλου έχουν κάνει ήδη αισθητή την παρουσία τους, με τη μορφή λεπτών αλλαγών στη ζωή αυτού του ατόμου[7][8]. Η έγκαιρη και ακριβής ανίχνευση της πρώιμης ήπιας γνωστικής εξασθένησης και η παρέμβαση σε αυτήν, είναι πολύ σημαντικές για την υγεία του ατόμου[8]. Ωστόσο, η παθολογία της πρώιμης ήπιας γνωστικής εξασθένησης παραμένει ως επί το πλείστων άγνωστη[8], γεγονός το οποίο μπορεί να αποτελέσει πρόκληση για την κλινική διάγνωση[8]. Για τον σκοπό αυτό, χρειάζεται να καταβληθεί περισσότερη προσπάθεια και δουλειά πάνω σε εφαρμογές που σχετίζονται με την συγκεκριμένη πάθηση.

Η πλατφόρμα εκπαίδευσης γνωστικών λειτουργιών περιλαμβάνει εκπαιδευτικές ασκήσεις, οι οποίες επικεντρώνονται σε καθημερινές δραστηριότητες, με κάθε μία από αυτές τις ασκήσεις αυτές να αποτελείται από τρία επίπεδα δυσκολίας. Κάθε επίπεδο αποτελείται από εννέα εξειδικευμένες ασκήσεις που εστιάζουν σε άτομα με πρώιμη ήπια γνωστική εξασθένηση , ενώ

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[3] Source: http://www.brainsinaction.co.uk/international-recognition-for-pioneering-dementia-specialists-brains-in-action/

[4] http://www.encephalos.gr/full/47-1-04g.htm

μερικές περιλαμβάνουν και υποασκήσεις. Όλες οι ασκήσεις και οι υποασκήσεις αναπτύχθηκαν χρησιμοποιώντας διαδραστικά στοιχεία. Η πλατφόρμα προσφέρει συνέπεια στην ροή εργασίας μεταξύ των ασκήσεων, καθώς και λεπτομερείς περιγραφές για την αποφυγή λαθών. Στο τέλος κάθε άσκησης και ενώ οι χρήστες έχουν υλοποιήσει αυτό που τους ζητήθηκε να κάνουν, λαμβάνουν την ανάλογη ανατροφοδότηση. Όλες οι ασκήσεις, κάθε επιπέδου, αξιολογούνται καταλήγοντας σε μια συνολική βαθμολογία για κάθε επίπεδο. Οι χρήστες έχουν τη δυνατότητα να έχουν πρόσβαση στους βαθμούς τους και να έχουν μια λεπτομερή εικόνα για την βαθμολογία που έχουν πάρει σε κάθε άσκηση. Τέλος, η πλατφόρμα έχει αναπτυχθεί ακολουθώντας απλό σχεδιασμός διεπαφής, ενώ περιέχει ένα ευρύ φάσμα εύχρηστου διαδραστικού περιεχομένου.

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Acronym	Definition
WBL	Wed-Based Learning
IBT	Internet-Based Training
ADL	Advanced Distributed Learning
WBI	Web-Based Instruction
OL	Online Learning
OFL	Open/Flexible Learning
LMS	Learning Management Systems
PLM	Participatory Learning Model
CLM	Cognitive Learning Model
S-R Model	Stimuli – Response Model
S	Stimulus
R	Response
DSS	Decision Support Systems
ICN	International Council of Nurses
CMS	Content Management Systems
LCMS	Learning Content Management Systems
VLE	Virtual Learning Environments
MLE	Managed Learning Environments
LSS	Learning Support Systems
ALM	Action Learning Model
CMS	Course Management System
AD	Alzheimer's Disease
MCI	Mild Cognitive Impairment
LMCI	Late Mild Cognitive Impairment
eMCI	Early Mild Cognitive Impairment
CSS	Cascading Style Sheets
PHP	Hypertext Preprocessor

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Firstly, I would like to express my gratitude to Prof. Manolis Tsiknakis for his support and guidance that inspired and motivated me, along the development of this thesis. Our cooperation was a valuable and beneficial experience that I will not forget.

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Dedication

Dedicated to my parents and my beloved grandmother, for always being my greatest supporters.

1. e-Learning and e-Training

1.1. e-Learning

E-Learning refers to the delivery of knowledge and information [9] through the use of technologies such as internet, audio tapes, satellite broadcast, CD-ROM, etc. Several terms are used, synonymously to e-learning, such as web-based learning (WBL), Internet-based training (IBT), advanced distributed learning (ADL), web-based instruction (WBI), online learning (OL) and open/flexible learning (OFL) [10]. The concept of e-learning has evolved into a mainstream phenomenon. Firstly, the internet started to change, then people using the internet started to change and finally e-learning pedagogy techniques started to evolve. Furthermore, the development progress of information and communication technology has emerged e-learning as the paradigm of modern education. The network technologies are used to: a) create, foster and deliver learning at any time and place, b) deliver individualized and comprehensive learning content in real time, c) facilitate individuals to keep up with rapid changes in the information society. Some examples of e-learning include free tutorials, online-degrees, certificate training, online continuing education classes, etc. Modern e-learning trends are focused on learner oriented design based on which, the learner have full control over the entire learning process and can control the appearance of the virtual elements [11]. The great advantages of e-learning include liberating interactions between learners, and learners with educators (affects how learners communicate with their educators and with each other), as well as flexibility on time and space through the asynchronous and synchronous learning network model [12][13][14]. Asynchronous e-learning is often supported by media (e-mails, discussion boards, etc.) and helps the work relations between learners and educators. In asynchronous e-learning, flexibility rises, while there is no need for learners and educators to log in or interact with each other, at the same time. On the other hand, synchronous e-learning is also commonly supported by media (such as chats and videoconferencing) and supports the learning experience of learners and educators, but in this case, with real time interactions [15].

1.1.1. *Pedagogical principles of e-learning*

The majority of pedagogical principles that apply to the traditional classroom delivery method, also apply to e-learning. However, these principles need to be expanded to facilitate and anticipate

the rapid changes in technology. Since e-learning is a fairly recent phenomenon, more effort in the adaptation of pedagogical principles is needed [16].

1.1.2. *Prior studies of e-learning*

E-learning has many advantages over traditional face-to-face training, however, concerns include the time and resources involved in the e-learning environment [11][17]. An advantage of online learning is flexibility, since learners can work at the time and pace that suits their learning needs, without having to leave the comfort of their home. Another advantage is that the learners' and educators' center of attention is on the contents of the course rather than on external issues that may arise in a physical class [17]. Models like the Technology Acceptance Model [18][19][20] and the Expectation and Confirmation Model, identified by researchers from the field of psychology and information systems [21][22][23], partly contributed to a better understanding of the e-learning's success. The Technology Acceptance Model suggests that perceived ease of use and perceived utility of technology are predicting user attitudes about the use of technology, subsequent behavioral intentions, and actual use. On the other hand, the Expectation and Confirmation Model ECM argues that an individual's intention to continue using information technology depends on three variables: the user's level of computing satisfaction, the extent of the user's expectations and the expectations after adoption, in the form of perceptual utility [24]. The focus of these models is on technology while there are six dimensions (Table 1.1) that are including thirteen factors (Table 1.1), and they are used to define student's satisfaction in the e-learning process. These factors cover almost all aspects of an e-Learning environment.

Table 1.1 Thirteen factors divided in six dimensions

Dimension	Factors
Student Dimension	Learner's attitude toward computers
	Learner's computer anxiety
	Learner's internet self-efficacy
Instructor Dimension	Instructor's response timeliness
	Instructor's attitude toward e-Learning
Course Dimension	E-Learning course flexibility
	E-Learning course quality

Technology Dimension	Technology quality
	Internet quality
Design Dimension	Ease of use
	Perceived usefulness
Environmental Dimension	Diversity in assessment
	Learner's interaction with others

1.2. e-Training

E-training is the process of developing the skills that are needed to perform specific tasks in an online environment. This development of skills includes providing information regarding certain processes and day-to-day operations using instruction methods which could include: interactive media, speeches, demonstrations, videos, text documents, etc. Additionally, e-training varies from other conventional e-learning solutions by meeting the requirements of a real time environment which consists of simulators and visualizations [25]. Training sessions provide the tools needed for trainees to perform and develop their primary tasks effectively. An essential part of e-Training is the learning component. As a matter of fact, without the existing principles of learning, the training can't be successfully supported. In particular, for a training system to be characterized as well-designed, it has to address expectations and be able to manage errors[26]. Subsequently, there is a set of parameters that are important for the development of effective and flexible e-training systems, as shown in Table 1.2 [25].

Table 1.2 Set of parameters for the effective design of e-training system

Parameter	Description
Agility	The ease of adapting to changes
Scalability	The use of resources depending on the load

Efficiency	The efficient use of resources
Lightness	Reduction of activities and functionality depending on the user's needs
Flexibility	Selecting solutions appropriate for the current needs

1.3. Differences between e-Learning and e-Training

Learning and training, as terms, are inextricably linked, but they are unique aspects of any educational process. Training focuses more on the development of new skills that will be used. Through training, we are not looking to reshape the behavior of an individual but to teach the learner how things are done so that they can carry out a process on their own in the future. On the other hand, learning is the process of absorbing that information to increase skills and abilities and make use of it under a variety of contexts. Learning is all about equipping a person to tackle today's issues, as well as preparing the participant to creatively come up with ways to tackle tomorrow's issues. The quality of the learning relies largely on the quality of the training. A successful learning atmosphere will utilize both principles throughout its curriculum, as the quality of training materials can affect how well learners absorb information[5]. This allows trainers to provide their learners with the tools to tackle current issues, develop life-long skills, improve on their problem-solving skills and utilize resources to the best of their ability. One way to bring e-training and e-learning together is to utilize an innovative Learning Management System (LMS), see Section 5.1. An LMS can enable participants to learn the skills needed for both specific and nonspecific situations.

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[5] Source: https://www.getbridge.com/lc/articles/difference-e-learning-e-training

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2. Learning models and theories

Learning is the process of active engagement. Any permanent behavioral change that may occur as a result of experience, can be considered as learning. Learning is also composed by an index of theories, models, technology and more.

A learning model is characterized as the framework that serves as learning guide in order to achieve specific learning goals, by organizing learning experiences[27]. Following, three basic learning models are described. First, a learning model that many e-training environments and processes are based on, is Action Learning Model (ALM)[28]. In ALM, learners aim to develop new insights into their workplace knowledge through the actions of discussion, questioning and personal reflection. Furthermore, learners perform activities and afterwards study them, in order to improve their performance [29]. ALM typically does not include explicit cognitive elements and almost exclusively assumes that the cognitive facilitation will occur through the interaction with other participants and through guidance[28][29]. In general, ALM is an example of the Participatory Learning Model (PLM). PLM describes that learning comes from active participation in a learning process. On the other hand, according to the Cognitive Learning Model (CLM) humans learn by thinking, not just by interacting, and that unless this is explicitly considered in developing training programs, optimal learning outcomes might not be achieved [29]. Overall, CLM is described by the learning process in which individuals acquire and accumulate concepts that are key units of knowledge[29].

On the other hand, learning theories emphasize the individual's nurture and the educator's ability to facilitate people's learning using verified instructional techniques [30][31][32]. Learning theories are classified in to four paradigms: Behaviorism (Section 2.12.1), Constructivism (Section 2.2), Cognitivism (Section 2.3) and Social Learning theories (Section 2.4) [33].

2.1. Behaviorism

Behaviorism is the first historical scientific theory of learning. Behaviorism affected the development of educational software, mainly through Burrhus Frederic Skinner's theory of dependency and didactic model of planned teaching [34][35]. Key features of this first approach to technology support for education and learning were: (a) the linear organization of content presentation and (b) systematic exercise with feedback from the system as the regulator learner.

Behavioral approaches focus in the retransmission of information and in the modification of the behavior [36]. The most important part is the clear and functional definition of the pedagogical and teaching goals that need to be achieved [35][36]. For behaviorism, learning involves behavioral modification. The forerunner was Ivan Pavlov and its main representatives were John Broadus Watson, Edward Lee Thorndike and Burrhus Frederic Skinner, briefly described as:

- *I. Pavlov – Pavlov's Classical Dependence Learning Model*

Pavlov's basic idea of the learning pattern was concealed in the assumption that learning is a connection of a certain behavior (reaction) with an occasional data (stimulus).

- *J. B. Watson - The principle of depreciation*

Watson supported that learning can be lost and that behavior ceases to be associated with an addictive stimulus, if repetitions do not occur or if the addictive stimulus is unpleasant.

- *E. L. Thorndike – Thorndike's Learning and Testing*

Thorndike studied the phenomenon of learning by experimenting with animals and came to a theoretical scheme based on which, learning is the transformation of associations between a given problem situation and human reactions.

- *B. F. Skinner - The Skinner's Advanced Learning*

Skinner's theory is based on operant conditioning which argues that to strengthen a behavior, it must be modified by reinforcement or punishment.

Behaviorists do not to assess the mental state of the learners i.e. their beliefs, their expectations, their intentions and their motives, but only describe the behavior without source explanation. Furthermore, they support that human behavior is acquired through conditioning according to which all behaviors are reflexes produced by a response to certain stimuli in the environment, Figure 2.1, [36][37]. In conclusion, behaviorism is not focusing on the cognitive function of the people, but rather on the analysis of the input-output characteristics of human behavior. Thus, learning is a matter of creating connections between stimuli and reactions, while positive reinforcement and negative reinforcement increase the probability of a behavior.

Figure 2.1 Stimuli-Response model
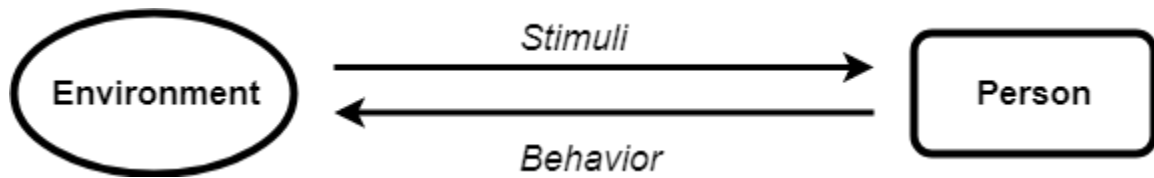
2.1.1. Classical Conditioning

Ivan Petrovich Pavlov (1849-1936) discovered and systematically studied the classical or respondent conditioning using the well-known experiment with the dog, as shown in Figure 2.2, [37] according to which:

➤ Before reliance: The dog is offered food, and salivation is observed (Figure 2.2 (1)), while when a neutral stimulus (whistle) sounds, the dog does not react (Figure 2.2 (2)).

➤ Creation of dependence: The dog is offered food while at the same time the initial neutral stimulus (whistle) is heard (Figure 2.2 (3)). The dog is systematically exercised to connect the sound of whistling with the appearance of the food.

➤ After dependence: The dog shows increased salivation when the dependent stimulus (whistle) appears without necessarily feeding (Figure 2.2 (4)). According to behaviorists, the animal has "learned", i.e. it displays a new behavior through systematic repetitive exercise.

Therefore, in classical conditioning, a natural stimulus from the environment is associated with a response of the being. Then a neutral stimulus appears and connects with the physical stimulus. Ultimately, the neutral stimulus ends up provoking a response without the presence of the physical stimulus [38]. The two elements: The Stimulus (S) and the Response (R) that are caused, are characterized as conditioned stimulus and conditioned response respectively, while classical dependence appears in the literature usually as S-R dependence [39]. Classical behavioral dependence remains a major psychological technique today in cases where it is necessary to de-treat the person from stimuli that can cause undesirable behaviors, e.g. treatment of psychological disorders such as phobias, anxiety and panic attacks[37][38].

