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A learning style – driven architecture build on open source LMS's infrastructure for creation of psycho-pedagogically – 'savvy' personalized learning paths

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1. Introduction

A host of research has been devoted to the way individuals acquire and perceive educational material in relation to their personality profile (Wallace et al, 2007). However, when e-learning is the case, the same issue becomes more complex than the traditional face-to-face learning process (Graf et al., 2008). Classic teaching approaches do not typically necessitate stern alignment to the learners' skills, aptitudes, preferences, perceptiveness, capacity and/or special abilities –how much more, to any fine inherent differences among knowledge recipients, mostly because they rely on the arbitrariness allowed or tolerated in any live contact. In contrast, it is now widely acknowledged that e-learners do differ in this variety of qualities (Jonassen et al., 2000) in so distinct and challenging ways that e-environments should at some point adjust to them –and this appears more pressing than ever, if effectiveness of e-education is the operative goal, since e-communication entails incalculably heightened demands from both e-tutors and e-learners being notably exposed through the medium. Contemporary e-educational methods are oriented towards satisfying this prerequisite to meet special characteristics of admittedly savvy e-learners and this tendency is reflected in the current web-based e-learning systems (Hauger et al., 2007).

The e-Learning Management Systems (e-LMSs) are most popular in the knowledge provision efforts made, and are constantly evolving, based on contemporary ICT research results, such as multimedia and broadband Internet, as well as offering flexibility in terms of the users' time-management and e-environment familiarization in order to facilitate e-learning processes within recognizable educational settings. They have thus found wide applications in an increasing number of educational institutions. Still, enough issues have to

be additionally addressed and solved before firm assessments of the efficiency of such approaches are satisfyingly conclusive. Such issues are here seen to pertain mainly to two major axes: **a)** the refinement of the very e-system itself by deepening meaningful methodologies of treating e-information and **b)** the expansion of its points of reference by seriously taking into consideration principles, tenets and actual applications of neighboring disciplines, with psycho-pedagogy being dominant in this account. A closer look to recent developments follows to highlight these issues. Emphasis is put in merging the former with the latter axis, with attention paid to the personalization of the content that the e-learner seeks for, and, correspondingly, the personification of the quest of the very same e-learner.

To avoid commonsensical traditional learning methods of the 'one-size-fits-all' approach and to consequently adapt to the users' personalized needs, the e-LMSs structures employ adaptive hypermedia systems (AHS) methods (Brusilovsky, 1996). Current e-Learning platforms have begun to benefit from these innovations. The availability of a variety of learning objects (digital resources that can be shared and accessed through the Internet and reused in multiple teaching and learning contexts) also boosts their wider acceptance. In addition, educational standards such as LOM, SCORM, IMS, and PAPI, have been implemented and lead up to their further development.

Progressively, however, a most interesting shortcoming arose, that an open source LMSs lacked features of personalization and subsequent dedication of learning paths for the individual learner. This limitation highlighted a closely related additional need: any features of personalization that would eventually emerge from research oriented towards satisfying such newly arising requirements should be structured by paying close attention to, and taking action for incorporating features which would directly and functionally reflect psycho-pedagogical theory in hard practice – indeed, using an automated procedure. Early efforts that approached provision of personalised learning paths were either based on the performance of the learner (Carchiolo et al., 2007), or on indications of her/his preferences (Graf et al., 2008). Many existing open source LMSs (e.g., Moodle) still confine their personalization approaches to adapting their interface to the preferences of the learner – a feature, which, however positive might be, does not, however, escape the peril of overgeneralization, thus leaving a considerable gap in the field of multidimensional provisions that become progressively essential for the contemporary e-user's needs. In addition, the mode of tracking e-learners' preferences has in many such instances risked breaching of personal data and confidentiality.

In this light, the current work firstly examines psycho-pedagogical principles connected to Technological Enhancement Learning in some detail, in order to tackle issues of interest in helpful tools and features of a capacity to be exploited for further improvements. It then proceeds in proposing an architecture that can be applied upon the current structure of any LMS and may contribute to a more integrative, even holistic approach of personalization. To this end, key-learning psycho-pedagogical theories with an emphasis on dialectic cognitive-constructivism are earlier discussed pointing at an effective knowledge provision favouring personalization; the theoretical background of adaptation is examined as the basis for their implementation; research done towards this purpose is selectively reviewed; and learning styles are inspected as a palpable method to concretize outcomes from the amalgamation of influential tenets which were selected as superior on personalization-relevant precepts.

2. Background

2.1. Psycho-pedagogical theories in Technological Enhancement Learning (TEL)

Technology Enhanced Learning systems (TEL) is a term referring to the actual activity of learning with the support of technology as inferred to be constantly evolving to incorporate increasingly sophisticated functions for the best interest of e-users. Important enhancements in this respect may well be signified by solidification of psycho-pedagogical precepts into e-provisions for advancing e-learning efficacy. This area will be hereafter looked at.

Each learning process may be perceived as a cognitive encapsulation of transformed information that is offered by different sources into new forms of (brain/thinking-) patterns /schemata. The nature of these transformations distinguishes the type of the pertinent learning strategy applied each time for elaboration. Each strategy in its own right constitutes a descriptor of this process. Largely, learning theories have evolved from behaviorism, holding that the 'student' is an 'empty container', but have eventually been scrutinized within the realm of cognitive approaches, averring that the process is dependent on brain functioning due to thinking activity in response to the information that is imported. A radical development of these conceptualizations has been relatively lately offered by the constructivist view according to which the 'student' creates his/her own milieu of significance (Ally, 2004). By concretization of the cognitivist metaphor: 'mind as computer' in both i) positivist methodological and ii) symbolic theoretical precepts, constructivism has gradually evolved to delineate with cognitive schemata, analyses and met-analyses, thus becoming a major learning paradigm, eventually termed cognitive constructionist approach (Wallace et al., 2007). This tenet places constructivism at the core of the most dynamic conception of contemporary management of learning, notably as it has lately encompassed a social milieu notion, wherein meaning is created by virtue of the learner's frame of reference as multiply related to people, places and objects plus to self- and time- dimensions.

Simpson (2002) credibly argued that constructivism is a psychological and philosophical perspective, and an epistemology rather than merely a learning theory. Indeed, without refuting certain behaviourist tenets, it is predominantly referred to as a learning theory in line with cognitivism (see, e.g., Schunk, 2003), in that it fosters active involvement of the student in the learning process that is offered within a democratic, dialectic environment aiming at essentially 'extracting' knowledge from within the individual, as structured or 'semi-structured' mental schemata allow for building new concepts upon 'preexisting' patterns. Notably, the latter are highly subjective, hence have to be regarded as (treatable as) individualized. It is foreseeable that increasingly educators and institutions will tend to adopt this line of thinking when handling educational issues especially in the realm of e-education, and to eventually challenge the traditional passively-lectured-trainee view, with a growing appreciation of different ways of prompting students to 'knowing the world'.

Constructivism acknowledges the active role of the learner in interpreting reality (Larochelle et al. 1998), challenging the objectivist view which suggests that 'facts speak for themselves' and it thus offers an alternative philosophy, according to which constructions and views of the world are not stable, but are in continuous change being largely built upon past experiences and potentially directed by the learner's degree of initiative to precisely energize alternative interpretations at each given moment of the knowledge experience. Unfolding in time constructivism has well passed its initial 'versions' of moderate/ exogenous approach, which dictated a close inspection of the learner by a tutor still bound to exert increased control over both the knowledge recipient and the teaching content. The

theory's two major consecutive phases/versions, though, have underlined the importance of gradual suspension of directiveness, at first favouring the radical/endogenous facilitation of knowledge acquisition, wherein democratic processes ease accessibility to knowledge. At its latest articulation, the approach inclined favouring the furthest conception of dialectic constructivist recourse, where a tutor acts as a mediating 'scaffold' remotely guiding the student near conquering, beyond knowledge, the alternating paths to it (Dalgarno, 2002).

Even though current theories embed elements originating from behaviorism and cognitivism, however, emerging online strategies tend to place emphasis on participation in online collaborations and in fact move to set as a goal the implementation of constructivism (Jonassen, 1999). With the support of rapid technological developments these modern trends in education lead to new methods of knowledge delivery. Ally (2004) claimed that all three approaches of learning can be used successfully at the process of designing online learning environments, by using "behaviourist strategies to teach 'what' (facts), cognitive strategies to teach 'how' (processes and principles) and constructivist strategies to teach 'why' (higher level thinking that promotes personal meaning and situated and contextual learning)".

Consequently, TEL should ably support and adapt to various psycho-pedagogic methods, as well as to the different functional requirements provided by these approaches (Lee, 2008).