Figure 2.2 Pavlov's dog experiment
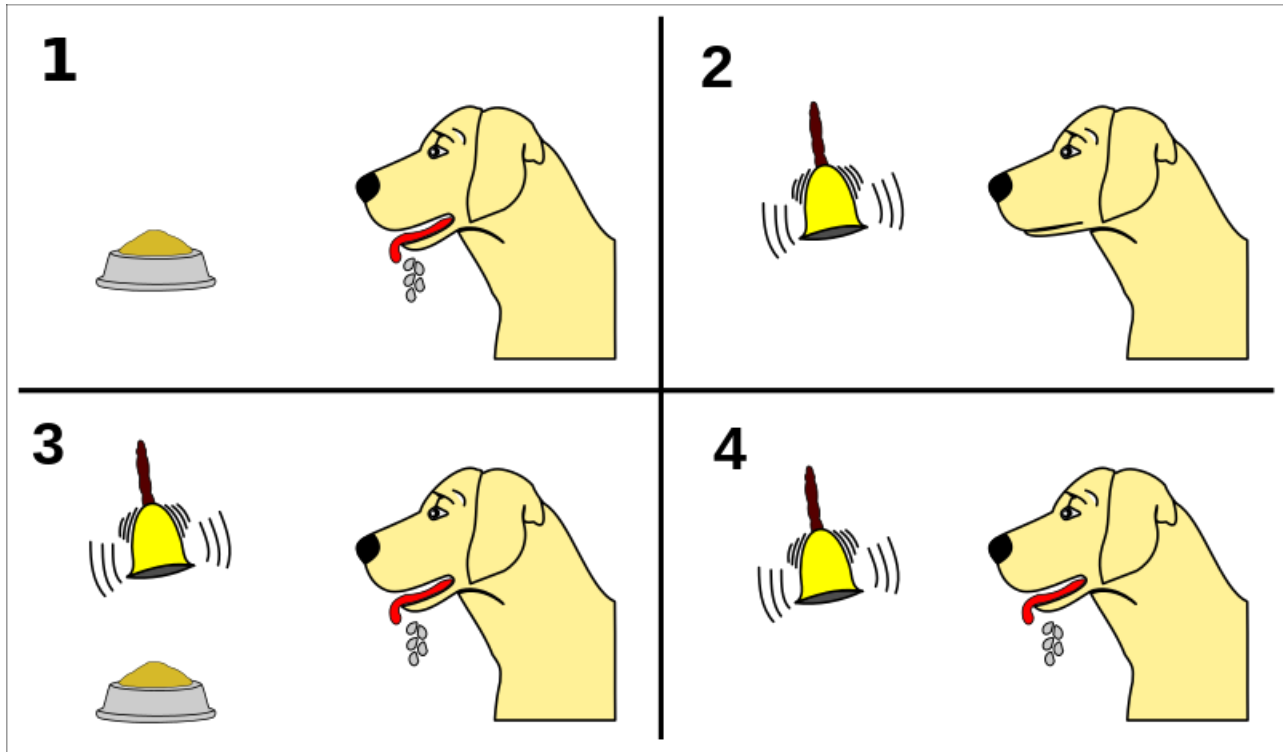

2.1.2. *Operant Conditioning*

Burrhus Frederic Skinner (1904-1990) studied the Operant Conditioning, on which the term "Operant" refers to the aftermath of a behavior which may be a punishment or a reward [40]. This ultimately shapes the behavior by enhancing it, if it is a reward, or discouraging and eliminating it, if it is punishment. Operant conditioning can be described as the behavior modulation method in which rewards or punishments are offered in order to make a correlation between behavior and the consistency of such conduct. It is expected that the mechanism of dependence will reinforce the desired behavior of the subject and discourage the wrong and undesirable one. Operant behavior is each behavior initially spontaneous, but whose consequences may reinforce or discourage it. It is a behavior that is mainly shaped, reinforced or discouraged by its consequences [40][41]. In contrast to classical conditioning, that focuses on the formation of reflective behavior (i.e. behavior induced by pre-existing conditions, such as Pavlov's dog salivation occurs after the occurrence of addictive stimulus), the operant dependency focuses on the dependency development through post-behavioral rewarding or punishment. Skinner conducted various experiments on rats by using a box known as "the Skinner box", as shown in

Figure 2.3. Initially, he set up the Skinner box and placed a hungry rat inside of it. At first, the rat was inactive but as the time passed, he began to explore the box and slowly discovered a lever, who released food by pressing. After he fulfilled his need for food, the rat started look around again. When the hunger came back, he pressed the lever for the second time, so this behavior started to happen continuously every time he felt hungry and the conditioning was complete. The focus of this experiment was to address the effects of positive reinforcement.

Skinner also conducted a second experiment where he placed a rat in a chamber, in a similar way, while subjecting the chamber to an unpleasant electric current. After a while, the rat started to feel discomfort and tried to move around the chamber. At some point, the rat accidentally knocked the lever and this event resulted to the reduction of the flow of unpleasant current. In this manner, to avoid the discomfort, the rat eventually started to go directly to the lever. In conclusion, this experiment addressed the effects of negative reinforcement, while the electric current reacted as the negative reinforcement, the pressing of the lever is an operant response and the discontinuance of the electric current is the rat's reward (Figure 2.3).

Figure 2.3 Skinner's rat experiment (Skinner's box)

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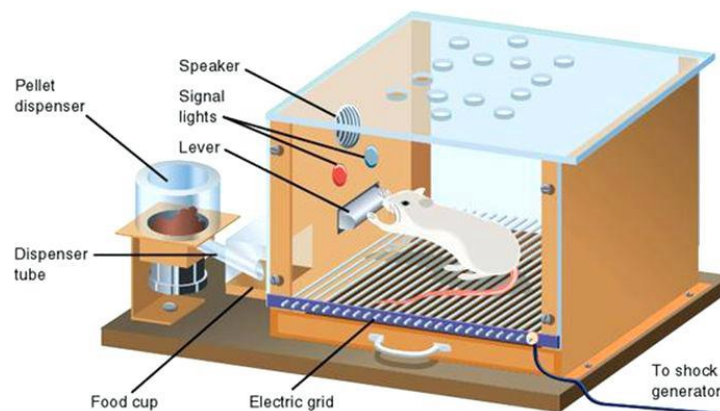
The principles of learning in a learning environment (such as a classroom, an e-learning course, etc.), as formulated by B. F. Skinner, require the active participation of the learners, the structuring of the curriculum in short teaching modules, the learner's gradually adaptation, the immediate verification of the answer of the learner in order to strengthen the correct answer to the question asked.

A different pattern of learning principles was formulated from, Norman Crowder who was working independently for the armed services on programmed instruction[6], based on which the learner's answer determines what is to follow [42]. Crowder recognizes four key functions in the educator's activity, which are:

1. Presentation of information
2. Requiring the learner to use this information when answering similar questions
3. Assessment of the learner's response
4. Decision making about the quality of the responses provided

Evaluating the quality of the answer has a very important role not only in enhancing the right answer, but mainly because it allows the determination of the information to be presented. The presence of a clear relationship between the learner's response and the learning material introduces the possibility of making customized learning arrangements. These methods quickly met the decline under the coordinated fires of cognitive psychologists and pedagogues [42]. The emergence of the computer in the early 1970s is a new development of the planned teaching movement, with the emergence of Classical Teaching with Computer Assisted Instruction, which in its elementary form was the computational implementation of the programmed book via multiple choice questions. In their most modern version, Computer-aided Teaching programs are designed according to the Instructional Design model.

2.1.2.1.   Instructional Design model

The Instructional Design model represents a systematic and structured approach to designing computer-based teaching systems, while representing a consistent strategy in the design of learning environments [43]. This model is based on the approaches of B. F. Skinner and R. Gagne (1916-

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[6] Source: http://edutechwiki.unige.ch/en/Programmed_instruction

2002), was an educational psychologist who created a nine step process called the Events of Instruction,

Table 2.1, and dealt with the systematic description of the different types of school learning, the associated teaching objectives and the ways in which they can be achieved. The three main development stages of the Teaching Design model are [44]:

- ➢ **Needs Analysis:** Identifies each activity of the student and any knowledge section to be acquired by him/her.
- ➢ **Selection of teaching methods and materials:** Instructors are based on the previous analysis and are based on measurable behaviors.
- ➢ **Student assessment:** It is mainly based on a series of tests that allow to decide on the achievement of the learning objectives.

The Instructional Design approach is geared towards providing instructions and procedures that need to be implemented to achieve learning objectives. There are nine didactic events that compose the Instructional Design model as described in

Table 2.1[7]. These nine events of instruction can be divided into three segments as shown in Table 2.2.

Table 2.1 Gagne's events of instruction

1.	Attracting Attention (Reception)
2.	Information on course objectives and incentives (Expectation)
3.	Stimulating the recall of previous knowledge (Retrieval)
4.	Presentation of stimuli with distinct features (Selective perception)
5.	Providing learning guidance (Semantic coding)
6.	Eliciting performance (Response)
7.	Providing feedback (Reinforcement)
8.	Evaluation of performance/results (Retrieval)

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[7] Source: http://thepeakperformancecenter.com/business/learning/business-training/gagnes-nine-events-instruction/

9. Enhancing retention and transfer (Generalization)

Table 2.2 The nine events of instruction divided into three segments

Preparation	Practice and Instruction	Transfer and Assessment
1. Reception	1. Selective perception	1. Retrieval
2. Expectation	2. Semantic coding	2. Generalization
3. Retrieval	3. Response	
	4. Reinforcement	

2.2. Constructivism

Pedagogical science had been seeking ways in which it could impart knowledge to young people. In this context, various theories have been developed from time to time that have approached the issue, always aiming at the effectiveness of learning. To this end, the theory of constructivism developed, which emphasize on the central role of the individual and his potentials in the process of learning rather than in the learning material. This theory has been greatly facilitated by the evolution of technology.

Constructivist approaches recognize that children, before they go to school, have knowledge and what they need is to help them build new insights into what they already have. This framework leads to the view that education should have as its primary objective, to help learners, bridge the gap between their informal and formal knowledge. Cognitive theories, Table 2.3, focus their attention on the cognitive system, its structure and its function, while believing that learning is to modify knowledge.

Table 2.3 Cognitive theories

1. Structural Constructivism (Jean Piaget)
2. Constructionism (Seymour A. Papert)
3. Information Processing (Gnostic Psychologists)

2.2.1. Structural Constructivism

Jean Piaget (1896-1980) was a psychologist, who claimed that learning, as a process, consists in processing the cognitive forms when they come to conflict with the environment. Therefore, either integrates new elements into these shapes without altering them (assimilation) or modifies these shapes to be able to integrate into these new elements (compliance). But that is not enough, while enriched or modified cognitive form must be used again and again, through exercise and repetition, to stabilize [45]. The stabilization of the cognitive form, in its new form, results in learning. The whole process of learning, through assimilation and compliance, takes place when the balance between the cognitive structures of the individual and the environment is disrupted and tends to achieve this balance again [46][47]. That is why, besides the adjustment process, it is called a balancing process. Piaget describes the development of the child's logical thinking, as an evolutionary process that is shaped through different stages. These stages are defined in chronological order: the sensory stage which is up to 2 years old, the stage of the preconceptions from the age of 2 to 7 is, the stage of the specific acts from 7 to 12 years old , and the stage of the logical formal acts from the age of 12 [47]. Age boundaries are not an absolute limit, but they are more of an average. According to Piaget, each person will pass through all stages in the order they are assigned. Basic concepts in Piaget's theory include assimilation, compliance, adaptation and shape, described in Table 2.4.

Table 2.4 Basic concepts in Piaget's theory

Concept	Description
Assimilation	Assimilation is the energy of the organization to integrate a situation into activity patterns, which are already in place.
Compliance	Compliance includes the actions performed by the organization, according to the requirements of the environment, to achieve a purpose and it leads to the modification of the subject's prior knowledge.
Adaptation	Adaptation is a biological principle and is the essence of assimilation and compliance.
Shape	Shape is the most important concept in Piaget's theory, which is a kind of learning unit. It is consisted of adaptation using assimilation and compliance after a series of activities.

2.2.2. Constructionism

Constructionism learning theory, developed by Seymour Aubrey Papert (1928-2016) based upon Piaget's theory of constructivism [46][48], focuses on experiential learning. Particularly, Papert's interest was on how learners engage in a discussion and how these discussions reinforce self-directed learning and accommodate the development of new knowledge. He emphasizes the importance of tools, media and technologies as well as participation in project-based learning and supports that knowledge is actively constructed by interactions with the world [46]. Furthermore, constructionism encourages collaborative learning environments while promoting communication and social skills. Nevertheless, there are some drawbacks about this theory, with one of them to be the fact that constructionism doesn't successfully distinguish content from procedures[49]. There are some characteristics that are needed for constructionist learning environments to be effective as described in Table 2.5.

Table 2.5 Characteristics of Constructionism

1.	Learner-centered approaches to instruction
2.	Defining expectations by presenting chapter at the outset
3.	Exploring many strategies for completing tasks
4.	Learning discussions
5.	Work presentation
6.	Revision and development of project ideas
7.	Learning collaboration
8.	Learners participate in authentic real-world tasks

2.2.3. Information Processing Theory

Robert Gagne, Allen Newell and Herbert Simon are the main representatives of Information Processing theory which perceives the learner's mind as an information processing tool. The basic principle of this theory focuses on the representation of the cognitive system and its processing [49] [50]. In this context, the processing of information is meant as calculation and the human spirit is modeled in the form of an information processing system, while the results of cognitive processes are inputs for other treatments. Additionally, each cognitive process consists of

representations and treatments [49]. Knowledge is a structure that is stabilized in the long-term memory and that is what distinguishes it from representations. Representations are occasional structures created in a specific situation and for specific purpose while stored in the short-term memory. In summary, representations differentiate knowledge because they are automatically active, while knowledge must be activated to be available, Figure 2.4.

Figure 2.4 Information Process model
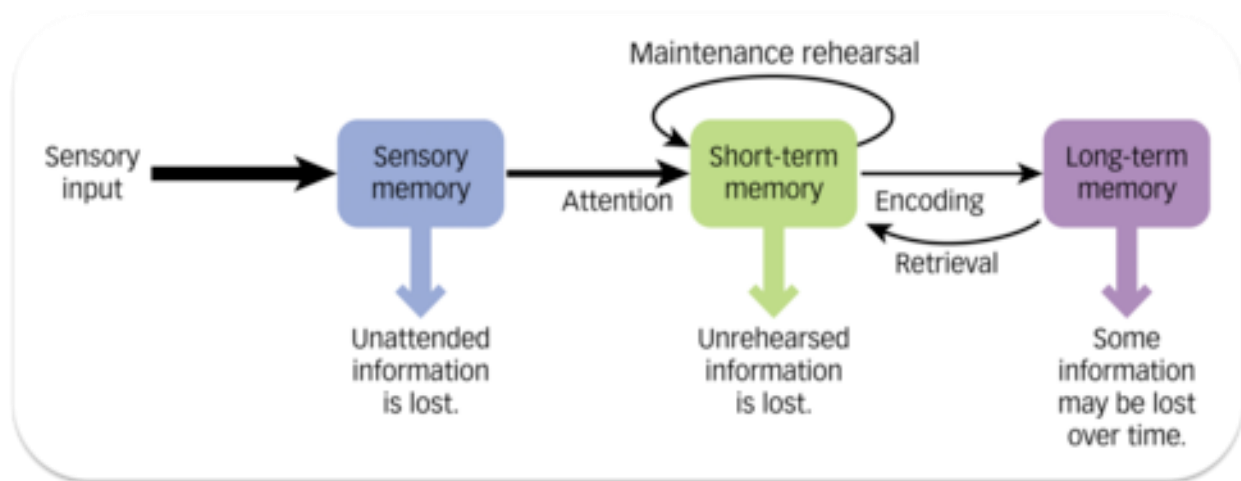
2.3. Cognitivism

A cognitive theory is generally a consistent scientific view which aims to interpret functions of the human cognitive system [34][35]. Two basic assumptions lie under this approach of cognitive theories: a) that memory is an actively organized information process system and b) that prior knowledge plays an important role in learning [49]. In brief, cognitive theories look beyond behavior to examine how human memory works, to promote learning, and to understand short-term memory and long-term memory, while learning is seen as an internal mental process, where the teacher focuses on building intelligence and cognitive development and the individual learner is more important than the environment [51].