Even though Dalsgaard (2005) partly concurred with Ally (2004) in the prospect of combining theoretical tenets, however, he also suggested that it is not possible to construct a generic-catholic-universal framework for TEL, because it should be founded on a specific learning theoretical approach, which, nevertheless, cannot give answers to all questions of educational design. Dalsgaard accordingly proposed the development of three consecutive frameworks based on three adjunct theoretical tenets on learning:

a) The cognitivist approach: having grown into a doctrine based on the various time-, empirical observation-, and hard data of field research evidence- proof, that there are mental structures underlying not only thought, but also emotion, as well as the very perception and interpretation of both, inner/internal and outer/external source information (Lazarus, 1999). Gardner (1993), whose multiple intelligence theory is based on cognitivism, asserts that mind consists of numerous fairly specific and independent computational mechanisms, and it is in this context that research on learning styles has also been promoted. Based on cognitive learning theory, the structure of content of the cognitive matter should be organized hierarchically. Relevant research (Deshler, 1986) has surely led to the conclusion that students learn mainly from the progressive and relation-linked construction of knowledge. This approach may well find applications in a Learning Management System (LMS) with a psycho-pedagogically driven learning path creation module.

b) The radical, as interlocked with the dialectic, constructivist approach: holding that learning is a subjective and internal process of construction of (subjective) meanings and is considered as a result of the organization and the adaptation of new information in already existing knowledge. Students are able to structure their mental forms from facts (experiences) filtering them through their previous experiences. The individual determines how to proceed based on his or her unique needs, perceptions, and experiences, distinguishes known from unknown, identifies resources available to support learning efforts, and formalizes and tests personal beliefs (Hannafin et al., 1999).

This constructivist view is cogitated in the work of Ernst von Glaserfeld (1984), the psychologist who depicted it as "... a radical theory of knowledge" –knowledge, as seen not to reflect an objective, ontological reality, "but exclusively an ordering and organization of a

world constituted by our experience" (p.24). Learning here is not taken as a phenomenon of the "stimulus-answer" type. The challenge faced by the teacher is how to build hypothetical model(s) for the diverse cognitive worlds of students, which might be extremely different to those initially 'predicted' (von Glaserfeld, 1996) –a challenge, that may well be met by LMSs. Lastly, the third framework advised to function in synergy by Dalsgaard was:

c) The activity theory approach: interpreting the *actions* of the individual as components of wider *activities* that are meaningful in social and practical situations of the physical world. Actions actually produce novel mental forms and structures that can be viewed as tools of interactive usefulness. Such powerful tools, in turn, may shape the basis of knowledge and learning, especially e-learning (Nardi, 1996). In this perspective, designers of a learning resource system implementing constructivism have to analyze human activity systems based on psycho/socio-cultural, psycho/socio-historical criteria focusing on the interaction of human activity and consciousness within its relevant environmental context. Educators have started to conceive the interesting possibilities of using technology (Fjeld et al, 2002), but the change in the psycho-pedagogical focus and the variety of psycho-pedagogic requirements import new prerequisites in the way in which the technology should be applied as well as in the way by which such an ideal psycho-pedagogical design should be realized by technology. Even today, technology still supports behaviourist approaches emphasizing instruction and practice rather than learning to learn –how much more, learning self-regulation towards learning. Learning technology should become more flexible, combining progress in both psycho-pedagogical methods and technological tools.

Consequently, a logical question arises: how can e-Learning systems be developed and used so as to apply such concepts, which, however complex they may be they nonetheless constitute an appealing challenge if the best interest of e-learners is to be the ultimate goal? According to the Hannafin et al. (1997) creed, as shown in Figure 1 (borrowed from their work), a pedagogical e-learning system can be founded on a) a learning theory, b) learning principles, and c) the use of technology (and other materials) for different activities in the learning environment. These dimensions represent three clashes of abstraction –the magnitude and depth of which are ideally expected to be reflected on the work of a designer of a learning object system while targeting e-learning success.
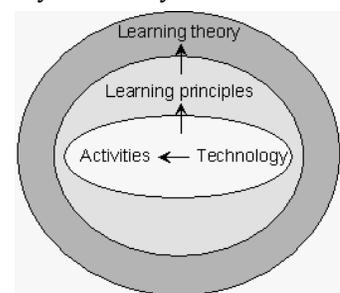

Fig. 1.Hannafin et al (1997) Founds of a pedagogical e-learning system

To the best of the current work's knowledge, a learning object system based in theoretical approaches steeped in cognitive constructivism has not yet been fully developed. The application, though, of processing theory and cognitive-constructivist principles in a parallel mode may surely offer a new perspective on the development and retrieval of learning object systems and it has been accordingly suggested that e-students should be encouraged to become actively involved in such a dynamic system in a manner that they can be creatively engaged in the very design of the repository of these learning objects: this can be achieved by stimulating representations of their knowledge –indeed, on a wide collaborative basis (Bannan-Ritland et al., 2000). In the same spirit, the process rather than the outcome is the optimal focus, with an aim to generalizing individualized gain-scend rather than any over-generalized trite-trend. Thus, an advanced learning objects system would provide the desired process-based frameworks and guidance to harmonize the

various resources and approaches – ergo assist the e-learner to make the best use of an authentic constructivist learning environment for a meaningful accessibility to knowledge.

2.2. Learning Management Systems (LMSs)

This most prolific stream of cognitive-constructivist thinking (Vygotsky, 1978; Brown et al., 1989; Jonassen et al., 2000) treats learning as an active collaborative process led by the learner her/himself and steered by problem-solving activities. Nowadays, a very popular means to provide knowledge is through information technology-based systems developed to support electronic delivering of knowledge. These systems are widely known as Learning Management Systems (LMSs), and, as Lee (2008) explained, they are a wide range of systems that organize and provide access to online learning services for students, teachers, and administrators, and which, as a wide-range set of services, usually include access control, learning content provision, communication tools, and organization of user groups. It is therefore precisely these systems that ought to align with, and keep up the cognitive-constructivist approach for the best interest of e-users.

The LMS are chiefly capable of offering services for administration and management of the learning processes/courses/Learning Resources (LRs), by being based on, rather than straightforwardly providing downright psycho-pedagogical explicit activities (Ismail, 2002). In this sense, psycho-pedagogical context is envisaged as circumscribed within the content of the Learning Resource (LR). Subsequently, the essential constituents of the application logic containing the psycho-pedagogic material are to be coded into the digital learning content. The actual systems designed to support teaching and learning over the Internet are known as Virtual Learning Environments (VLEs). Nevertheless, the common use of the term LMS is to describe the actual role of the VLMs. Henceforth, the term: "e-Learning Management System(s)", abbreviated as: 'e-LMS(s)' is adopted to describe the functionalities of the VLMs.

2.3. Adaptation & Personalization in e-LMSs

Adults, the main recipients of e-LMSs provisions especially when solely e-learning requirement is the case, have specific needs regarding their e-training, as they face specific restrictions, mainly connected to time, personal obligations and vocational duties, along with possible limitations in terms of the degree of their familiarization with knowledge accessibility and fast-track acquisition tactics as well as possible ambiguities and even insecurities on refining their vision and prospects for developing their professional career – especially as the latter is increasingly connected to pertinent educational needs, which, in turn, are mainly incited within a rapidly evolving era towards life-long-learning demands and reforms. Moreover, adult e-learners are fairly seen as of a more-or-less solidified personality (Rogers, 1999), with more-or-less rigid cognitive schemas and with a more-or-less reluctance if not resistance to re-evaluate attitudes and re-script interpretations. These as challenges are to be met by the e-LMSs. To fulfill these needs e-LMSs have to be adaptable to the e-learners' current state/profile. Adaptive Hypermedia Systems (AHSs) do provide the theoretical principles of adaptation sought for (Brusilovsky, 1996) being the systems that can alter the interface or their content in accord with the attributes of their user. Web-based e-Learning systems are AHS with applicability especially in educational settings.

Adaptation techniques can be largely distinguished into two categories: i) those that provide navigation support and ii) those that provide presentation support. Several implementations of these techniques are on the whole based on facets of the direct navigation of the user, potentially differential interfaces for each user, etc. An adaptive system that supports such aspects must be designed so as to take into consideration:

A. the user's goal or user's task as related to the context of the hypermedia system,
B. the user's background, i.e., his/her previous experience beyond the subject of the hypermedia system, which is relevant enough to be considered –including lemmas such as the user's profession, experience of work in related areas, etc, and, finally,
C. the e-user's preferences as understood here to include learning styles and indications on profiling any additional number of their properties.

Features of the first category match the situational dimensions of the e-use ad hoc.

Features of the second category concern the content presented in each user. It is here deemed that an adaptive e-LMS emphasizing content personalization should contain:

1. a learner history profile, on details about his/her broadly relevant background, history of thematic preferences, degree of past (un)successful exploitation of the medium, demographic characteristics such as age, gender, family status, training objectives, as well as alternative objectives envisaged and/or hoped for in the course of the e-search
2. a learning resources (LRs) detailed description, with records of existing contents and capabilities plus updates on additional auxiliary and/or supplementary tools, and
3. a correlation function associating e-learner's characteristics with characteristics of the LRs during the learning process – that is, a function that accounts for various facets of the effect that several LRs characteristics have (and had) upon the e-learner. Finally,

Features of the third category refine and deepen the conditions of e-use by pondering into the e-learner's qualitative characteristics, her/his capabilities in knowledge acquisition that is described by his/her learning style, traits and trends regarding e-content uses, etc.

2.4. Learning resources and their role in personalization in e-LMSs

As indicated, a LR is adequately described as any digital entity which can be used, reused and/or referenced during a technology-mediated learning process – hence useable for learning, educational, and/or training purposes. The LRs are in the core of a e-LMSs with the latter being the apt vehicle for the LRs to be provided in a most discernible and at the same time flexible formulation for education and practice.

Their probably most generative method is their capability to construct small, independent units that can be (re)used and (re)arranged in taught e-courses. The creation of different courses is an apposite combination of these e-course units. Moreover, in current e-LMSs several methods are available to create the same educational result, as they provide i) a variety of LRs formats (docs, html, ppt presentations, video/audio files, different kinds of questionnaires etc) and ii) a vast collection of tools, as for assessment (particularly of types automatically scored and stored, as multiple choice), discussion forums, chat, file sharing, video conferences, shared whiteboards, message, e-portfolios, content uploading, students' work return, peer assessment, student groups admin, their grades' collection and clustering, questionnaires, tracking tools, etc. Most recently developed features in these systems include wikis, blogs, RSS and 3D virtual learning spaces. This variety allows the e-tutor to comfortably select from a wide range of facets in order to address each e-learner's learning

needs – on the basis of significant findings (Graf et al., 2008) establishing that the learning process is highly and effectually facilitated when the learner learns the way s/he prefers.

2.5. Learning standards

Notwithstanding their indisputable assets, the reusability and interoperability of learning objects has been presented as a major problem in adaptive learning, inasmuch solutions of their technical linking are not directly presupposed. Standards have been thus adopted by the e-learning community to facilitate and foster interoperability and reuse of learning artifacts among different e-learning platforms. The pertinent use of predefined sets of metadata promotes the exchange of LRs among different e-learning systems and content providers, while offering higher potentials for finding existing learning content as well. Such standards for the learning resources are Learning Object Metadata (LOM) and Sharable Content Object Reference Model SCORM[1]. Standards have likewise been developed for the description of learners as well, such as LIP, PAPI, Dolog LP, FOAF[2].

LOM and PAPI are important to briefly review in the present account, as viewed to not only be popular, but also concentrate the most interesting characteristics for multi-purpose LMS applications in accord with psycho-pedagogical cognitive-constructivist principles.

2.5.1. Learning Object Metadata (LOM) standard

Indeed, most broadly used for the description of the LR is the Learning Object Metadata (LOM) standard. Its specifications can be found on the Learning Technology Standards Committee (LTSC) of IEEE (2002), the certified body that originally promoted LOM, in order to provide structured descriptions of every digital entity, namely, the LR, precisely towards learning, education, and/or training usability. To describe the content of LRs, LOM is stratified into a pre-defined vocabulary classified in nine main categories:

1. general, which groups the general information that describes the resource as a whole,
2. life-cycle, referring to the history- and current state- related resource features, and those that have affected this resource during its evolution,
3. meta-metadata, on information about the meta-data per se,
4. technical, about the technical requirements and characteristics of the resource,
5. educational, which groups the educational and pedagogic features of the resource,
6. rights, defining the rights and conditions of use for the resource,
7. classification, which describes the taxonomy of the resource, and finally,
8. annotation, offering and storing history of comments on the LR's educational use.

These categories treat a given object in an inclusive way, thus allowing easy usage of them in an e-Learning system.

2.5.2. Personal And Private Information (PAPI) Standard

The Personal and Private Information (PAPI) standard presents the learner's educational and professional progress. The PAPI descriptors refer to the learner's:

 1. educational level, learning experiences, and background,

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[1] specifications of SCORM can be found in Advanced Distributed Learning (ADL, 2004).

[2] a brief comparative presentation of these standards can be found in Ounnas et al. (2006).

2. performance in different educational topics, certificates, qualifications, licenses, diplomas, skills granted by authorized institutes,
3. rights to access information (herein suitable to enrich by ethical standards insertion)
4. preferences, as for, e.g., written/spoken language, favored document format etc, or LRs.

2.6. Learning Styles

Keefe (1991) asserted that learning style is both a student characteristic and an instructional strategy. As a student characteristic, learning style indicates how a student learns and likes to learn. As an instructional strategy, it informs about cognition, context, and content of learning aspects. Roy & Chi (2003) examined whether the way a learner approaches the educational process, the way s/he searches for information, and even the LRs' format and content, contribute to improving his/her learning performance. Mitchell (1994) identified more than 100 proposed models which claim to depict the e-learners learning styles.

From the available learning style models, the Felder and Silverman model prevailed for the current account, chiefly due to its clear-cut multidimensionality. This model distinguishes two styles of learning, physical and sensing, and contradistinguishes their subtypes by discerning special properties: For each style, 5 different learning types of learning are further defined: sensing-intuitive, visual-verbal, deductive-inductive, active-reflective, and sequential-global. It also provides clear relationships between the different characteristics of the LRs and the learning characteristics of the learners, as shown on Table 1.

Learning style	LR properties	Learning style	LR properties
Sensing	Experiments, data, facts, LRs of high interactivity	Intuitive	Pictures, diagrams, flow charts, primitives, concepts, theories, LRs of high semantic density
Visual	Books, printings, diagrams, flow charts, videos, avi, presentations, timelines, demonstrations, films	Verbal	Case studies, experiments
Deductive	Books, diagrams, presentations	Inductive	Text, books, pictures, videos, avi
Active	Experiments, tutorials, presentations	Reflective	Papers, books, self-assessments
Sequential	Books, flow charts, algorithms	Global	Maps, pictures, novels

Table 1. Felder-Silverman learning types and their preferred LR characteristics

Outcomes of the learning style models have been used in several experiments (Graf et al., 2008; Kerkiri et al. –in press) as a method to provide personalization.

3. Determinants of an architecture built upon open-source LMSs

Incentives: Stepwise following the evidence examined above, the currently proposed model of content personalization, by employing TEL enhancements linked with psycho-pedagogical tenets, is triggered by a number of key-factors, including: **a)** the desired availability of a variety of well annotated LRs for the same educational purpose, with each one: **i)** having different characteristics that shall feed the LMS, and **ii)** being able to be contained in either an internal or an external repository; and **b)** the preferable and advisable

large number of capabilities that would yield automated matching of the characteristics of LRs on the one hand, and e-learners' on the other.

Additionally posited here is that the desired automated matching is to be guided by proper description of the LRs properties. Such directly generated knowledge indicates the LRs' educational capabilities and it also eases their automatic discovery from software agents.

Initially, to tackle any availability of such capabilities in the open source LMSs, the most popular of them were exhaustively evaluated. Open source LMSs were focused upon mainly because: i) a great number of the educational institutes satisfyingly support their curricula by them and ii) a great number of resources are already available for them.

Trailing: Still, on the pretty colloquial, yet ratified whim: 'better is the enemy of the good', it was postulated that at least three e-attributes on provisions to e-learners could be closely inspected: First, the existence (or not) of a shielding umbrella-formation keeping essential structures of the already existing fundamental framework both intact and operable without jeopardizing the system's accord. Second, the existence (or not) of any kind of supporting platform furnished with tools, concepts and features well-coordinated to offer qualitative services via a quantitatively rich range of educationally valuable materials (e.g., e-teaching modules); such a platform would not merely function as a pallet of 'assorted' supplies, but as a stage of action in terms of the required interoperability of these materials. A third, and equally critical determinant to trail – and, if not found, to create anew in favour of e-learners' satisfaction and progress – would be a robust mathematical formula, namely, an algorithm, which would be designed in a psycho-pedagogic spirit and be performed so that it would unambiguously rule, stem and sort information, material, and sequences for the best interest of all e-users engaged in an electronically conducted educational interaction.

Since these prerequisites point at, and almost directly presuppose personalization processes, a transitory trailing of favourable features would involve exploration of the capabilities of the existing open source LMSs for fostering such complex entities, equipment and operations. Results of this search are briefly presented in the following paragraph.