The term Cognitivism generally refers to the theoretical framework of cognitive theories as an effort for a comprehensive understanding of cognition and more specific mental functions[36][51]. This framework has emerged as a response to behaviorism, for which cognitivists have pointed out that is failing to explain cognition[52]. The general position of Cognitivism is that people develop knowledge and meanings through the development of their individual cognitive abilities, such as the mental processes of recruiting, processing, encoding and recalling information [36][53]. Behavioral changes are observed as an indication of what the learner thinks. In this framework, the learner's mind is compared to a computer, with information entering, then being processed and finally come to conclusions [52]. According to Cognitivism, reality allows different interpretations, so knowledge is negotiable through the individual's experiences, while within the framework of Cognitivism, the concepts of learning and knowledge are essentially linked to the cognitive processes of the brain, Table 2.6 [52].

Table 2.6 Basic views of Cognitivism

Process	Description
Cognitive processes	Processes of information processing and internal representations in the brain
Learning	Dynamic process of information processing and representations through cognitive processes
Knowledge	Knowledge structures which are built into long-term memory

2.4. Social Learning Theories

Social Learning theories suggest that observation, imitation and modeling are the key factors for the learning experience between learners [54][55]. These theories posit that learning activities take place inside the social, historical and cultural context [55][56]. The four main social learning theories are: Discovery Learning (Jerome Bruner), Social Development Theory (Lev Vygotsky), Situated Cognition (John Seely Brown, Allan Collins, Paul Duguid) and Activity Theory (Lev Vygotsky) [34].

2.4.1. Discovery Learning

Jerome Seymour Bruner (1915-2016), was the psychologist who introduced the Discovery Learning model, which suggests that, in order for the learner to understand the information and develop cognitively, he needs to build enactive representations that are related to the execution of actions and are mainly developed in the very young ages, as well as, iconic representations, which are relatively independent of the action. These representations are related to visual perception and are internal mental images[33]. Lastly, symbolic representations, which do not have a virtual relation to what is represented. Each symbolic representation is mainly culturally built and allows the learner to make extensive use of the perceptual features of the world to develop categorization and conceptualization skills to achieve his goals. According to Bruner, the learner must be confronted with problematic situations[55][57]. Additionally, the curriculum should be organized in a spiral form and the teacher should take the role of the coordinator and facilitator in the learning process [33]. Finally, Bruner emphasized on the cultural and social context of the emergence of cognitive processes[33].

Respectively, Discovery Learning theory was proposed by J. Bruner, where learners use their experiences/knowledge to learn something new, in problem-solving situations [58][59]. Learners are required to discover concepts and processes that could otherwise be transmitted through direct teaching. Subsequently, this theory emphasizes on facilitating learning by understanding the structures and scientific principles of a cognitive subject [36][60]. Overall, Discovery Learning theory suggests that learner's interaction with the outside world can be achieved by using or exploring objects, or by performing experiments, or even by being faced with questions [60].

2.4.2. Social Development Theory

Social development theory was developed by Lev Semionovich Vygotsky (1896-1934) when he was in the Soviet School of Psychology [61]. This school focuses on the communicative and cultural dimension of learning [59]. The development of intelligence is a process of social interaction in which language plays a predominant role. The child in this process is not a passive receiver but a subject who, through his actions, shapes his cognitive reality [59]. Thus, mental development is indissolubly linked to the historical dimension and the cultural context in which it

evolves. The basic principle of Vygotsky's theory is the "Zone of proximal development", which defines what the child can succeed with the help of others, but not on his own [61].

2.4.3. Situated Cognition

The originators & proponents for the Situated Cognition theory were John Seely Brown, Allan Collins, Paul Duguid [62]. The Situated Cognition theory argues that learning is not an individual function of human intelligence but a social learning function that takes place through communication and interaction with other people[62][63]. This theory provides a modern framework for explaining the learning difficulties in the school environment, emphasizing the distributed nature of cognitive competence and arguing that behavior is the product of interactions between individuals and the physical environment, in which they live.

2.4.4. Activity Theory

Activity Theory has its roots in the psychological school of Lev Vygotsky, Aleksei Leontiev and Alexandr Luria [64]. The basic principle of this theory is that the human action is mediated by cultural signs, such as words and tools that affect the individual's activity and mental processes. This theory is a framework for studying different forms of human acts as developmental processes, interconnected with the individual and social levels. The basic unit of analysis is the activity, which consists of the subject, the object, the functions and the operations. Human activity is mediated by internal and external tools. Mediation is done by objects that define and include instruments, signals, and languages that are created by individuals to control their behavior. The Activity Theory has important applications in human - machine communication research, as well as in the design of computer collaborative learning environments [65]. Computer Collaborative Learning is based on the interaction between the subject, the available tools and the learning objective. In this interaction, the learning ability and the division of labor in this context have an important role.

2.5. Learning Theories Conclusion

In conclusion, it is believed that learning theories are important for the way learning process occurs, as well as how we define learning in learning environments and educational software. Behaviorist theories led to drill and practice software in educational technology and target the speed and accuracy of the learner's ability of computing. However, they present the result as the purpose of learning, while they give little value to the process and how someone reaches out to it.

On the other hand, constructivism is a predominant model in the design of modern educational software. Constructivism's principle is that the knowledge of the world is built by the individual. The individual, based on his interaction with the world, builds, controls, rearranges his cognitive representations. The main goal of such educational software is to provide learning activities integrated into problem-solving processes from the real world and to encourage expression and personal involvement in the learning process. Finally, the presence of awareness about the learning theories is very important in terms of building knowledge. In the design of learning environments, it should be facilitated active, constructive and collaborative learning processes to help learners to understand and promote their ideas.

3. Usability

Usability is an important factor in adopting products and systems in the daily activity of users, and is associated with virtually any product, system or service. In simple terms, usability means to be able to use a system, product or service quickly, easily and efficiently [66]. Concerning to computer systems, usability has become an important part in the design and evaluation of them and its importance is growing as the use of systems becomes more common in our everyday life [67][68].

3.1. Usability Testing

Usability testing is an evaluation method of the ease of use of information products, such as systems or services [69][70]. This method involves individuals who represent the target end-users, while it simulates the interaction between the user and the system, under controlled conditions, in order to evaluate the usability of the system[70][71]. Five steps are described to compose a standard procedure of usability testing, and are listed below[71][72]:

1. Acquisition of representative participants
2. Design of test scenarios
3. Conduction of usability sessions
4. Interpretation of the test results
5. Production of recommendations

In the process of usability testing, a prototype of the product (information system, service) is presented to one participant at a time, who then tries to figure out how the product functions or tries to perform a particular tasks [72][73]. The focus of usability testing is on the participant/user and his/her overall experience while interacting with the product [72][73]. In conclusion, beneficial outcomes can be found with the use of usability testing before launching a product since usability improvements are considered to be fundamental to the product's success[71].

3.2. Heuristic Evaluation

Heuristic evaluation is a usability analysis method [74] where, a number of evaluators are testing a user interface in order to detect possible usability problems [75]. Specifically, testing is based on a set of usability principles, which are named "Heuristics" (Section 3.2.1), in order to proceed to the inspection of the user interface [76][77]. The heuristic evaluation analysis method is considered to be a leading, valuable and reliable method for usability testing in the user interface (UI) design of a software [75].

3.2.1. General Usability Principles/Heuristics

Usability principles, heuristics, are general principles that have emerged through the experience of using different interactive systems and concern each case of interactive technology or system [76]. In the evaluation process, the evaluator must choose the most relevant usability principles, depending on the interactive system, and must specify the principles in guidelines and measures [68]. Jakob Nielsen in 1994, proposed ten general principles of usability as a measure to evaluate interactive systems [8][68][78][79][80] which are still used today as baseline evaluation metric in UI usability testing:

1. **Match between system and the real world**: The system's language should be familiar to the user and accommodate user-friendly phrases and concepts instead of system terms.

2. **Visibility**: The most relevant system elements (controls, buttons, content, etc.) need to be visible to the user, in every stage of interaction.

3. **System's aesthetics:** The system's dialogues should contain only relevant information.

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[8] Source: http://www.useit.com/papers/heuristic/heuristic_list.html

4. **Error prevention**: The system should prevent the user from making mistakes.

5. **Help**: The system should assist the user at every point of interaction and offer him ways to recover from errors if they occur.

6. **Consistency**: It should be clear for users, what different words, situations, or actions mean.

7. **User control**: The user should be able to have control of the system at any time.

8. **Flexibility**: The system should offer user different ways to achieve his goal.

9. **Documentation:** It is preferable for the system to provide relevant documentation.

10. **Recognition rather than recall**: Using user-recognizable objects, actions, and options, while system instructions should also be visible.

3.3. Cognitive Walkthrough

Cognitive walkthrough is a methodology, focused on the ease of learning [81], that simulates a user's problem-solving process [82]. Usability experts attempt to accomplish typical user tasks, based on a task-scenario, while they inspect the user interface step-by-step and discuss the usability issues that may arise [82][83]. At each step, usability experts are requested to answer the following questions[83]:

- Will the right action prove to be sufficient for the user?
- Will the user link what he's trying to do with the description of the correct action?
- Will the user correctly interpret the system's response to the chosen action?

Design evaluation with the application of the cognitive walkthrough methodology aims to review how easily can a user perform a task with or without guidance [81]. In conclusion, cognitive walkthrough is a useful method of evaluating online platforms [83] due to its focus on understanding the system's learnability and is widely used in the assessment of applications' interface[68][81].

4. Case study: Early Mild Cognitive Impairment and Cognitive Training

4.1. Early Mild Cognitive Impairment

A common inevitable accompaniment to aging is memory impairment. However, over the last few years, the view of the elderly's memory impairment has been transformed by the medical community and it is now considered that memory impairment, to some extent, is pathological[5]. Physicians review the extent that memory loss has progressed, if the extent of memory impairment makes normal independent functions impossible, like day-to-day basic needs and managing skills, then it can be judge as pathological memory impairment, which to such degree is referred to as dementia.

Tsolaki, Kounti et al. [2], refer to the term of Mild Cognitive Impairment (MCI) as the intermediate stage of cognitive impairment, which addresses a group that may or may not be high risk for developing dementia[5][6]. Kounti, Bakoglidou et al.[1] state that mild kinetic impairments are observed in MCI patients. These mild kinetic impairments can be joint function problems, balance, walking, position in space, or even posture and praxis[1]. Nevertheless, there is the possibility that intervention at the early stages of MCI may maintain or even improve patients' cognitive function[2][3] [84].

The earliest and mildest symptomatic phase of MCI is called early-stage MCI (eMCI). In eMCI, subtle impairment in brain functionalities, such as memory, language, attention and visuospatial skills, have already occurred in the form of small changes in the individual's life[7][8]. These changes may not be always noticeable without the observation of a close friend/family or the proper examination by a professional. Even though the pathology of eMCI remains mostly unknown[8], which can be challenging to the clinical diagnosis, the detection and intervention for eMCI is of major importance for the individual's health[8]. Therefore, more work needs to be conducted on tracking and identifying markers of transitions related to eMCI [8]. The diagnostic measures of eMCI are limited to the traditional means and scales. Thus, the need for more research on screening tools and invasive tools for MCI is rising, in order to aid the identification of the early stages of MCI. Implementing effective and trustworthy tools could potentially support the early diagnosis, even to the point where the memory function remains substantially within the normal

range. Hence, the development of tools for an early and effective prevention could be of high value in the detection and identification of early stages of MCI and dementia.

4.2. Applications for early Mild Cognitive Impairment

Early detection of MCI and recognition of subtle changes in the brain functioning aim to hopefully improve the quality of patient's life through the effectiveness of therapies [85]. The production of applications focused on the early detection of MCI could also potentially compliment to the clinical diagnosis and therapeutic assessment.

Serious Games refers to computer games designed for a primary and carefully studied educational purpose that are played other than pure entertainment [86]. Serious games have been developed in a number of domains[9], including defense, education, scientific exploration, health care, emergency management, city planning, engineering, politics, and religion[87] and they are used to support learning in the broadest sense of the term, while they can have an educational, therapeutic and social impact. A commonly accepted definition about Serious Games does not exist, but there is a consensus that these games are aimed at learning, they are a delightful interactive resource which withhold some gaming elements [88].

A serious game, 3D virtual environment-based platform, designed by the action group A3 of the EIP on AHA in collaboration with game developers, neurologists and neuropsychologists, aimed at the early detection of MCI in individuals aged from 50 to 80 years old [89][90]. The game scenario is based on navigation in a 3D environment that simulates home living and daily interactions, Figure 4.1. The Smart Aging platform invites people to perform five real-life tasks in order to proceed to the valuation of different cognitive functions. In brief, the five tasks include the following functions: a) identify an object, b) water the flowers while listening to the radio, c) make a phone call, d) recognize an object and e) repeat Task 1 (Object Identification) [91].

Figure 4.1 Example of the Smart Aging virtual scenario[86]

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[9] Source: https://cs.gmu.edu/~gaia/SeriousGames/index.html

This platform aimed to the successful conversion of scientifically-driven tasks traditionally evaluated in paper, into tasks to be performed in a virtual environment. Furthermore, the creation of a user-friendly navigation system that could be satisfactorily used by potentially cognitively impaired individuals or by individuals with minimum experience in information technology, was another objective of this platform. Meanwhile, an ongoing scientific validation is in progress on a sample of 1,000 users to collect evidence about the system's effectiveness and usefulness [90][91].

War Cognitive Assessment Tool (WarCAT) was developed by Kyle Leduc-McNiven [92] and represents a mobile card-game, Figure 4.2, aimed at the early recognition of MCI while it provides MCI assessment function via the analysis of an individual's game-playing data [92]. The base of this mobile game is a simple card game usually played by two players, that uses a standard card deck[93].

Figure 4.2 WarCat Game-play Example
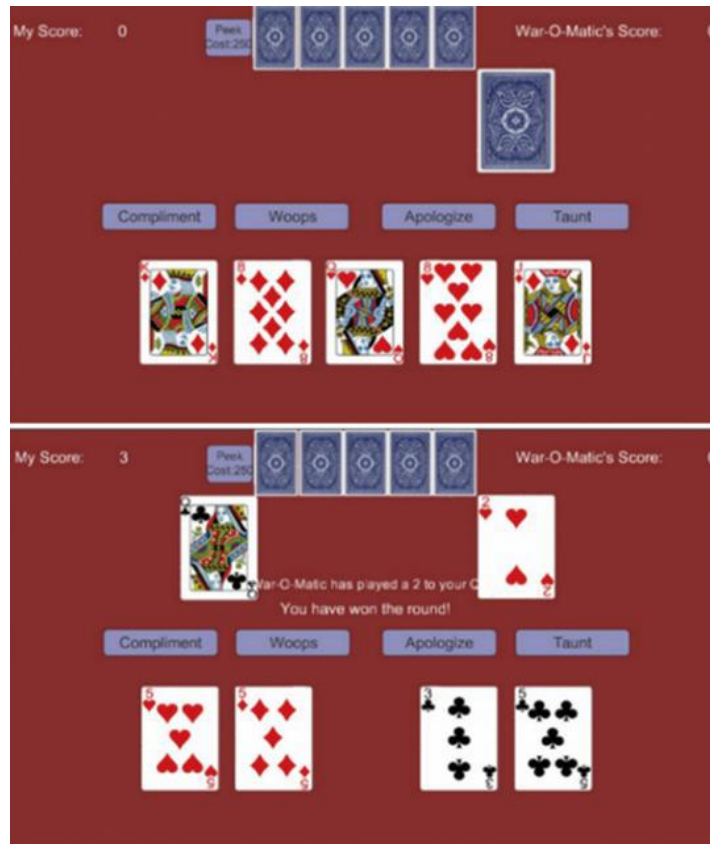
At first, the window is evenly divided, with each player receiving 26 faced down cards stacked in front of him. Each player displays one card up at the same time and the player with the highest card picks up both cards[94]. Subsequently, each player displays one card down and one card up and the player with the highest cards gets both piles. The game goes on until one of the players has won all the cards [94]. WarCat consists of five rounds of the War card game, while three levels of 100 games each, with the player playing against a bot, which he's trying to win in order to level up. WarCat engages different algorithms and heuristics to solve the respective problems, while it provides players with immediate feedback and tracks real-time player behavior during play time [92][93]. The player's data is gathered on large scales, long-term performance of individuals and groups can be established and thereupon potentially employ machine learning methods to detect subtle cognitive changes in an individual's life.