3.1. Open source LMSs personalization capabilities

To experiment on the open source e-LMSs capabilities towards personalization the most popular of them were installed: ATutor, Ilias, Claroline, Dokeos, Docebo, Moodle (Kerkiri & Paleologou, 2009). To explore their pertinent capabilities several apt criteria emerging from the definition of personalization systems as stipulated above (see section 2.3) were set: Thus, it was examined whether: i) these systems have a user model, ii) the LR is described as an autonomous entity, iii) these LMSs use properties to describe LRs and learners, iv) they create and/or handle repositories and lastly, vi) they employ a personalization algorithm.

Hence, the same course was created within each one of them. Some interesting findings emerged from this comparative research:

1) by and large, all LMSs contain a sufficient number of different kinds of resources and activities, as, e.g., forums/chats, questionnaires, quizzes, html/doc/pdf documents, surveys etc. This capability may potentially support different kinds of LRs which can better fit with different learning style types. This large, yet fairly scattered, variety, though, may well be seen as confusing for, e.g., an inexperienced e-tutor, who might be puzzled as to what and how to chose from, and technically, even as a 'l'art-pour-l'art' almost inconsequential feature, not necessarily functional for e-users;

2) in examining their storage-structure, each of these LMSs surfaced to lack consistency in supporting each LR and learning activity; besides, storage is not performed uniformly for all material. Albeit standards, such as SCORM, are often adopted as mediators for the transfer, yet, the observed storage disparities tend to complicate sharing between the several LMSs;

3) these e-LMSs do not support a storage-structure to maintain the properties of the LRs. Although Ilias was a brilliant exception, able to record LRs properties, and to follow the LOM standard, still, it did not seem to further utilize them. So, the e-tutor is deprived from seeing these properties during a course creation, and thereafter s/he is somewhat impeded to clearly decide on selecting over various features of, e.g., their quality, their place in a learning chain, etc, and, generally, feels uncertain of their value in an educational section.

4) only some of them, as, for instance, Docebo, Claroline, and Dokeos, as well as Ilias, do support repositories containing LRs, thus allowing their reusability. Also, the same e-LMSs support a tree structure (learning path) to build the course, while their capability to incorporate LRs from external repositories does not reach a full hierarchical taxonomy – so they tend to treat the LRs as rather unstructured, dispersed repository for the course; also,

5) no one of them managed to provide an automated method of creating the course – how much more to render genuine and serviceable personalization methods.
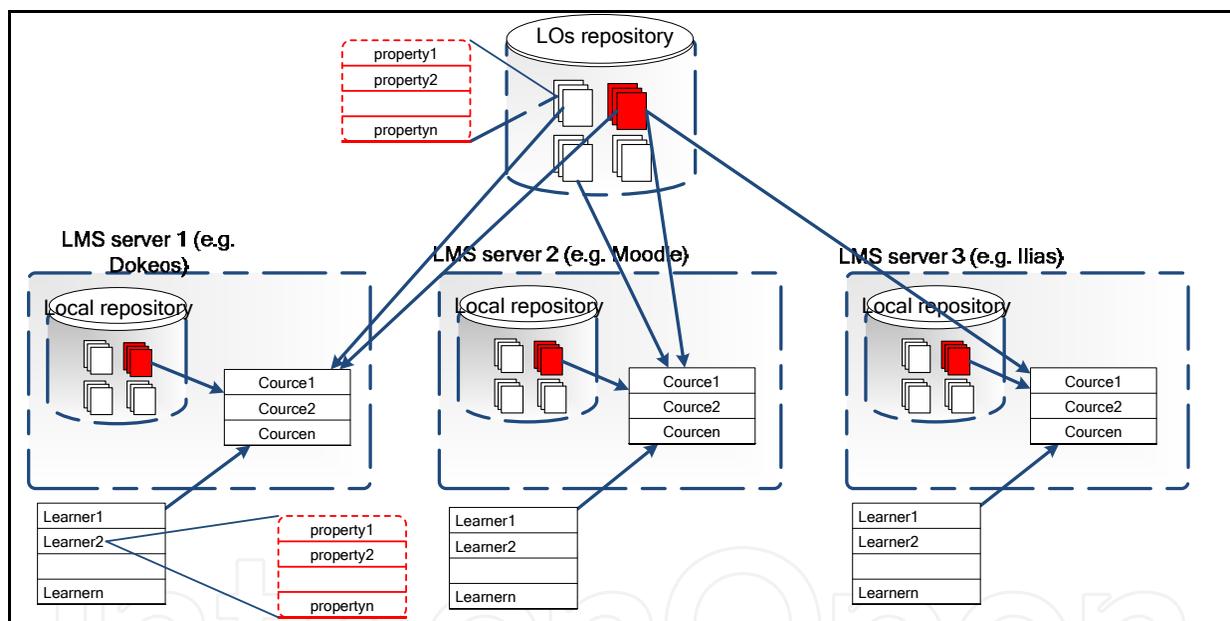

Fig. 2. The architecture of the proposed e-LMS

The herein proposed use of the LRs in e-LMSs is seen in Figure 2, displaying the relationship between the LRs and the e-LMS. As seen, this design ensures that properties of the LRs are obvious at a glance, facilitating their manual or automatic selection for even highly dedicated courses based on the e-learner's profile and their educational outcomes.

4. The structural components of the proposed architecture

To build a reliable personalization algorithm in open source-LMSs and in chorus keep these LMSs intact within their current structure, a concrete course of action is here submitted, chiefly pertaining to the creation of: **I.** a super-structure, **II.** an integrative platform, planned

to encompass certain key- functions and modules, and **III.** a bridging algorithm aiming at cognitive constructivist-founded personalization. This process is stepwise described below:

I. Creation of a super-structure, which would uphold the LRs properties and subsequently describe the factors that determine their capabilities. It is here suggested that upholding the properties may be attained by using metadata selected from an educational standard. This information is tied to the LR and is swept along the LR during its export from the LMS, henceforward being available in other LMSs through its import to them. This makes the LR both reusable and self-defined, thus reducing the LRs' creation cost. In a similarly developed additional structure, apposite information for the learner would be maintained as well.

Technologies that can identify an entity as a knowledge-structure along with its properties, their values, cardinalities, and constraints are those of the Semantic Web (Berners-Lee et al., 2001). In its framework, to define an entity a unique id (Unified Resource Identifier -URI) is ascribed and its properties described through metadata. For each instance of these entities a unique URI is also defined, and several properties are attached to it, via the format:

```
<resource Id><propertyName><property value>
```

e.g.

```
<LR-#201><hasDifficulty><Very Difficult>
```

which means that the LR having URI=LR#109 has the property: 'hasDifficulty', and the value of this property is 'Very Difficult'.

This method allows the extension of the LR's description, without affecting the whole model, with properties which have not been initially predicted.

II. Design of an integrative platform based on these two structures and automating the course creation. The modules accommodated in the platform of this architecture are seen in Figure 3, where input/output, functionality of each module, as well as their intermediate informational flow, are graphically shown as staged in a dynamically interoperable manner.
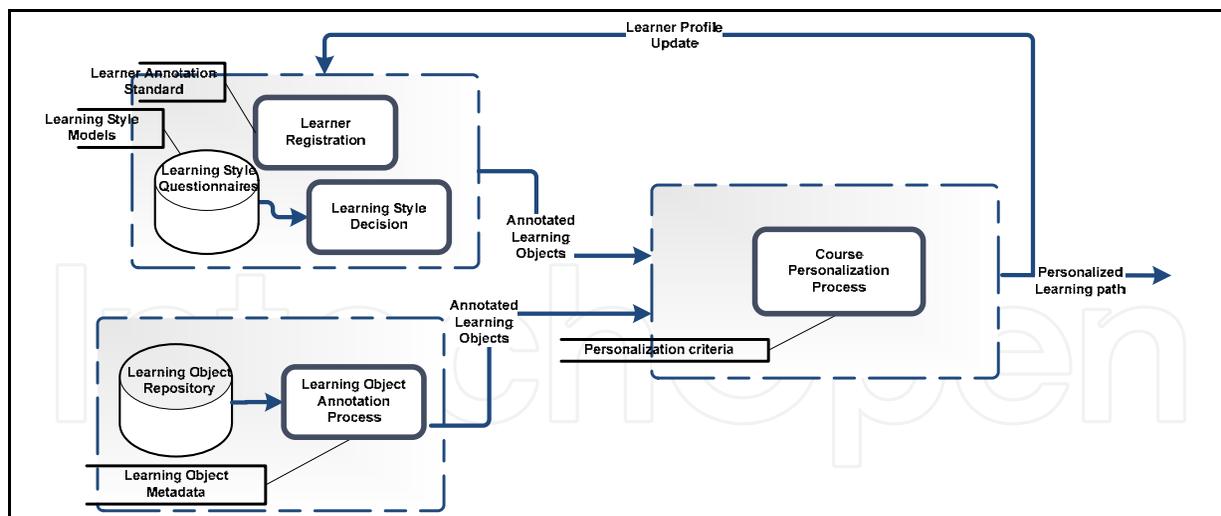

Fig. 3. The functional modules of the 'staging' platform of the proposed architecture

One by one, these modules are reviewed below:

a) learner profiling module: this module creates and maintains in a repository various learner-related demographic information (e.g., age, gender, learner's current goal and interest in the educational material), navigational history, etc. (Muntean & Muntean, 2008). These entries are maintained in a continuous and uninterruptible process via:

i) personal direct registration: securing information about the user's demographic details and (dis)likings, as time availability, appealing material format, means of delivery, etc.

ii) indirect updating derived from his/her navigation in the e-LMS. This type of information may relate to his/her progress, preferences, constraints, inclinations, etc.