4.3. Cognitive Training

Cognitive training refers to the repeated practice of tasks that aims to maintain or improve the cognitive functioning of an individual[10] [95]. These tasks are described as a variety of structured exercises designed based on specific cognitive abilities such as maintenance of attention, visual and auditory processing, memory improvement, self-control, perception, reasoning and overall executive functioning [2][96]. The process of cognitive training can take many forms, such as computer or paper training, either individually or in small groups[95], while it involves teaching strategies that aid to the improvement of impaired cognitive abilities by exploiting other spared cognitive abilities [96]. Cognitive training can lead to improved meta-cognition, which refers to the participants' knowledge of memory mechanisms and their own memory and also cognitive self-efficacy, which refers to the idea that participants can exercise some control over their knowledge[96].

Cognitive training is supposed to improve performance on specific abilities which is important for people with MCI [96][4]. In addition, while cognitive training optimizes the cognitive function of MCI individuals, it can also delay the cognitive decline as well as the appearance of major neurosensory disorders [4]. Overall, MCI individuals have a great need for healing and maintaining cognitive abilities to learn and implement new strategies [1][3]. This possibility arises, especially when the cognitive training takes place in the early stages of MCI. With the proper design, cognitive training could optimize cognitive function of eMCI and MCI individuals, to alleviate the stress resulting from their cognitive difficulties[11]. These individuals often feel uncertain about the evolution of their mental state and, over time, they realize that their health's progress is worsening and so often experience feelings of sadness and frustration that result in increased levels of anxiety. Such effective training programs could therefore bring enormous benefits to life quality, mental state and cognitive abilities of MCI individuals [96], while they could also aid to the early detection and identification of MCI in eMCI individuals.

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[10] Source: https://en.wikipedia.org/wiki/Brain_training

[11] Source: http://www.encephalos.gr/full/47-1-04g.htm

5. Methodology

In this chapter a detailed description of the tools/platforms that were used in the implementation process of the developed web-based cognitive training platform, is documented. In brief, for the design and development of the platform, the state-of-the-art Learning Management System, named Moodle, was used. In conjunction with Moodle, the most well-known, open source authoring tool, named H5P, for creating interactive content was used.

5.1. Learning Management System

Learning Management Systems (LMS) are software that grew from a range of multimedia and internet developments and combine the functionality of computer communications, online teaching materials delivery methods and learning process management tools, providing a comprehensive online learning environment [97][98]. There are many similar or different terms that can be used to describe Learning Management Systems, such as: Content Management Systems (CMS), Learning Content Management Systems (LCMS), Virtual Learning Environments, Course Management Systems, Managed Learning Environments (MLE), Learning Support Systems (LSS) [98] [99], etc. In online teaching LMS allow educators to create online courses and training courses and can also track the progress of their learners by accessing detailed reports and statistics. Another important aspect of LMS is that learners are provided with online classrooms where they can learn in an interactive environment [100][99]. In addition, learners can access these classrooms anytime, even after they have finished taking the courses, ensuring uniformity and continuity in training and learning. Furthermore, LMS software has several features to help educators to better manage their learners, like organizing learners into groups or classes to centralize reporting and assignment of courses or quizzes [99]. Tracking the progress of large groups or individual learners, with advanced reports and statistics, is much easier and educators save valuable time spent in grading assessments and calculating the results. International standards are continuously developing, and the precise specifications vary from system to system[98], while most of the products that are currently available differ in terms of conformity with these standards[98], while they typically provide tools for course administration and pedagogical functions, Table 5.1, of differing sophistication and potential [101].

Table 5.1 Tools for course administration and pedagogical functions[101]

Course Administration Tools	Examples
Asynchronous and synchronous communication	Announcement areas, e-mail, chat, discussion forums
Content development and delivery	Learning resources, development of learning object repositories and links to internet resources
Formative and summative assessment	Submission, multiple choice testing, collaborative work and feedback
Class and user management	Registering, enrolling, displaying timetables, managing student activities

5.1.1. The Moodle Platform

Moodle (Modular Object Dynamic Learning Environment) is a Learning Management System adapted on the pedagogical principles of Social Constructivism (Section 2.2) which is a learner-oriented philosophy developed by L. Vygotsky based upon Piaget's theory of constructivism (Section 2.2.1) [102][103][104][105][106]. Moodle is written in PHP and enables the dynamic creation of flexible online courses. It is an open source platform that is addressed to professionals, such as developers and educators, who intend to develop technology compatible courses while it provides access to a wide range of activities and information resources[102][107]. Furthermore, it has free distribution with no license restrictions, it's possible to obtain the code and to parameterize the system using community sourced plugins, keep track of statistics, and provide multilingual support [108]. Moodle is supported from a large and active online community, which cooperates to the development of the platform and provides support to Moodle discussion forums [109]. Moodle community is the most important qualification of this platform, with Moodle forum's participants solving almost every problem that may occur [109]. Following are some key points of

this platform: a) fully operational CMS, b) suitable for online courses, c) easy to install and to use, d) durable, efficient, compatible and customizable core features, described in Table 5.2, [107][105]. In conclusion, Moodle is considered a valuable platform due to its strong community, pedagogical design, wide variety of customization and course/activity development tools and, in addition, ease of integrating external resources[110].

Table 5.2 Moodle's core features

Feature	Description
Interface	Responsive, accessible, easy to navigate on both desktop and mobile devices
Dashboard	Display courses and tasks due
Tools and activities	Forums, wikis, glossaries, database activities, etc.
Calendar	Keep track of course deadlines, group meetings and other personal events
File management	Store files from cloud storage services
Text editor	Format text and add media with a compatible editor across all devices and web browsers
Notifications	Receive automatic alerts on new assignments or deadlines and send private messages.
Progress	Track progress and completion with plenty of options for tracking activities or resources individually and at course level

5.1.1.1. *Tools available on Moodle*

Moodle offers a wide variety of tools that can be used for delivering learning [107]. All the tools[12], which are characterized as activities, resources and blocks, are listed and described below, in alphabetical order:

i. **Announcements forum**

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[12] Source: https://teaching.unsw.edu.au/moodle-tools

The Announcements forum tool may be presented on the course home page of every course and contains announcements and general news.

ii. **Assignment**

The Assignment activity offers students a place to submit their work (Figure 5.1) and for teachers to evaluate, Figure 5.2, students submits. In addition, with this activity there is the ability to inform students whenever there are assignments that they need to complete and to return feedback from teachers back to students.

Figure 5.1 Assignment activity - Student's View Example[13]
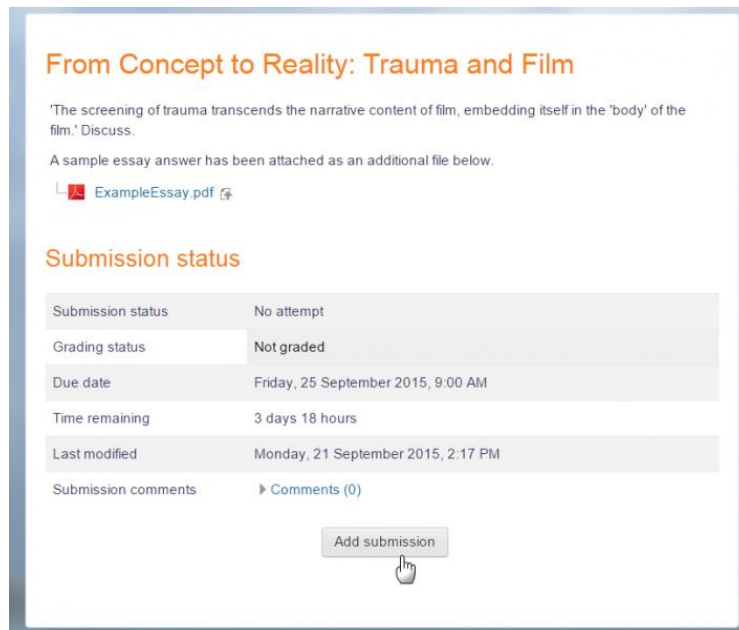
Figure 5.2 Assignment activity - Teacher's View Example[14]
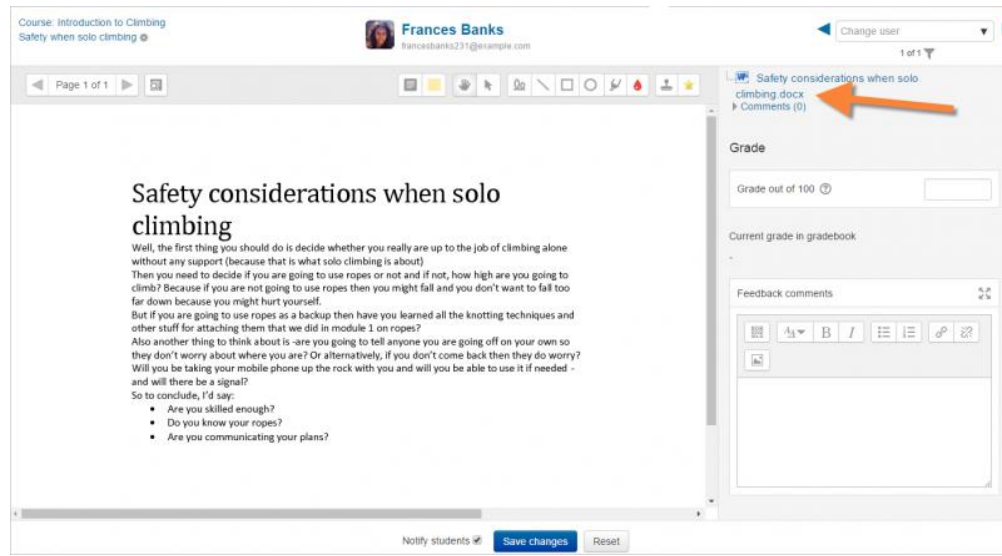
iii. **Attendance**

The Attendance activity can be used by teachers in order to monitor attendance during a course. Furthermore, students can view their own attendance record and track down their presence in every course.

iv. **Blog**

The Blog tool is a user-based module of Moodle that can be created and driven by an individual or a team. A blog can be internally created on Moodle platform or it can be developed on another external platform, such as WordPress or Blogger, and then registered on Moodle (Figure 5.3).

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[14] Source: https://docs.moodle.org/36/en/File:assignmentgrading3.png

Figure 5.3 Registration example of an external blog in a Moodle blog[15]

v.   **Book**

A Moodle book is a multi-page resource which is book-like formatted. In this resource there can be main chapters and subchapters, similarly to a book, that can hold content, such as text, media (videos and pictures), or even previously created sites, Figure 5.4.

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[15] Source: https://docs.moodle.org/36/en/File:Registerblog.png

Figure 5.4 Example of the Book module[16]
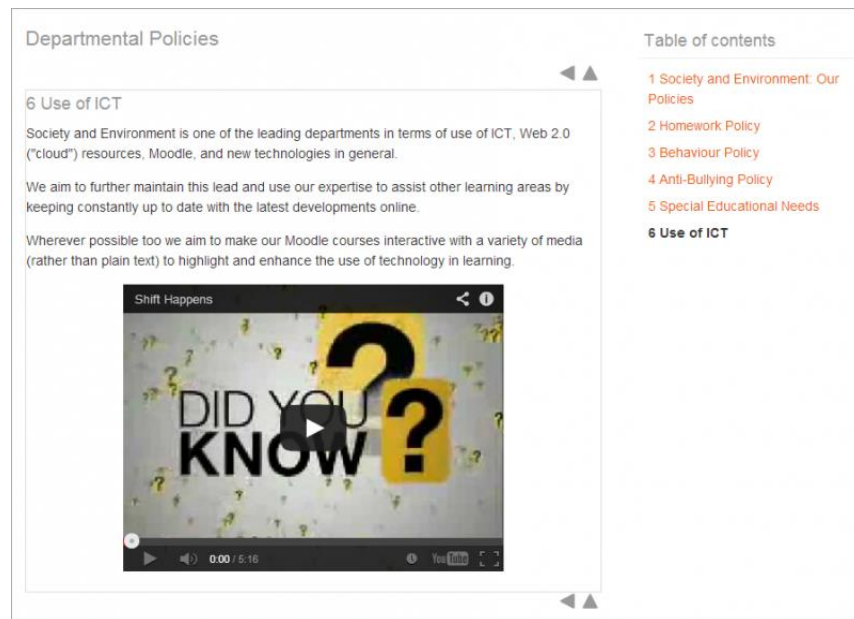
vi.   **Chat**

The Chat activity manages chat conversations and allows students and teachers to have real-time, synchronous, text-based discussion in a Moodle course, Figure 5.5.

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[16] Source: https://docs.moodle.org/36/en/File:book.png

Figure 5.5 Example of Chat Activity Module[17]
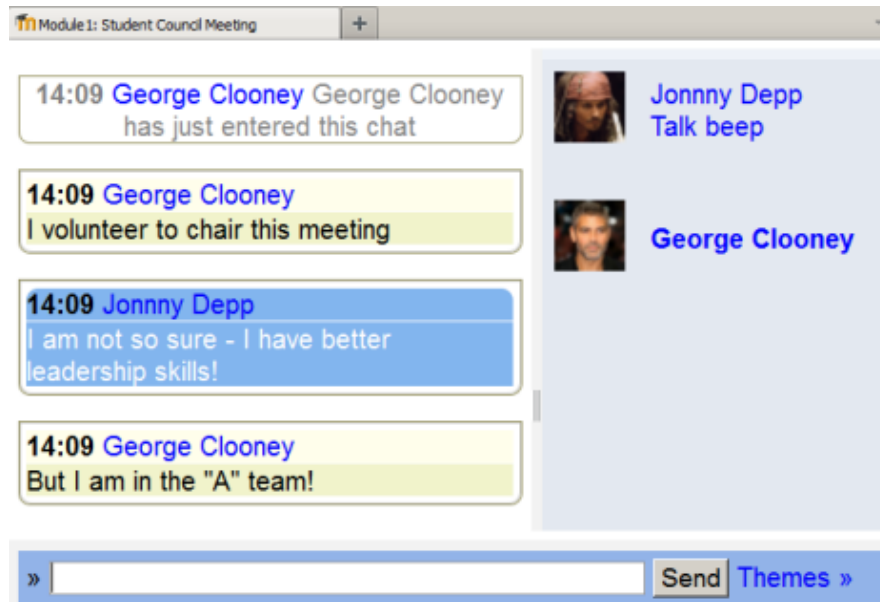
vii.   **Choice**

The Choice activity can be used by teachers, Figure 5.7, to form a one-question quiz with multiple answers, for students to choose from, Figure 5.6. This specific activity could also be found useful as a poll about a subject or as a tracking method of students' answers.