Current LMSs, even the open source ones, keep tack of a number of a learners' actions, e.g. the time s/he spent over a course, the order in which s/he was engaged with several LRs and activities, the scores s/he made on quizzes, etc, thus tracing evidence on what might affect his/her professional carrier and on how his/her profile might be shaped. However, such records: are typically stored without being further utilized in a maximally productive way; remain independent entries far from being interoperable with other LMSs features; are invariably static, based on fixed characteristics of the e-user, not easily, flexibly, or at all correlated (e.g., tag a change of her/his navigation habits); and are not incorporated within the existing infrastructure in order to improve quality of her/his access to knowledge.

In contrast, one of the most important functionalities of the module submitted here is the learners' learning style specification, usually achieved by issuing the germane questionnaire. On the basis of its partial and total scores, the learner's profile is then manually updated.

Certain efforts have been made (Tuparov & Dureva, 2008) to enhance LMSs with the proper infrastructure and the functionality of learning style-decision oriented web-sites. Graf and colleagues (2008) reached extraction of the learning style based on the LRs that a learner has preferred. Generally, though, invariably using indirect updating of the learner's profile risks some considerable ambiguity. In this respect, perhaps the only reliable property for claiming valid results is the e-learner's performance per se – again, only when his/her examinations marks, and course/semester grades can be electronically delivered.

As learning approaches and strategies are still over implementation; tackling effect(s) of several factors such as learning style is under investigation; and concurrent e-LMSs are still under development; it appears that the safest method to trace the e-learners' learning style is an immediate update through a well-designed questionnaire.

If $C = \{c_1, c_2, ..., c_n\}$ defines the proffered structure describing the learners of an LMS, each learner c_i has k properties, posed by the ordered vector $c_i = \{p_1, p_2, ... p_k\}, \forall\ i = 1, ..., n$.

Every one property of the learner assumes a value from a well-defined domain. Explicitly, if:
```
hasPreferredLanguage, hasPreferredFormat, hasCertification, hasUserRole,
hasIntendeduserRole, hasLearningStyle, has Age, hasGender, hasLearningTime,
hasPerformance, hasClassification
```
are all part of the description properties of a learner. Their corresponding domains are:
```
PreferredLanguage={el, en, fr, …}
PreferredFormat={pdf,doc,wav,avi,...,txt}
Certification={Vocational Training, Higher Education, MSc, PhD, Continuous Formation}
UserRole={Beginner, Pro-Intermediate, Intermediate, Post-intermediate, Advanced}
IntendedEnduserRole={Lecturer, Learner, Trainer, Trainee}
LearningStyle={Sensing/Intuitive, Visual/Verbal, Deductive/Inductive,
Active/Reflective, Sequential/Global}
AgeRange={5-8, 9-12,13-15,16-18, 19-23,24-29,30-40,41-50,51-60,60-70, …}
Gender={m,f}
LearningTime={0:30-1,1-2, …}
Performance={ {lessonId, Grade} }, Grade E [0,10]
```
and then his/her profile is:
```
Ci ={hasPreferredLanguage, hasPreferredFormat, hasCertification, hasUserRole,
hasPerformance, hasIntendedEnduserRole, hasLearningStyle, hasAgeRange, hasGender,
hasLearningTime, hasPerformance}
```

Consequently, the vector of the specific learner c_i having id='URI2-User' is:

```
Ci ={User-2,http://www.uom.gr/eLearning/user2.htm,{el,en}, {doc,avi}, MSc, Advanced,
7, Learner, Active/Reflective, 24-29, m, 5-8, {Multimedia,7,6}, {H.2.5.2, Photoshop-
Masks} },
```

and his/her description using the ontological language Web Ontology Language (OWL) is:

```
<oxml:instance id="a:L#09"><oxml:instanceOf concept="a:Learner"/>
 <oxml:hasAttribute relation="a:name"><oxml:value>User 2</oxml:value>
 </oxml:hasAttribute>
 <oxml:hasAttribute relation="a:learnerURI">
   <oxml:value>http://www.uom.gr/eLearning/user2.htm</oxml:value>
 </oxml:hasAttribute>
 <oxml:hasRelation relation="a:hasPreferredLanguage" instance="a:el"/>
 <oxml:hasRelation relation="a:hasPreferredLanguage" instance="a:en"/>
 <oxml:hasRelation relation="a:hasPreferredFormat" instance="a:doc"/>
 <oxml:hasRelation relation="a:hasPreferredFormat" instance="a:avi"/>
 <oxml:hasRelation relation="a:hasCertification" instance="a:MSc"/>
 <oxml:hasRelation relation="a:hasUserRole" instance="a:Intermediate"/>
 <oxml:hasRelation relation="a:hasPerformance" instance="a:7.0"/>
 <oxml:hasRelation relation="a:hasIntendedUserRole" instance="a:Learner"/>
<oxml:hasRelation relation="a:hasLearningStyle" instance="a:Active/Reflective"/>
<oxml:hasRelation relation="a:hasAgeRange=" instance="a:13-15"/>
<oxml:hasRelation relation="a:hasGender=" instance="a:f"/>
<oxml:hasRelation relation="a:hasLearningTime=" instance="a:5-8"/>
</oxml:instance>
```

b) learning resource treatment module: the functionality of this module is to create and maintain a repository of well-annotated resources which can be used alternatively to teach the same topic. Towards this aim it has to record a set of LRs and clearly and specifically define their properties, so that each one shall be a self-described entity. These properties can describe their suitability for a specific type of learner, their suitability for a particular course, their potential classification in a learning path, their learning outcomes and educational aims/objectives. Using the various existing standards, e.g., Learning Object Metadata (LOM), or Sharable Content Object Reference Model (SCORM) is a very popular modus operandi to facilitate the LRs description.

A notable advantage of this module is the classification of the LRs in a hierarchical structure. Even the simplest taxonomy which only supports the: is-A relationship provides semantics as to the connection of the classified entities. In this case, a hierarchy is used to describe the learning path of a course, with each node of this hierarchy describing the course sections. This hierarchy also defines pre-requisition chaining (precedence-succession relationships) between the LRs. This categorization and the arrangement in a hierarchical node are further facilitated by usage of existing taxonomies, e.g., ACM especially for the Informatics. Thus:

Let the LRs of a repository be shown by the structure $L = \{l_1, l_2, ..., l_m\}$, where each l_j has l properties $l_j = \{p_1, p_2, ..., p_l\}, \forall\ j = 1, ..., m$. The properties and their domains D consist of the corresponding data elements chosen from educational standards, e.g., LOM. Indicatively, if using the LOM standard, the LR is described as:

```
lip={title, author, hasClassification, hasFormat, hasLanguage, hasResourceContext,
hasLearningResourceType, hasInteractivityLevel, isForEndUserRole, hasSemanticDensity,
hasCoverage, hasDifficulty, isForLearningStyle}
```

where the domains of these properties are correspondingly:

```
Description,
Classification={H.5.1.1 Web Design Tools, H.5.1.2 Image Processing Tools, ...},
ResourceContext={Vocational Training, Higher Education, MSc, PhD, Continuous
Formation},
LearningResourceType={Exercise, Figure, Book, Lecture, Tutorial, Paper, Diagram,
VideoAudio, Presentation, Lecture, Simulation, Questionnaire, Graph, Index, Slide,
Table, Narrative Text, Experiment, Problem Statement, Self-Assessment},
InteractivityType={Active, Expositive, Mixed},
InteractivityLevel={Very Low, Low, Medium, High, Very High},
SemanticDensity={Very Low, Low, Medium, High, Very High},
Coverage={Very Low, Low, Medium, High, Very High},
Difficulty={Very Easy, Easy, Medium, Difficult, Very Difficult},
isForLearningStyle={Sensing/Intuitive, Visual/Verbal, Deductive/Inductive,
Active/Reflective, Sequential/Global}
hasPerformance={ {lessonId, Grade} }
TypicalLearningTime
```