Figure 5.6 Student view of choice[18]

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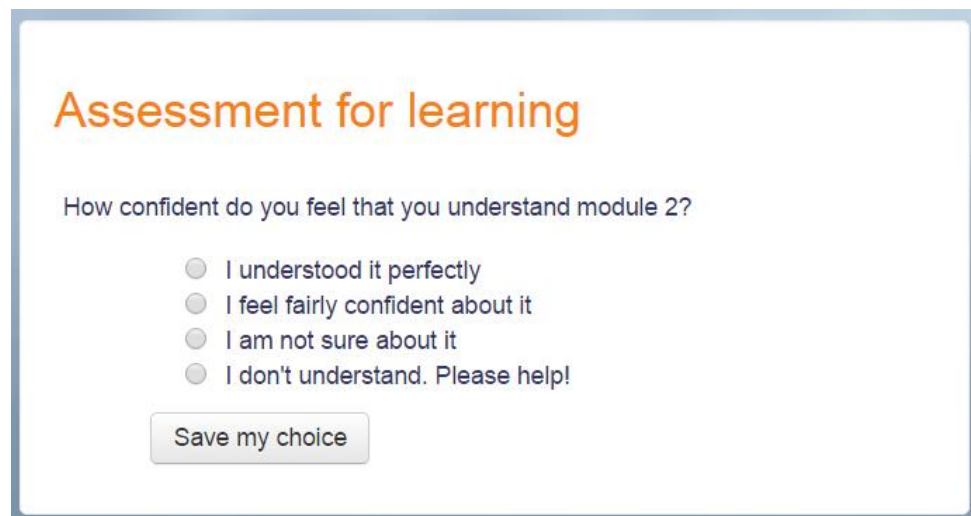
[17] Source: https://docs.moodle.org/36/en/Chat_activity

[18] Source: https://docs.moodle.org/36/en/File:choicestudentview.png

34

Figure 5.7 Teacher's view of choice results[19]
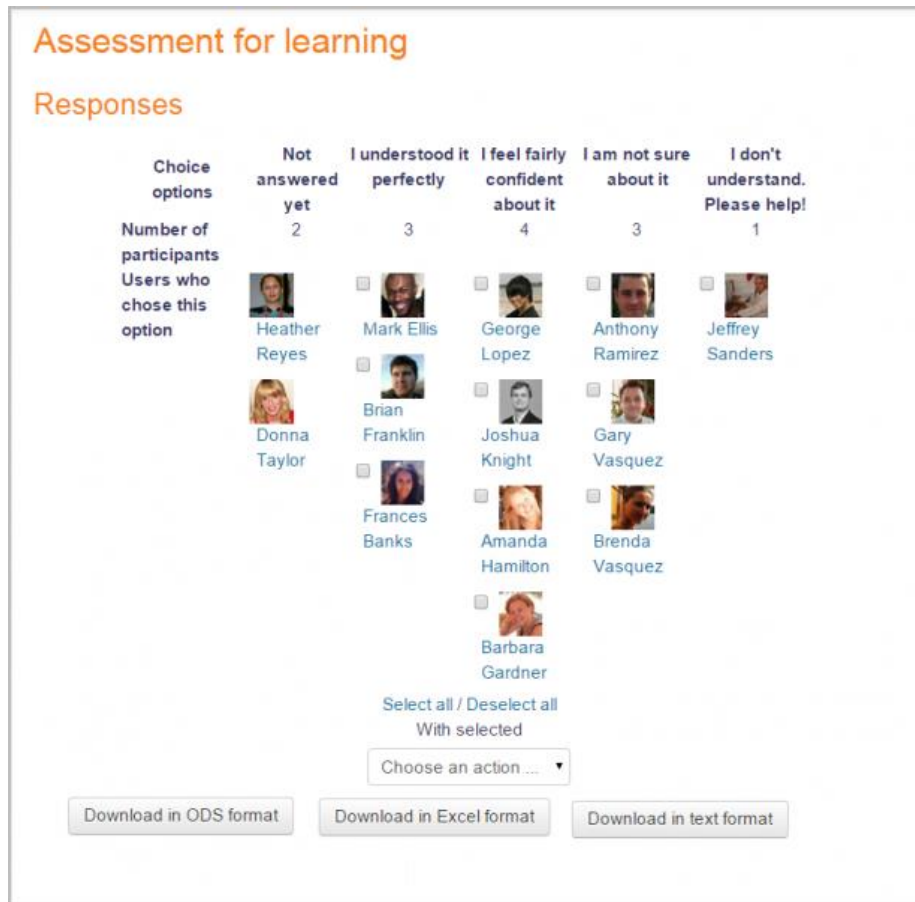
viii. **Database**

The Database activity allows teachers and students to develop a place which can hold records about any topic. These entries can have, an almost unlimited, variety of different structures such as files, text, images, URLs, etc.

ix. **Dialogue**

The Dialogue tool can be used to start a private conversation between a user (teacher or student) and another user who belongs to the same course (Figure 5.8).

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[19] Source: https://docs.moodle.org/36/en/File:choiceresults.png

Figure 5.8 Example of a Dialogue Conversation List[20]
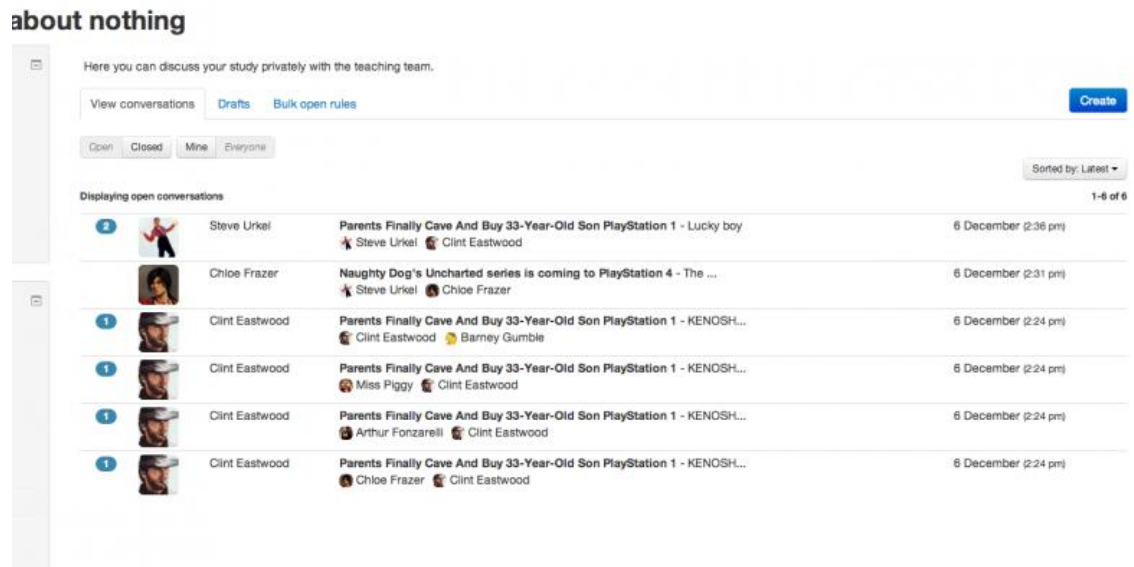
x. **Feedback**

The Feedback tool allows users to create their own questionnaires containing their own questions, rather than choosing questions from a template list. Particularly, this tool can be found useful for surveys (anonymous or not) and course evaluations.

xi. **Forum**

The Forum activity is an online discussion board where teachers and students can interact, post comments or start individual discussions. The forum posts may contain files such as images and videos, while they can be rated by other users (Figure 5.9) (Figure 5.10).

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[20] Source: https://docs.moodle.org/36/en/File:dialogue-conversationsTeacher.png

Figure 5.9 Student's view of "Standard forum" type[21]
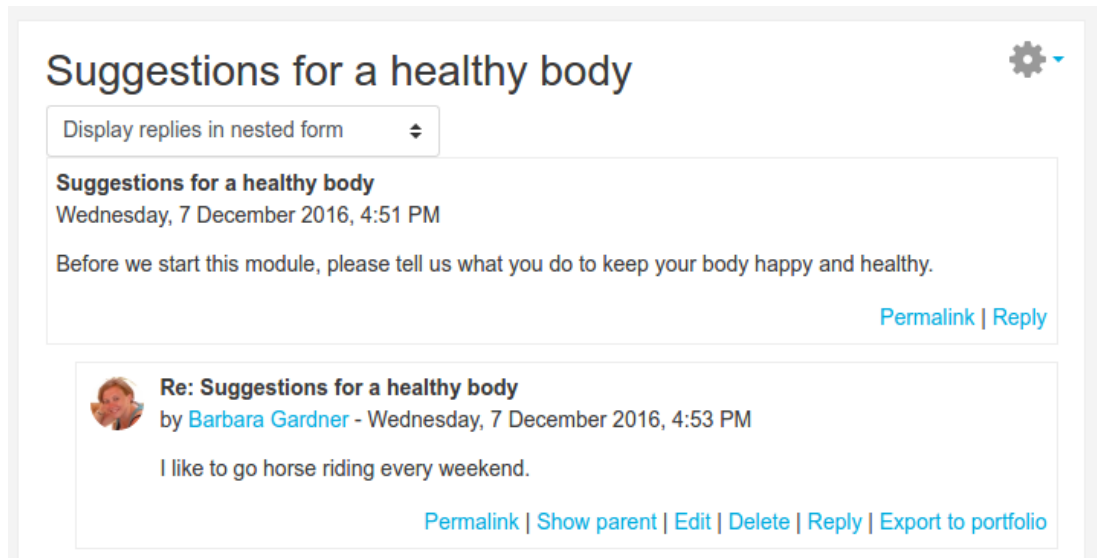
Figure 5.10 Student's view of "A single simple discussion" forum type[22]
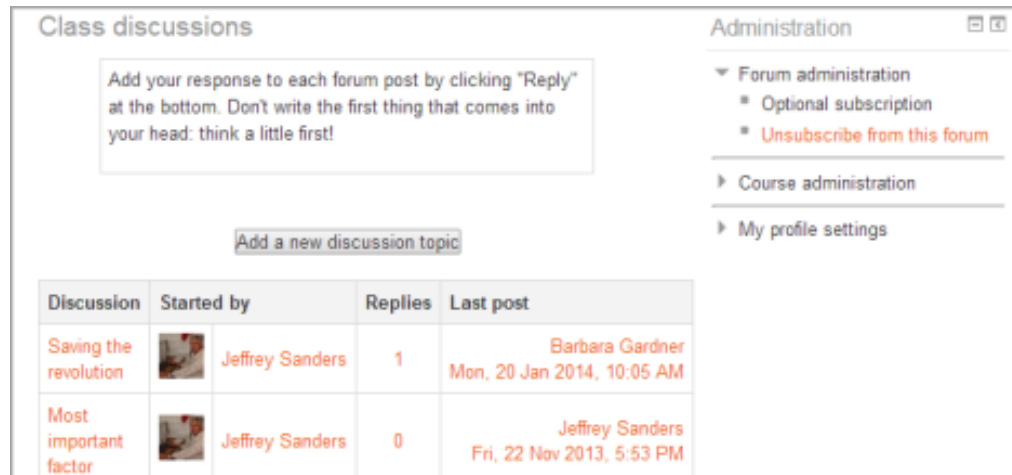
xii.   **Glossary**

The Glossary activity is a tool that allows users (teachers and students) to create interactive glossaries of terms. This tool acts like a dictionary which can hold a list of definitions, as well as images and related links (Figure 5.11).

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[21] Source: https://docs.moodle.org/36/en/File:Single_simple_discussion.png

[22] Source: https://docs.moodle.org/36/en/File:standardforum.png

Figure 5.11 Glossary Module Example[23]

xiii. **Gradebook**

The Gradebook tool (or else Grader Report) can be used to record, track and calculate all the grades, for each student in a course, on the Moodle platform.

xiv. **Lesson**

The Lesson activity allows the creation of complex branching lessons. Particularly, these lessons are programmed learning units in which each correct answer brings up a new piece of information and a new question.

xv. **Participants**

The Participants page presents the course participants by group or role, while it allows users to filter, edit, enroll and assign roles to course participants.

xvi. **Questionnaire**

The Questionnaire module allows to obtain feedback by surveys to course participants. It contains a wide range of question types, such as essay boxes, ratings, etc.

xvii. **Quiz**

The Quiz module helps teachers to create and design quizzes which can contain

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multiple different question types, such as multiple-choice questions, true-false, etc. Furthermore, this module allows students to retake a quiz as many times as they need (Figure 5.12).

Figure 5.12 Quiz Module Example[24]
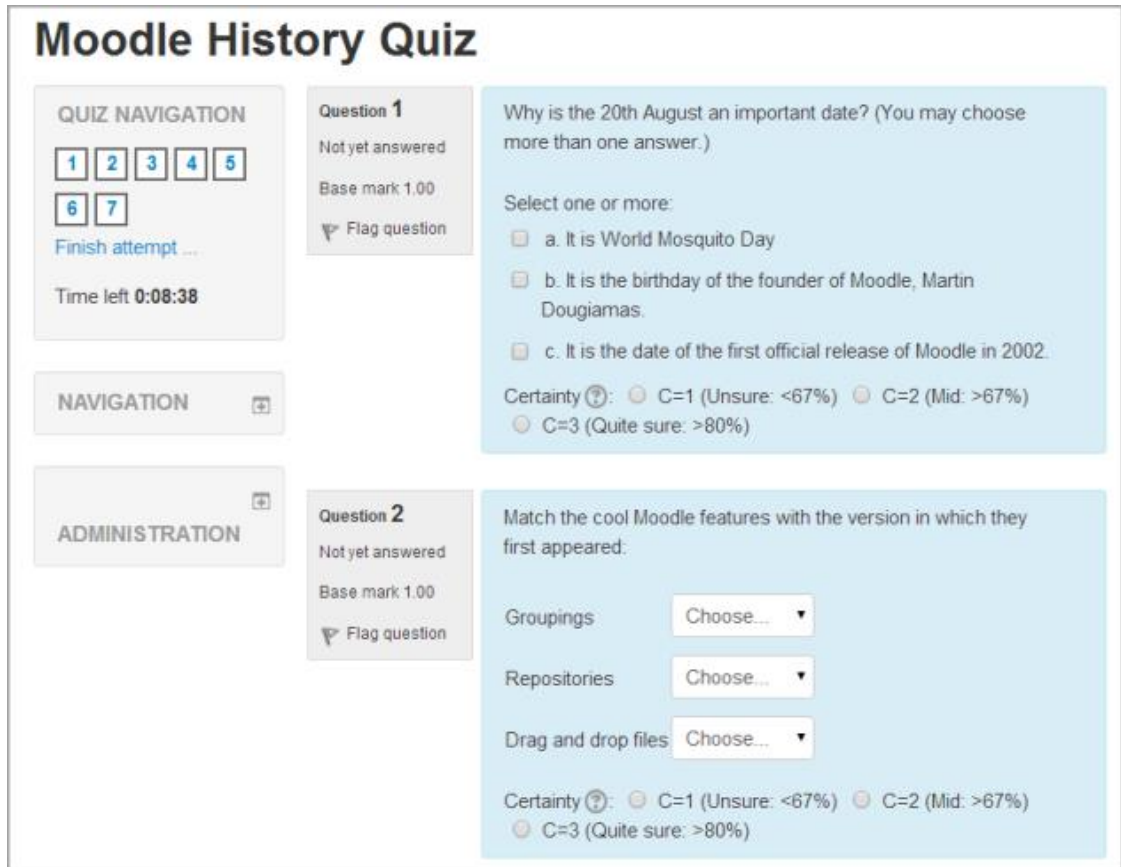
xviii. **SCORM Package**

The SCORM Package module enables teachers to include any package of SCORM (Sharable Content Object Reference Model) in a Moodle course, by uploading it. SCORM is a set of technical standards of web-based learning content. This type of content is created using HTML, JavaScript, SWF files and SCORM authoring software.

xix. **Wiki**

The Wiki activity is basically compiled by an online page which can be created by one user or a group of users. This page contains a home page which each user can edit or link other pages.