etc, where Format, Language, UserRole, IntendedEndUserRole, LearningStyle are defined as earlier and the 'lessonId' is derived from the curriculum of each educational institute. Consequently, the description metadata of an LR is:

```
<oxml:instance id="b:LR#201"><oxml:instanceOf concept="b:LearningResource"/>
 <oxml:hasAttribute relation="b:title"><oxml:value>Photoshop CS3</oxml:value>
 </oxml:hasAttribute>
 <oxml:hasAttribute relation="b:description"><oxml:value>Try this illustrated
reference guide ... available information during the exercises</oxml:value>
 </oxml:hasAttribute>
 <oxml:hasRelation relation="b:hasClassification" instance="b:H.5.1.2 Photoshop"/>
 <oxml:hasRelation relation="a:hasFormat" instance="b:html"/>
 <oxml:hasRelation relation="a:hasLanguage" instance="b:en"/>
 <oxml:hasRelation relation="b:hasLearningResourceContext" instance="b: MSc "/>
 <oxml:hasRelation relation="b:hasLearningResourceType" instance="b:SelfAssessment"/>
 <oxml:hasRelation relation="b:hasLearningResourceType" instance="b:Tutorial"/>
 <oxml:hasRelation relation="b:hasLearningResourceType" instance="b:Exercise"/>
 <oxml:hasRelation relation="a:hasInteractivityLevel" instance="a:High"/>
 <oxml:hasRelation relation="a:isForUserRole" instance="a:Pro-Intermediate"/>
 <oxml:hasRelation relation="b:isForIntendedEndUserRole" instance="b:Trainer"/>
 <oxml:hasRelation relation="b:isForIntendedEndUserRole" instance="b:Trainee"/>
 <oxml:hasRelation relation="a:hasCoverage" instance="a:Very High"/>
 <oxml:hasRelation relation="a:hasDifficulty" instance="a:Medium"/>
 <oxml:hasRelation relation="ab:isForLearningStyle" instance="a:Sensing/Intuitive"/>
 <oxml:hasAttribute relation="b:hasPerformance"><oxml:rId>DatabasesII</oxml:rId>
....................
 <oxml:grade>9.81</oxml:grade>
 </oxml:hasAttribute>
</oxml:instance>
```

So, an LR is an entity having a set of properties, which are directly and immediately shown, and can be straightforwardly combined to the properties of the learners, using a set of rules that are derived from the outcomes of the educational system.

c) personalization module: the adjacent personalization module is engaged with applying the proper parameters that connect the learners' characteristics to the ones of the LRs. The functionality of this module is shown in Figure 4.
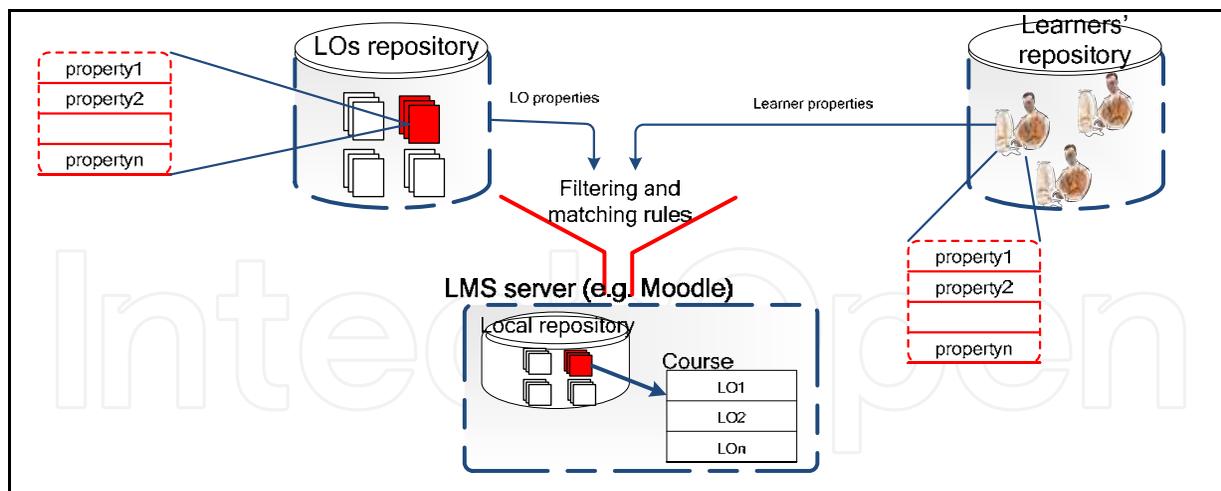
Fig. 4. Functionality of the personalization module

As seen in Figure 4, for a specific learner the personalization module uses the properties of each LR and the intermediate alignment structure that contains the matching rules, while selecting the most suitable learning resource from each node.

To create personalized learning paths the most apt LR is discerned from each node of the hierarchy for the specific learner depending on a number of chosen parameters. To this aim, an intermediate structure is created, used to combine characteristics of the two entities. This structure is of the form:

```
<alignenment>
  <LearnerPropertyId> </LearnerPropertyId>
  <weightL> </weightL>
                    //weight by which it participates in the matching
  <weightl,pr-id> </weightl,pr-id>
  <LRPropertyId></LRPropertyId>
  <weightLR> </weightLR>
                    //weight by which it participates in the matching
<weightlr,pr-id> </weightlr,pr-id>
                    //weight of this instance of the LR property
</alignenment>
```

Indicative entries of this structure are shown in Table 2:

Properties deriving from heuristic rules based on learning style						
Learner properties			Learning resource property			
hasUserRole	0.55	Beginner	hasDifficulty	0.33	Very Easy	0.9
hasUserRole	0.55	Beginner	hasDifficulty	0.33	Easy	0.7
hasUserRole	0.55	Beginner	hasDifficulty	0.33	Medium	0.5
hasUserRole	0.55	Beginner	hasDifficulty	0.33	Difficult	0.3
hasUserRole	0.55	Beginner	hasDifficulty	0.33	Very Difficult	0.1
hasUserRole	0.55	Intermediate	hasDifficulty	0.33	Very Easy	0.3
hasUserRole	0.55	Intermediate	hasDifficulty	0.33	Easy	0.5
hasUserRole	0.55	Intermediate	hasDifficulty	0.33	Medium	0.9
hasUserRole	0.55	Intermediate	hasDifficulty	0.33	Difficult	0.5
hasUserRole	0.55	Intermediate	hasDifficulty	0.33	Very Difficult	0.1

Table 2. Indicative entries connecting learner and LRs properties

This structure is used to create rules that match learners and LRs. Each rule indicates that a learner of given properties identified by the: <LearnerPropertyId> participates in the match with a specific weight <weight$_L$> and these are connected with specific properties of the LR having, e.g., id: <LRPropertyId> which also participates with a specific weight <weight$_{LR}$>. The connection between these properties becomes more accurate by also linking the intermediate values of these properties, which bare their own specific weights: <weight$_{lr,pr-id}$> and <weight$_{l,pr-id}$>. This structure combines propertyIds of LRs and learners respectively for each specific value of these properties. As seen in the scenario of Table 1, the properties: 'hasUserRole' of the learner and 'hasDifficulty' of the LR are combined, where the property: 'hasUserRole' participates with a weight of 0.55 (weight$_L$), while 'hasDifficulty' with a weight of 0.33 (weight$_{LR}$). Moreover, following the same scenario, the intermediate values of each one are aligned to the intermediate values of the other. The weights defined for each intermediate value of these properties, e.g., weigh$_{LR,1}$=0.9 being the weight of the value 'Very easy', for the beginner learner show the % that a 'Beginner' would prefer an 'Easy' LR against a 'Very Difficult' one. In the specific scenario, a Learner having "UserRole"="Beginner" prefers LRs having "Difficulty"="Very Easy", in a percentage 90%, while the preference of the same Learner for "Very Difficult" LRs is 10%.

Adoption of this LRs/learners description and their alignment, as seen in the previous examples, results in that: the learner L#09, prefers LRs of "SemanticDensity"="High", "Difficulty"="High" and "Format"="avi". While examining the LRs of a specific node to find the most suitable ones for this learner, with the LR having, e.g., URI="LR#201", then the following alignment document is going to be created based on the matching of Table 1:

```
<alignenment>
<LearnerPropertyId> L#09 </LearnerPropertyId>
  <connection-to-LR>
  <LRId> LR#201 </LRId>
  <weight>
     <LearnerPropertyId > UserRole, Pro-Intermediate </LearnerPropertyI>
     <weight_L> 0.55 </weight_L>
     <LRPropertyId > Difficulty, High < /LRPropertyId>
     <weight_LR> 0.33 </weight_LR>
     <weight_LR,pr-id> 0.1 </weight_LR,pr-id>
  </weight>
....
  <weight>
     <LearnerPropertyId > UserRole, Pro-Intermediate </LearnerPropertyI>
     <weight_L> 0.55 </weight_L>
     <LRPropertyId> Interactivity,high </LRPropertyId>
     <weight_LR> 0.55 </weight_LR>
     <weight_LR,pr-id> 0.5 </weight_L,pr-id>
  </weight>
...
  <connection-to-LR>
...
</alignenment>
```

By having so far explained the entire integrative platform described above as aimed at resembling a stage of action rather, than merely an assortment pallet, the prospects of its structuring may now be more clearly understood: Along with its modules, this platform

carries a number of notions encapsulated in each step of its processes that are here believed to ensure both its expansiveness and its compliance with cognitive constructivist principles. The third component of the proposed architecture is presented below.