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[24] Source: https://docs.moodle.org/36/en/File:Quizexample.png

5.1.1.2.   Moodle Plugins

One of the biggest advantages of the Moodle platform, is the wide variety of plugins. Plugins, third party or not, are offered by Moodle developers and contributors in the Moodle plugins directory. These plugins aid to the best functionality and easier customization of the Moodle site.

5.1.1.2.1.   The Moodle Adminer Plugin

For the purposes of this platform's development and database support, we used the Moodle Adminer plugin (Figure 5.13). The key-functions of this plugin are: to define trigger, to create or alter views, to change the order of fields, to define foreign key with referential integrity and to create stored procedures. Furthermore, Moodle Adminer can handle different types of database and that is one of its great advantages, while it works properly with MySQL, MSSQL, PostgreSQL and Oracle. Moodle Adminer is a highly useful tool in case we want to, amongst others, modify, download or upload our database.

Figure 5.13 Moodle Adminer Administration Page[25]
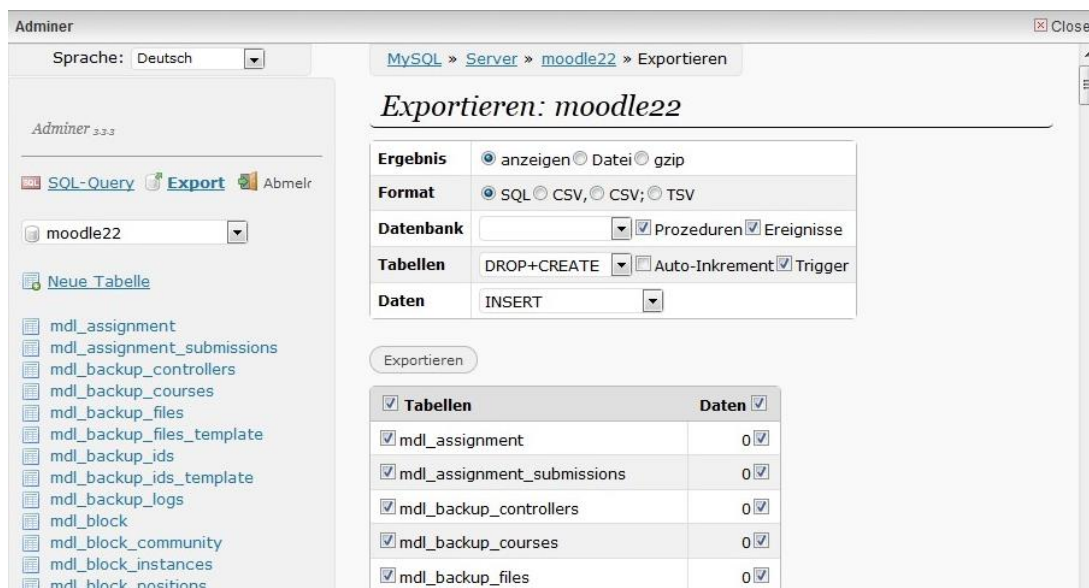
5.1.1.2.2.   The Essential Theme Plugin

A Moodle theme allows the user to change the look and feel of a Moodle web page. Themes can be applied to a site, course, activity, while these themes can be designed for specific devices, such

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as mobile phones or tablets. There is also the possibility of changing the theme's structure through the existing theme settings or through editing the theme's code. Specifically, in this thesis, we used the Essential theme from the plugin repository on the official Moodle site (https://moodle.org/plugins/). The Essential theme is a clean and customizable three column responsive theme based on Bootstrap, which is tested and used by thousands of users, according to its installation numbers which come to 10061 sites[26] and 8k downloads[27]. Essential theme has a flexible structure and modern appearance, in which we can rely on, in order to process our site's look and feel. Furthermore, Essential offers a wide variety of advanced customization tips using HTML and CSS code in order to customize the theme to meet our needs. Lastly, Moodle has given Essential an official review of 10/10 score in usability and performance[28] which makes it a reliable tool/plugin to have.

5.2. Authoring Tool

Authoring tools integrate a wide variety of media to create professional, engaging and interactive software content [111][112]. These tools can repurpose learning objects from an existing course for use in a new course [113]. Furthermore, an authoring tool can be used by a large team of people with different skill sets and can offer a way for achieving e-learning goals [114]. Some rating factors of an authoring tool could be [115]:

- Technical expertise
- Content goals (simple vs. sophisticated learning experiences)
- Content scale (translation, multiple variations)
- Authorship (single author vs. collaboration)
- Budget

5.2.1. The H5P Authoring Tool

H5P is an open source e-learning authoring tool based on JavaScript, which offers a wide variety of interactive HTML5 content types, Table 5.3, that can be easily integrated with learning

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[26] Source: https://moodle.org/plugins/theme_essential

[27] Source: https://moodle.org/plugins/theme_essential

[28] Source: https://docs.moodle.org/36/en/Essential_theme

platforms, content management systems and websites [116][117]. H5P facilitates the creation, sharing and reuse of the HTML5 content, while it's highly flexible, with cross-platform compatibility for all its content types. Furthermore, there is a large community that contributes in technical support, while improvements, updates and new features can be found on the community portal (https://h5p.org/). Currently, there are the following four integrated platforms: Moodle, Drupal, WordPress and Tiki [118]. Equally important is that web content should be accessible by all users, those with disabilities included. As an e-learning authoring tool, H5P accommodates several accessibility requirements, in many of its content types, such as subtitles in videos, captions, keyboard navigation, and more[116]. Regarding Moodle, H5P is a valuable tool since it offers access to content types that can be useful in the process of efficiently developing a Moodle course[113]. The H5P plugin is widely known in Moodle community and has been commonly used by many users who depend on it for the creation of their courses[113].

Table 5.3 H5P available content types

1. Accordion Vertically stacked expandable items	2. Agamotto A sequence of images that gradually change	3. Arithmetic Quiz Time-based arithmetic quizzes	4. Audio Recorder An audio recording
5. Chart Bar charts and pie charts	6. Collage A collage of multiple images	7. Column Layout (column-like) for H5P content	8. Dialog Cards Text-based turning cards
9. Dictation An instant feedback dictation	10. Documentation Tool A form wizard with text export	11. Drag and Drop Drag and drop image tasks	12. Drag the Words Drag and drop text tasks
13. Essay Instant feedback essay	14. Fill in the Blanks A task with missing words in a text	15. Find Multiple Hotspots A task with multiple image hotspots	16. Find the Hotspot A task with an image hotspot

17. Flashcards	**18.** Guess the Answer	**19.** Iframe Embedder	**20.** Image Hotspots
Modern flashcards	An image with a question	Embed a set of files or from a URL	An image with multiple information hotspots
21. Image Juxtaposition	**22.** Image pairing	**23.** Image Sequencing	**24.** Image Slider
Interactive images	Drag and drop game with image matching	Images that need to be placed in the right order	A slider with images
25. Impressive Presentation (ALPHA)	**26.** Mark the Words	**27.** Memory Game	**28.** Multiple Choice
A slideshow with parallax effects	A task with words highlight	An image pairing game	A multiple choice question set
29. Personality Quiz	**30.** Questionnaire	**31.** Quiz (Question Set)	**32.** Single Choice Set
A matching personality quiz	A questionnaire with feedback	A sequence of various question types	A question set with one correct answer
33. Speak the Words	**34.** Speak the Words Set	**35.** Summary	**36.** Timeline
A question answered by speech	Questions answered by speech	Tasks with a list of statements	A multimedia timeline of events
37. True/False Question	**38.** Virtual Tour (360)	**39.** Interactive Video	**40.** Course Presentation
Questions with true/false answers	Interactive 360 environments	Interactive enriched videos	A presentation with interactive slides

5.3. Programming Languages

During the implementation of our web-based platform for cognitive training, along with Moodle and H5P, we also used the following programming languages: JavaScript, CSS and PHP. By using these particular programming languages, we succeeded to modify Moodle's source code and plugins' code, in order to customize the platform's appearance and functionality to our needs.

JavaScript is a high-level, interpreted programming language for the web, supported by the majority of web browsers, such as Chrome, Firefox, Safari, Internet Explorer, etc. [119][120][121]. The primary usage of JavaScript is to enhance web pages for a more user-friendly experience and includes features such as user interface improvements (menus and dialogs), animations, 2D and 3D graphics, interactive maps and many more [122][123].

Cascading Style Sheet (CSS) is a simple design style sheet language used to describe the appearance style of HTML elements [124]. CSS consists of layouts, colors, fonts and other features that can improve flexibility and control of the elements presented, content accessibility, while it can also reduce structural content's complexity, as well as repetition[29].

PHP (Hypertext Preprocessor) is a web development scripting language which is usually used in server-side web development. The PHP code can run integrated in HTML code, either with a Command Line Interface (CLI), or embedded in various web content management systems[30].

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[29] Source: https://en.wikipedia.org/wiki/Cascading_Style_Sheets

[30] Source: https://en.wikipedia.org/wiki/PHP

6. Implementation

For the purpose of this thesis, different tools and programming languages were used, including: the Moodle platform, the Moodle Adminer plugin, the Essential theme plugin, and the H5P authoring tool, along with the JavaScript, CSS and PHP programming languages. The cognitive training platform developed is targeted for individuals with eMCI and is based upon specialized exercises developed by Dr Foteini Kounti,cognitive psychologist and co-founder of The Greek Association of Alzheimer's Disease and Related Disorders[31], [1][2][3][4] [32].

The specialized exercises given by Dr. Kounti are associated with activities of daily living i.e. grocery shopping. A number of different product catalogs are included, containing, amongst others, several food items and hygiene products. The understanding and observation of these catalogs are the key to solve the exercises. The exercises are divided into three levels of difficulty, each of which contains nine exercises. Each level follows a similar framework for the solution of the exercises, which includes cognitive functions such as observation, memory and compliance. The developed cognitive training platform follows the structure of the specialized exercises of Dr. Kounti and consists of three difficulty levels with each one of them to include a series of interactive content aimed to the cognitive functioning of eMCI individuals.

In a step-by-step process of how the platform works, the main features and components of this platform are described. Starting from accessing the platform, the user is asked to login as a user or guest, or to create an account in order to proceed, Figure 6.1. If the user chooses to create a new account, then he proceeds to a new page in order to fill in a form with the information needed, Figure 6.2.

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[31] Source: http://www.brainsinaction.co.uk/international-recognition-for-pioneering-dementia-specialists-brains-in-action/