III. The bridging algorithm refers to a method that would be robust enough to unambiguously rule, stem and sort information, material, and sequences while being generated in a creative psycho-pedagogic spirit by respect to cognitive constructivist tenets, that would in turn allow the attempted personalization be implemented in the best interest of all e-users involved in the educative e-interactivity.

It is stipulated that this algorithm is not to serve as merely a static formula for connecting different entities of the proffered platform or for linking its contents with existing structures of the Semantic Web; it rather is designed to function as a circuit amid them, thus ensuring interoperability, hence efficacy. It markedly uses the enhanced super-structure offered here, and is shaped in a mature psycho-pedagogic milieu inscribing eclectic methods of the platform that emerged, in a conscious orientation to wisely use the vast pool of the learning objects so as to choose which of the latter shall offer the e-user the optimal learning path.

The personalization algorithm of the presently proffered framework bares different content for the individual learner, so it highly depends on the existence of different LRs for the same educational topic. On this account, in each node of the hierarchy several educational objects are attached and can be used alternatively to teach the same didactic subject to learners of different profiles. The algorithm that selects the most suitable LRs for a dedicated learner follows:

Step 1: For a specific learner, his/her properties are compared to the properties of all the learning resources of each node through the alignment-structure,

Step 2: For each LR of the specific node the weights of all matching properties are multiplied,

Step 3: For each LR a total weight is calculated (formula 1) by summarizing all the intermediate results,

$$weight_{li} = \frac{\sum_{k=1}^{t} \left(w_{lr,i} * w_{LR,k} * w_{L,k} \right)}{\sum_{k=1}^{t} \left(w_{LR,k} * w_{L,k} \right)} \tag{1}$$

where w_{LR} and w_L are the weight$_{LR}$, and weight$_L$, as defined in the alignment structure, the weight $w_{lr,i}$ is the total weight of the instances of the LR, and k is the number of the records of the alignment-structure for which the properties of the LR l_i are matched to this learner.

As seen, the weight $w_{l,m}$, i.e., the weight of the learner, does not participate in this formula.

Step 4: From each node the LR having the greater weight is selected,

Step 5: The process is repeated for the LRs of the ontology.

This method selects the best ranked LR from each node according to the selection-criteria; consequently, the whole learning path turns out to be the most suitable one.

The concluding choice to be made in this module is a custom-made learning path based on characteristics of the specific learner.

The use of weights is brainwave approach as the fluctuation of their values is very easy. In this way examination of the influence of these parameters can be done, and the promotion of the desired parameters is feasible. For example, if it were supposed that one has to examine whether or not the property "semanticDensity" influences the "Performance" of a specific type of learner, e.g. the one who has "MSc", then, the same course can be delivered

twice: firstly using a high weight to this parameter, and later a lower one. For the specific course, inspection of the outcomes of his/her "Performance" as run in parallel results in that the influence of the characteristic "semanticDensity" is checked.

5. Implementation

To attest these proposals a web-based application was implemented and used in parallel with the most popular open source LMS, the Moodle. The software was used to implement the personalization algorithm and Moodle was used to deliver the ensuing course. This application implements the proposed super-structures that store the properties of the LRs and handles these metadata. The maintenance of the LRs properties is seen In Figure 5.
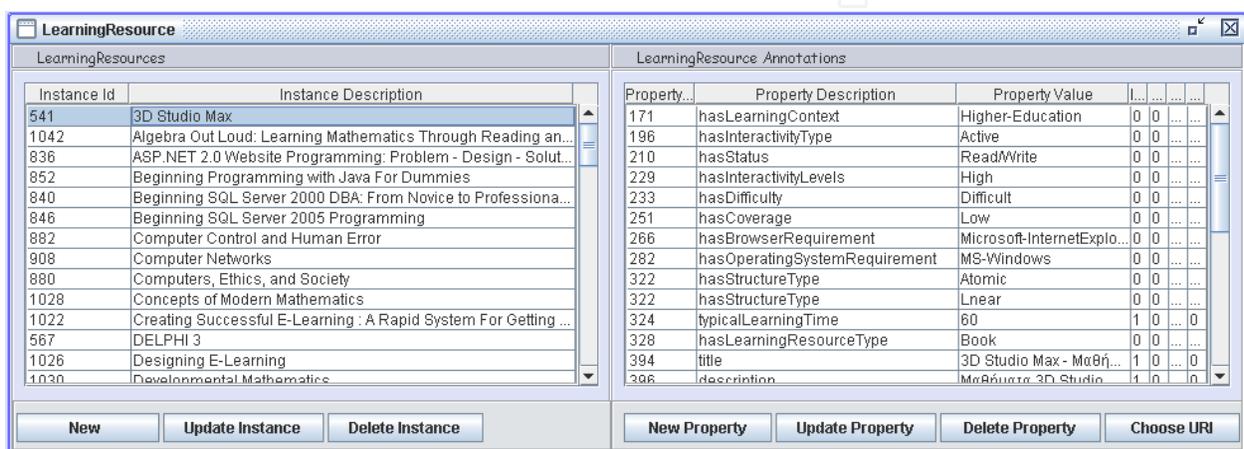
Fig. 5. The LRs Repository and the treatment of their properties

As seen, the properties of the LRs are described using the LOM educational standard. The available resources of the repository used here are shown on the left side and the number of the available properties of a single LR of the repository is shown on the right.

To create the e-course hierarchy, the web was exhaustively searched to discover suitable LRs that met the experiment specifications for alternative learning resources varying in formats, interactivity degree, semantic density degree, context type, etc. While planning the courses, a great effort was put to include a variety of LRs categorized into 20 scrutinized educational activities, intended to cover the overall experimental prerequisites. The ensuing material was thoroughly inspected, evaluated and accordingly attached to the ontology. The adopted personalization method was based on the Felder and Silverman (1998) learning style model. The factors under examination in the pertinent experiment were the effect of the "UserRole" to "Difficulty", "InteractivityLevel", "SemantciDensity" and the effect of "LearningStyle" to "InteractivityLevel", "Format", "LearningResourceType" and "SemanticDensity". The weights that were used to connect these factors are shown in Table 3.

Combination of properties of LRs – Learners based			
Learner property		LR property	
hasUserRole	0.55	hasDifficulty	0.33
		hasInteractivityLevel	0.33
		hasSemanticDensity	0.33
hasLearningStyle	0.45	hasInteractivityLevel	0.25
		hasFormat	0.25
		hasLearningResourceType	0.25
		hasSemanticDensity	0.25

Table 3. Combination of properties of Learners and LRs

From a specific node of the hierarchy this personalization bridging algorithm 'chose' one specific LR which is picked as the optimal object for each learner. The final learning path was provided to each individual. After the course completion, two decisive dimensions were examined: **i)** the satisfaction of the learners from their participation in the experiment and **ii)** the difference of their performance in this course lesson as compared to the performance of other students, who had not participated in the experiment. Albeit these indicators could hastily be viewed as insufficient for a denotative feedback, however, due to the novel and purely tentative character of the experiment per se, they were reckoned as reasonably fitting the aims of the whole effort. This was thought because the current effort in its entirety, was, as initially indicated, primarily centered in the theoretical and mathematical verification of merging two important axes: on the one hand, **a)** the potential refinement of the e-system supporting educational actions and activities by pondering into its technical methodologies and attempting mathematical manipulations that would perhaps endow further sophistication to its treating e-material, and, on the other hand **b)** the potential expatiation of even the very theoretical framework of cognitive constructivism along with the prospects of its applications into its largely unfamiliar e-environment, via precisely an algorithmic expression. This vision would have been adequately proven even if a single case-study was involved in the experimentation process, of a pair of a single e-tutor interacting with a single e-learner together dealing with the existing system's capacity and the currently proposed intervention's ability to: store information, retrieve material and process e-education in a smooth and functional manner.

Again, in this light, the success indicators selected for the present purposes could prove sufficient, provided that the relevant measurements would be markedly high in the gauge. Indeed, the related hypotheses were confirmed, with outcomes of these experiments being considered as very promising: i) the percentage of the participants who reported great satisfaction with taking part in the project reached a quite impressive 78%, and ii) their mean performance in the course increased against the mean performance of the control group at a considerable 18%.

Further Improvement Tactics: Consecutive steps for improving results in both i) quantitative and ii) qualitative terms are readily conceivable: i)For example, more indicators on outcomes would include general course performance ratings, intermediary grades, marks on midway assignments, participants' assessments of partial provisions, time management pointers, and gauges on speed of retrieval of information. It was also deemed that in order to arrive at even more reliable results, the experiment would have to be continued and

enriched towards qualitative improvements: ii) For example, variables which should also be included at such a future phase include: variety of several courses assessed in parallel, larger and varied (e.g., in demographics) samples of e-learners, a greater quantity of educational material qualitatively assessed as for, e.g., the conditions of delivery of its components, the appropriateness of the format of its components as ascribed to different users, the degree of users' satisfaction in the cooperation with specific e-tutors, different weights in the properties that are examined, etc. More specifically, given that the proffered architecture has satisfactorily inter alia shown its expansiveness due to its integrative platform of operations as conjunct with its bridging algorithm; and given that it does provide the capability to easily: i) change values of the existing parameters included in the system and ii) add more in order to cover a wider spectrum of characteristics to each tally, improvement tactics as the aforementioned should and could (Kerkiri et al, -in press) be promptly followed.

6. Conclusions

The present work attempted to abridge tentative, yet influential findings and concepts of two distinctly disparate doctrines traditionally ascribed to ICTs and psycho-pedagogy respectively. By focusing on relevant illustrative evidence it aspired to primarily provide some indication as to the feasibility of linking these two seemingly unrelated fields of study in a way that would benefit the end-users of this alliance. The open source LMSs as a fertile environment on the one hand and the cognitive constructivist approach on the other were purposefully selected as it was deemed that almost by definition they could be exploited in synergy with respect to the contemporary needs of savvy e-users. Although certain exemplary theoretical studies have been asserting the legitimacy of such alliance in the past (e.g., Dalgarno 2002), however, no one known to the current one has proceeded beyond theoretical to empirical experimentation, which was the general objective of the present effort. On a consecutive layer, this work chose to deal with the popular, yet delicate issue of contemporary e-educational methods addressed to undeniably savvy and demanding e-learners, whose special, idiographic characteristics craving for e-material personalization did not appear to be practically taken into account by most of the thoroughly investigated existing e-systems that support electronically conducted teaching processes. In this way, it not only hoped to trail this shortcoming, but also to offer a viable solution for it. The focal point of interest in this study being indeed the issue of personalization, it was accordingly led to advance beyond examining the capacity, yet inertia of the most popular open source LMSs to cover individual e-learners' needs for effective knowledge accessibility, and thus to present a coherent architecture of novel factually interoperable components that were ad hoc attested to efficiently serve such personalization purposes by applications compatible to the existing e-LMSs. These components were **I.** the creation of a superstructure that would secure fundamental functions of the LMSs environment on which the proffered architecture would unfold, **II.** the design of an integrative platform that would stage methods, tools and features derived from both the theoretical and empirical realms in question, and finally **III.** a bridging algorithm, that would function as a circuit amongst these features in order to uphold, not only interoperability, but also expansiveness of the spectrum of tools and services provided –again, not only to the e-learners themselves, but also to their e-tutors.

In the research involved in this work an architectural structure and a personalization algorithm for e-Learning systems were presented focusing on a gradually apparent need of

e-users for what was here depicted as a double concern: namely, the personalization of the content that the e-learner seeks for, and, likewise, the personification of the quest of the very same e-learner. The underlying concept dictates that once the characteristics of a learner are fed into a psycho-pedagogically founded and indeed cognitive constructivism-inspired e-system, it is not only the system itself that would take care of the user by supplying her/him with information suitable to his/her type by use of the proposed architecture; it would automatically empower the user to choose and change the type of the e-educational material that s/he seeks for, by simply altering/modifying/enriching the previously stored information about him/her. A significant finding in this research aspect of the study is that the proposed architecture also appeared to promise cost-effectiveness, inasmuch as it was shown that it can be also applied even in already developed LMSs.

The design of this system is coordinated through the utilization of learning style outcomes (Kritikou et al., 2008), educational standards (cf LOM, SCORM, PAPI, LIP), Semantic Web technologies (Berners-Lee et al., 2001; Kerkiri et al., 2009). The capabilities of this design rely on the creation of self-defined LRs. This leads to i) appreciating and exploiting their educational properties at a glance and ensuring their suitability for a specific learner by abiding to a multidimensional matrix of parameters, ii) promoting its characteristics so that they can be discovered by proper software (e.g. s/w agents), through an aptly computerized process, and iii) steering their automate classification in the right position of a learning path.

The personalization algorithm of the proposed system is based on divergent properties of equally divergent weights for the matching. This offers the maximum flexibility to a researcher to produce a dedicated course for the individual, as s/he can easily change these parameters depending on the outcomes s/he wants to examine. In this work's future plans the layered development of a number of functionalities are scheduled. Accordingly, next steps to be taken aim primarily to the creation of a repository of alternative LRs for a number of courses. A collation of courses shall follow which are to be created from the personalization algorithm with, and without evaluations. To this end, the relevant evaluation strategy shall be more refined and based on evaluating both educational approaches, observing students that follow the learning-styles approach courses and those that do not. With all the outcomes of the first experiment having being very promising, an even deeper examination is foreseeable, so that in the long term using different LRs, and a number of learner profiles of a wide variety of learning styles may well be available to extensively serve a multitude of users in progressively more meaningful ways.

7. Future Orientations

In an effort to respond effectively to e-learners' increasing demands and at the same time follow the Dalsgaard's three-fold proposition by also upholding Hannafin and colleagues' suggestions while continuously verifying the capacity of this architecture for meaningful expansiveness, it is further postulated that the hardiness model could be employed in the future, as the next step for an even more inclusive, unifying framework, that combines these qualities by actually coordinating distinct principles into an applicable instrumentation.

Hardiness theory holds that three distinguishable, yet interoperable and, ideally well balanced, personality components are interwoven in the cognitive schemata construction modes of each individual in the form of a highly idiographic/personalized frame of (subjective) reference. The latter may be reconstructed, inasmuch flexibility is encouraged or

not by use of, both, inner and outer, inherent and interpersonal/communicable resources. These components are defined as [self-]Control, Commitment –Responsibility and Challenge– Enthousiasm, repsectively (Maddi, 1980). Found in both, balance and, fairly, but not excessively, high levels in the individual profile, these "3C's" ensure i) good general, both mental and physical health, ii) fulfilling goal-setting, iii) adept goal-pursuing, iv) effectual stress-management, v) emphatic interpersonal/communicational skills and vi) general successfulness in an overall vii) productive, creative and pleasing quality of life. In contrast, when detected at both, imbalance and low levels in the individual profile, their fusion entails Alienation, i.e., aloofness and widespread hazy dissatisfaction with the self, others and any future prospects (Paleologou, 1996). Regardless of the degree of sturdiness indicated and irrespectively of the breadth of balance between these '3C's', the hardy-vs-alienated profile is portrayed as the compass of a person's navigation in life. Because repeated scrutinization of its components and consequent adaptations to the concurrent measurements of individual and group profiles have been optimized through three decades of study and applications, this theory's revisions and enrichments have led to detailed systemization of i) principles and ii) practical steps aiming to reconstruct a) dysfunctional schemas underlying the attitudes of alienated profiles and b) functional, yet potentially upgradeable, hardy profiles towards bettering their already satisfying lifestyle (Paleologou, 2001). The constellation of the emerging cognitive re-scripting approaches is now at a stage that may be addressing and treating information and interpretation processing that secures body, mental, social and spiritual harmoniousness of a person's inter-, and intra- cohesion in competency (e.g., idem, 2009). This structural system appears to be appealing to serve as a common denominator for an effective stabilization of both theoretical psycho-pedagogical plus learning principles and e-tools as well as functions of LMSs in favour of e-users.

Hence, almost by definition, the hardiness components seem appropriate for a concrete future inclusion in the currently proposed architecture at a level beyond mere profiling of the e-learners' individual persona, but by proceeding to aid them also in corrective actions towards precisely improving their learning style, capacities and future projections

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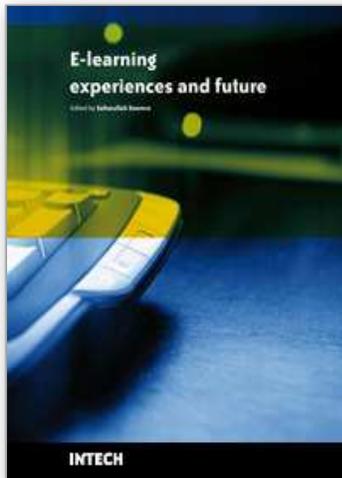
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