[32] http://www.encephalos.gr/full/47-1-04g.htm

Figure 6.1 Login Page
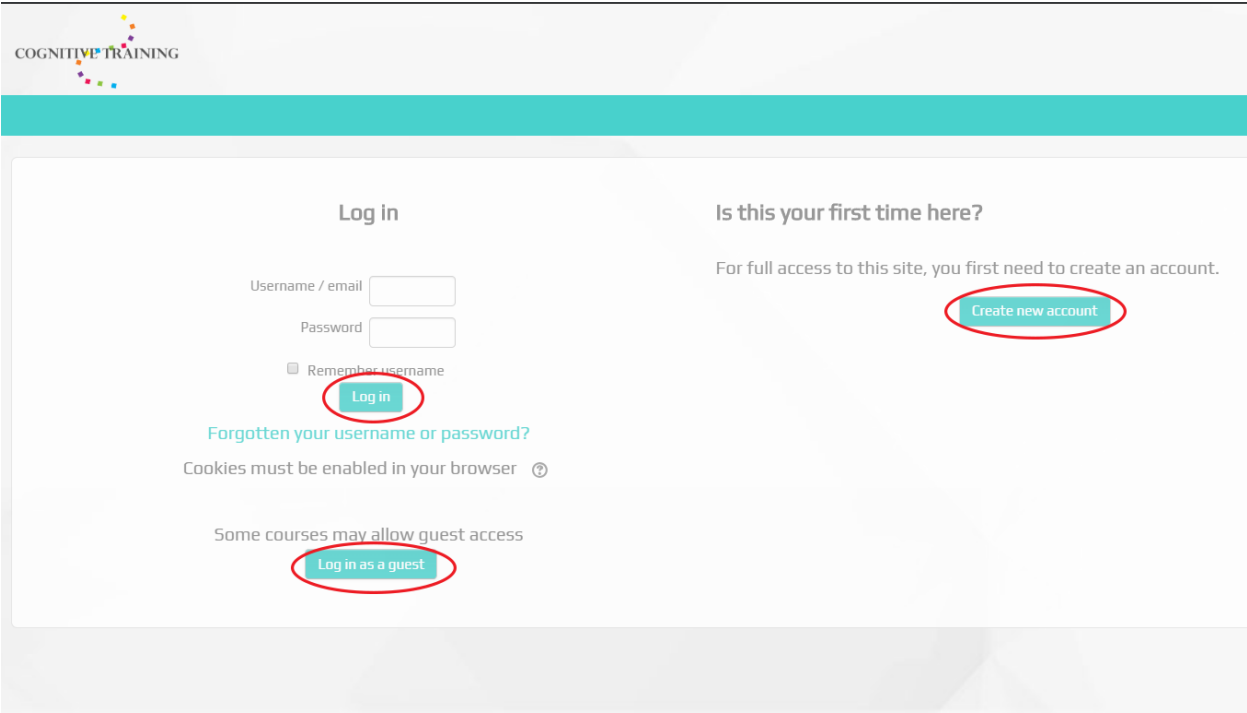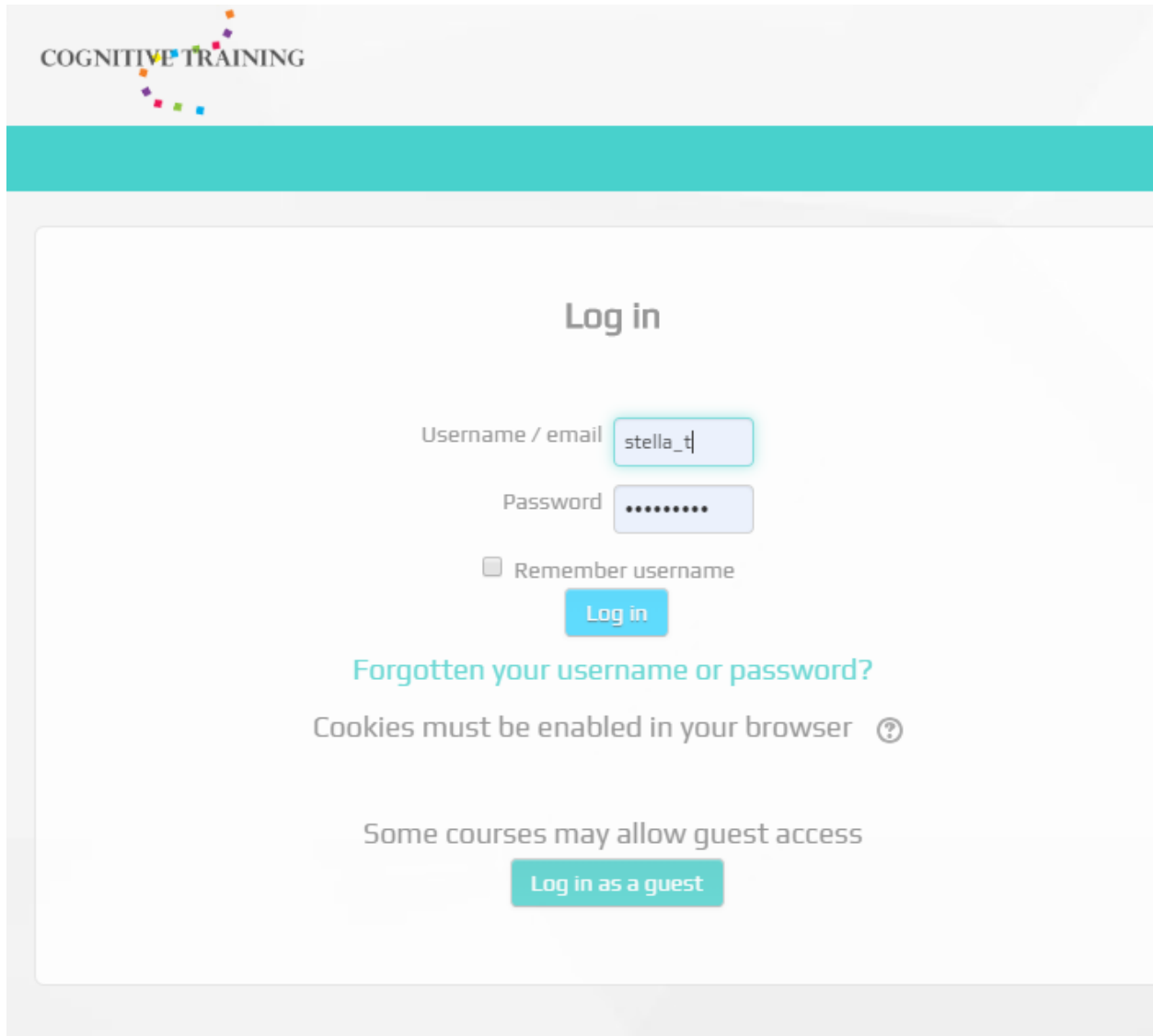
Figure 6.2 Create New Account Process
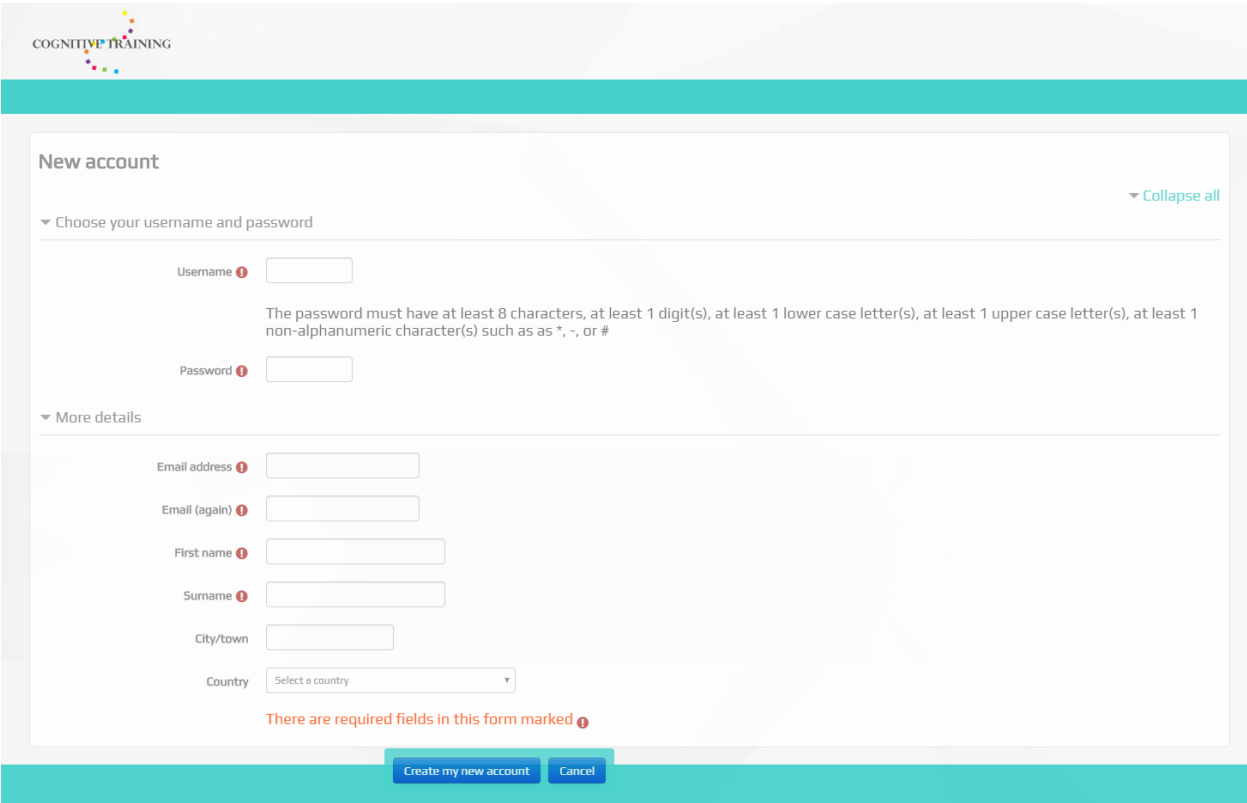
On the other hand, if the user already has an account, he can log in by entering username/ email and password, Figure 6.3. Finally, if the user chooses to log in as a guest, he proceeds to the platform's frontpage, but without the ability of entering any level's exercise, Figure 6.4.

Figure 6.3 Registered User Login

Figure 6.4 Guest Frontpage View
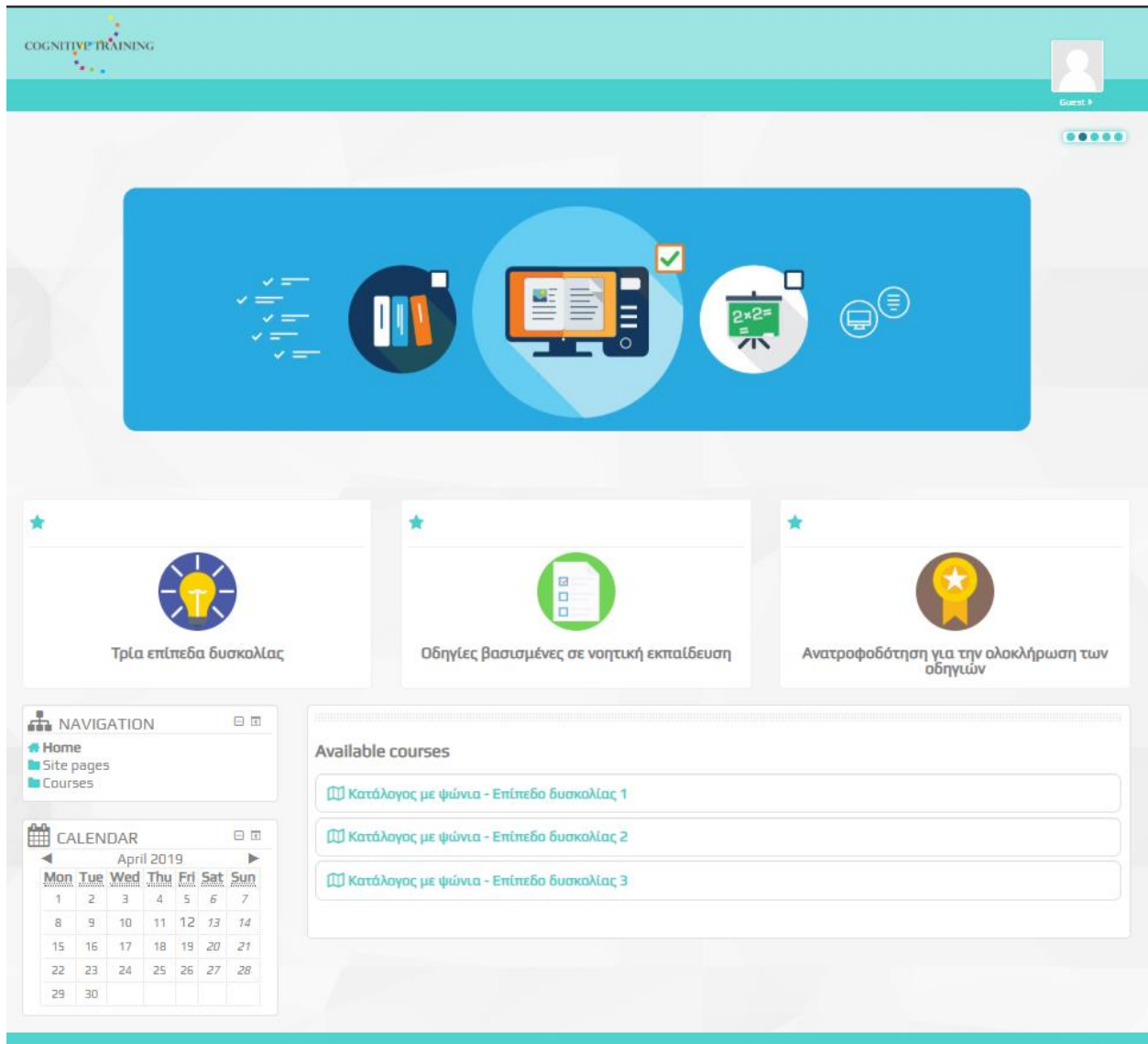
Only authenticated users have the privilege to full access in levels, exercises, grades, personal information etc., while guests can only view the front page. After login or sign up, the front page of the cognitive training platform is presented. If the user is an administrator, then the administration menu is visible, Figure 6.5 & Figure 6.6, otherwise for simple users, the administration menu is hidden and inaccessible, Figure 6.7. The administration menu contains all the settings of the platform.

Figure 6.5 Administrator Frontpage
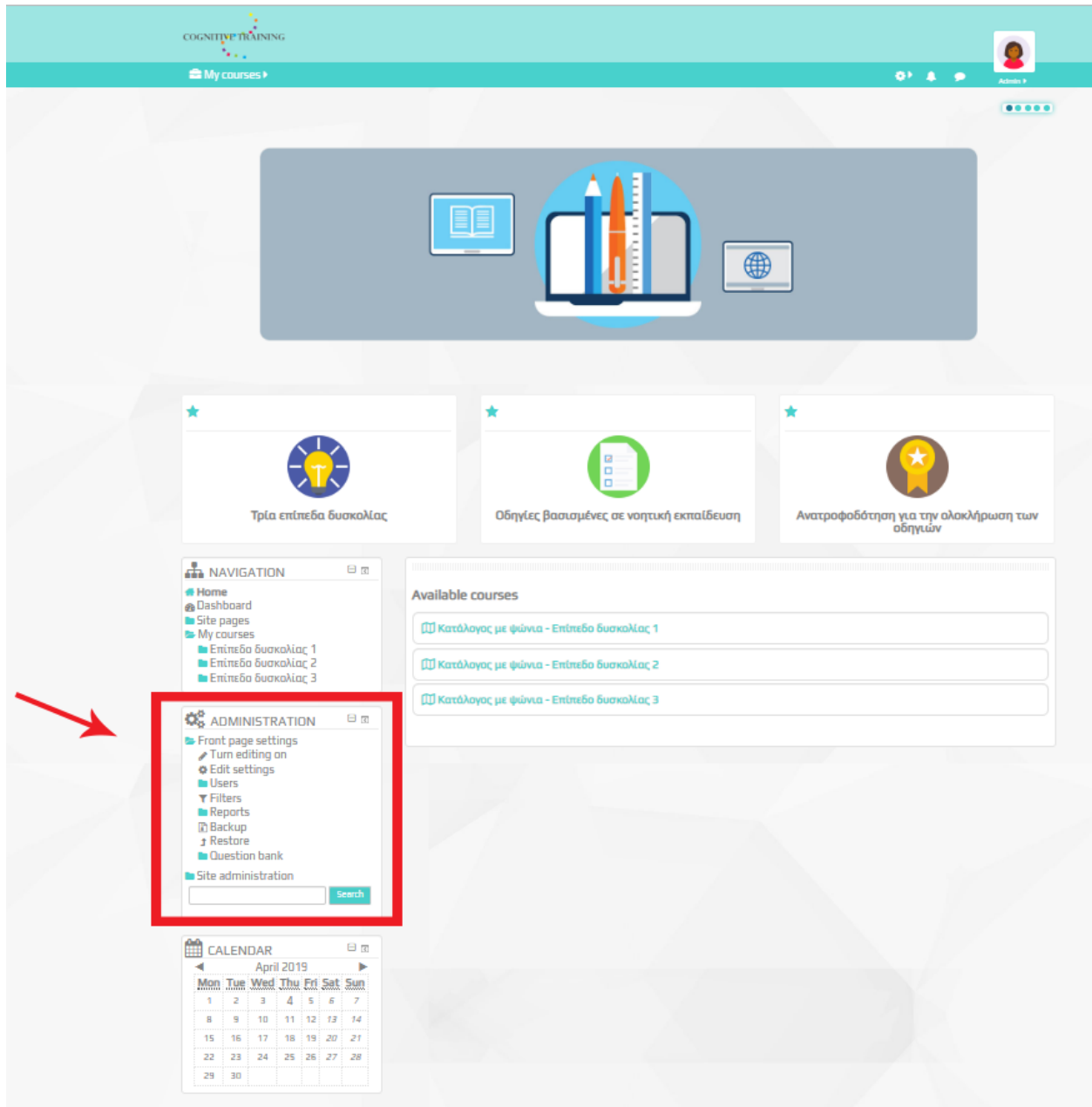
Figure 6.6 Administration menu close-up
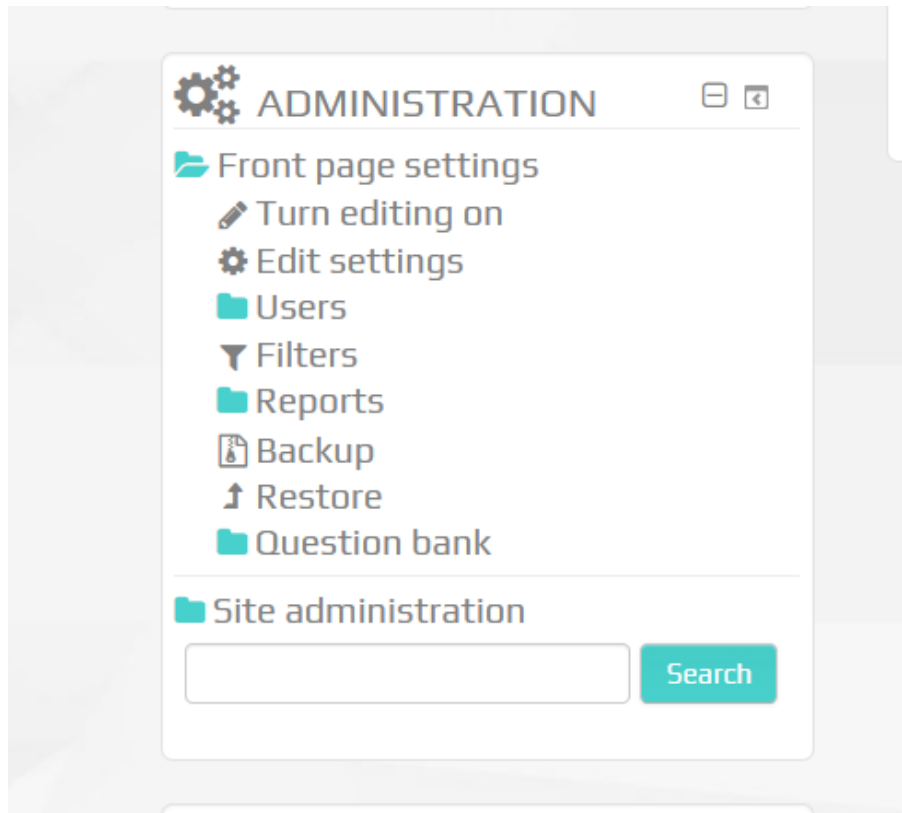
Figure 6.7 User front-page
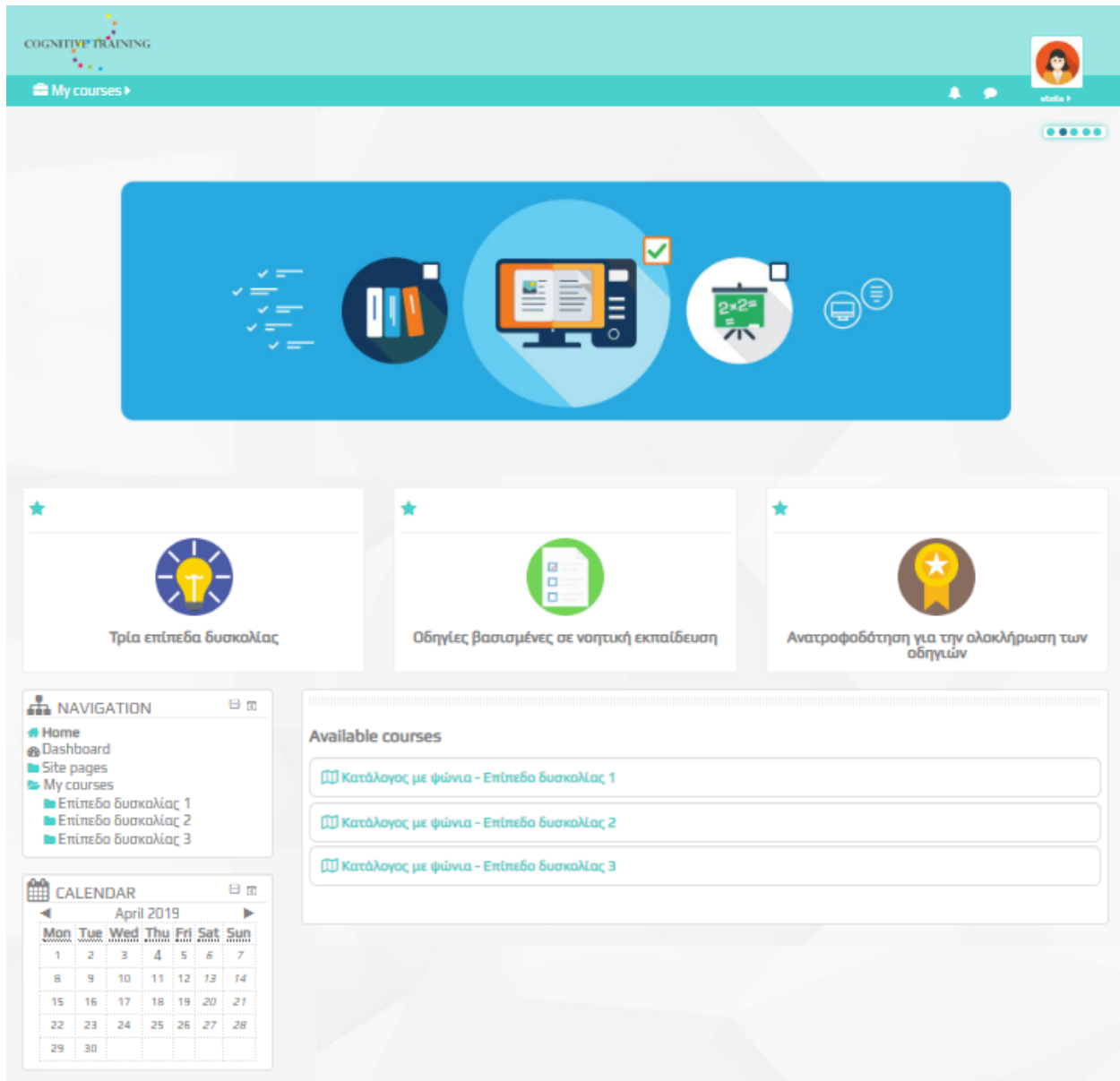
On the front page, the three difficulty levels are displayed as titles, each one of them leads to the exercises of each level, Figure 6.8. Each level is similar to the others in layout and way of exercise solution. Every level also contains a wide range of different interactive contents, using the H5P authoring tool plugin. Furthermore, the difficulty is increasing from level to level with exercises becoming slightly more demanding towards users.

Figure 6.8 The three difficulty levels presented on the front-page
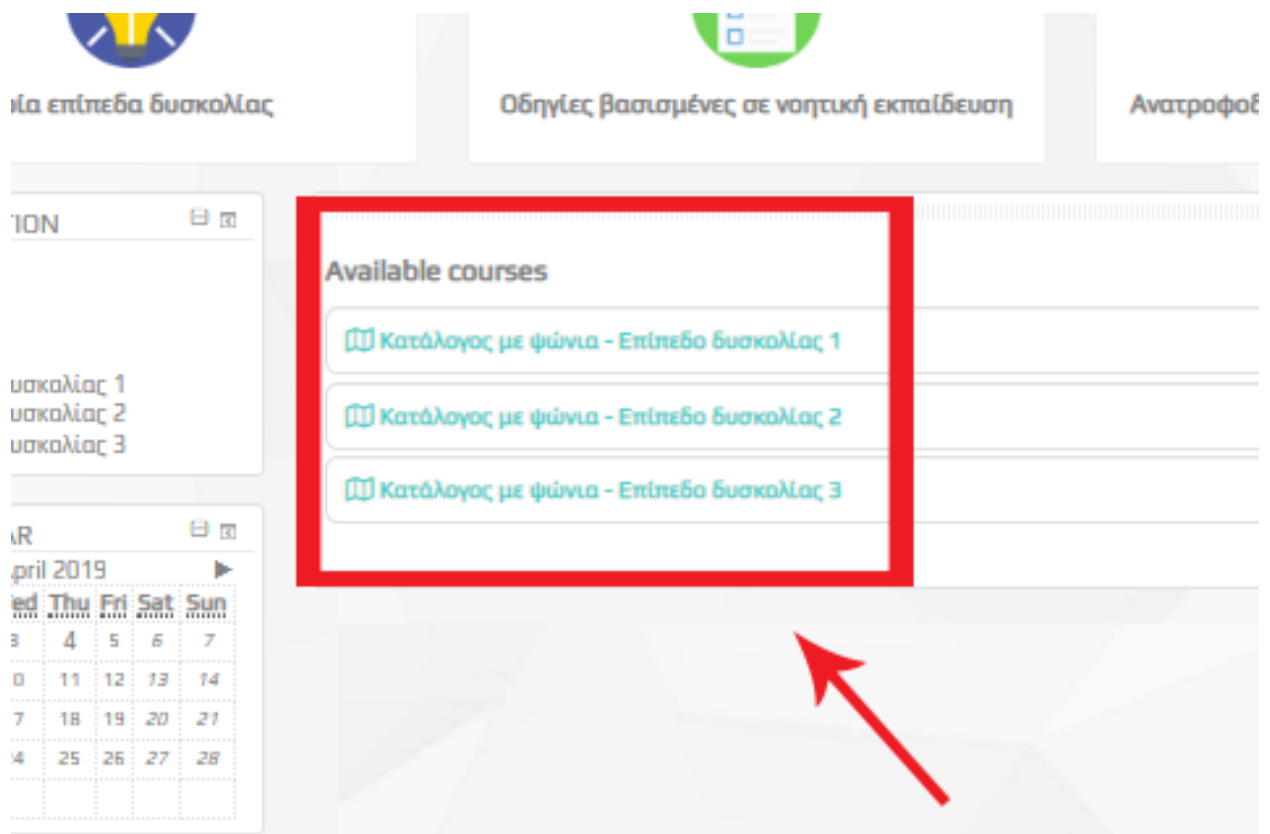
Starting by accessing difficulty level 1, the page with the level's exercises is presented and then we can have access to the exercise's content by clicking on an exercise's title. As seen in Figure 6.9, in difficulty level 1 there are nine exercises, some of which have extra sub-exercises. The sub-exercises are a part of the same framework and they do not differ in concept or the way of solution.

Figure 6.9 List of exercises - Level 1

After we access exercise 1, the content of the exercise is displayed with a clear description, in order to be solved. In the content there is a product catalog which contains various foods or items. Below every product, there a description with the product's name, in order to be more specific and to avoid misunderstanding. Subsequently, on the exercise page, along with the task, there are also a navigation menu, a progress bar and a link to the next exercise, as seen in Figure 6.10.

Figure 6.10 Exercise 1 - Level 1

After the completion of each exercise, there is the option of proceeding to the next one, return to level 1 page with the list of exercises, or navigate through the menus. If we choose to return to level 1 page, we can see that a completion mark is displayed next to the title, as displayed

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in Figure 6.11, which means that the exercise has been marked as completed. Almost every exercise is automatically marked as completed, as soon as the user receives a grade, except from exercise 9 on each level. Exercise 9 is an observation exercise and it is manually marked as completed by the user when it is completed.

Figure 6.11 Exercise Marked as Completed

A brief example of an exercise and of its solution is displayed in Figure 6.12 and Figure 6.13. Based on the instructions displayed below, this exercise's goal is to drag the proper food items/products and drop them on the right spots, in order to achieve forming three pairs with these food items/ products. After the completion of this exercise, the same as all the exercises in every

level, the user can continue to the next one or navigate somewhere else on the platform, such as the front-page, the levels, the grades area, his profile etc.

Figure 6.12 Example of Exercise 4.2 - Level 2

Figure 6.13 Completion of Exercise 4.2 - Level 2

Another example of an exercise and of its solution, this time in level 3, is displayed in Figure 6.14 and Figure 6.15. In this case, the difficulty level has slightly increased. There is a clear description with the task that the user needs to accomplish. The task of this exercise needs the user to identify the items that belong to either one of the categories described on the tags, if they exist. Then he needs to find if these items are placed between any of the given letters in the description based on the category that they belong. Finally, if the user finds any items that fulfill the requirements, he needs to drag and drop the tag on the correct item, in order to complete the task.

Figure 6.14 Example of Exercise 2 - Level 3

Figure 6.15 Completion of Exercise 2 - Level 3

At the time that the user starts to solve an exercise, then the evaluation process begins automatically. The user is evaluated based on the completion score of each exercise in every level, based on the answers that were correct and these scores are kept in a specific area on the platform, called "Grades". In order to access Grades, click on user icon and then click on "My Grades" on the dropdown menu, Figure 6.16. In the Grades area, the three difficulty levels are displayed under the tag "Courses I am taking".

Figure 6.16 How to access Grades
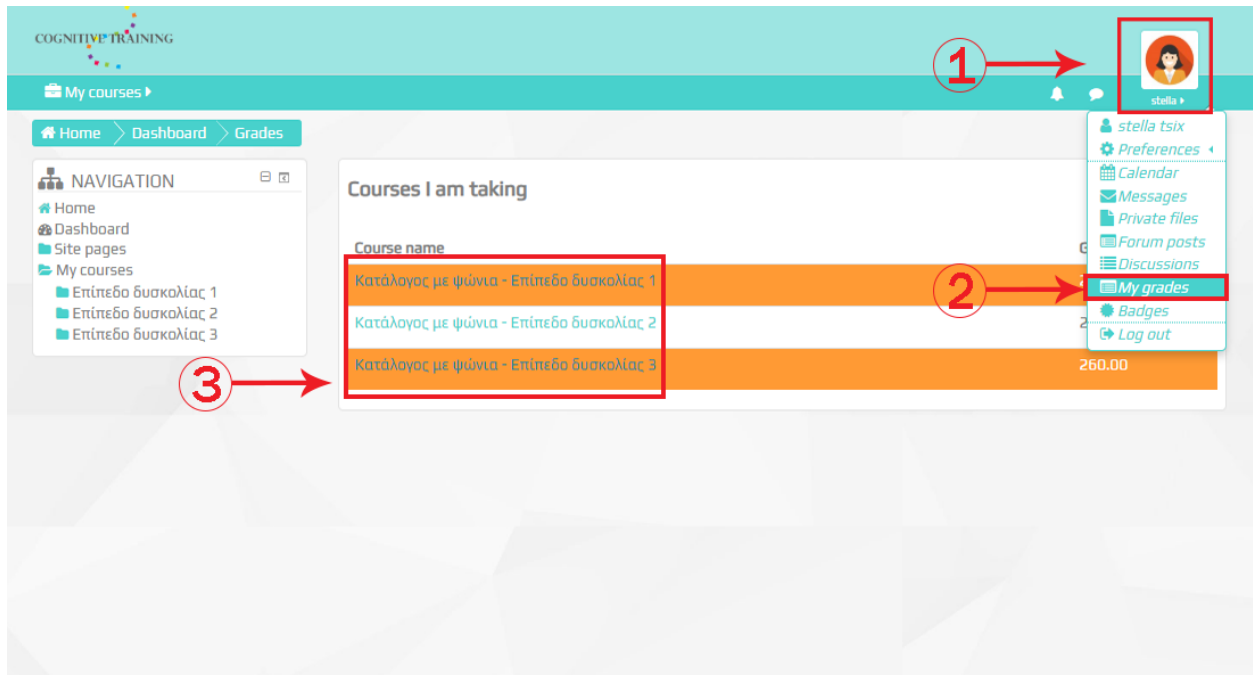
In addition, there is the ability for the user to see an overview of his grades in the User Report area (Figure 6.17), by clicking on the desired level. A detailed table is displayed, containing a list with all the exercises of the level along with grade, range, percentage, feedback and contribution to course total for each exercise, as displayed on Figure 6.17. User Report is a valuable tool since it provides all the grades for every exercise in each level and the user has the ability to see exactly in which exercise, he didn't fully complete the task.

Figure 6.17 User's Report

Grade item	Calculated weight	Grade	Range	Percentage	Feedback	Contribution to course total
Κατάλογος με φώνια - Επίπεδο δυσκολίας 2						
Οδηγία 1.1	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 1.2	0.00 % (Empty)	-	0–10	-		0.00 %
Οδηγία 1.3	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 1.4	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 2	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 3.1	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 3.2	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 4.1	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 4.2	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 8	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 5.1	0.00 % (Empty)	-	0–10	-		0.00 %
Οδηγία 5.2	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 6.1.1	0.00 % (Empty)	-	0–10	-		0.00 %
Οδηγία 6.3.1	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 6.1.2	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 6.3.2	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 6.1.3	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 6.3.3	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 6.3.4	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 6.1.4	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 7.1	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 7.2	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 7.3	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 7.4	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 6.2	4.17 %	10.00	0–10	100.00 %		4.17 %
Οδηγία 6.4	4.17 %	10.00	0–10	100.00 %		4.17 %
Course total	-	230.00	0–240	95.83 %		-

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7. Conclusion and Future Work

The work reported in this thesis aimed to the development of a cognitive training platform specialized in eMCI individuals, in order to support the duration of proper cognitive functioning focusing on the sustentation of activities of daily living and the possible early detection and recognition of MCI by clinical experts. Since, to our knowledge there are limited eMCI-focused applications, the development of an online platform for cognitive training of individuals of high risk or individuals facing eMCI, is of high value. Three difficulty levels, with a series of interactive exercises each, were designed and developed focused on eMCI individuals [1][3][33].

Diagnosis of eMCI can be done only by the assessment of an expert managing the scores and results of the exercises of the cognitive training platform and not automatically. The overall goal of this thesis was to create a valid and useful tool/platform for the cognitive training and the evaluation of individuals with eMCI. Future work includes further development of interactive contents in order to be included in the existing exercises, along with the possible existence of new levels for empowering the training process and formation of proposed diagnostic branches to clinical experts for supporting their clinical decisions.

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