Adaptive Educational Hypermedia Systems in Technology Enhanced Learning: A Literature Review

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ABSTRACT

This literature review focuses on the educational benefits afforded to learners by Technology Enhanced Learning Environments (TELE) which adapt and personalize the learning experience. More specifically it focuses on Adaptive Educational Hypermedia Systems (AEHS) that incorporate Learning Styles. Adaptive approaches to learning offer alternatives to the traditional "One-size-fits-all" approach and have driven the development of dynamic educational environments. The use of such environments can deliver educational benefits as educational offerings are personalised based upon various characteristics of individual learners.

Categories and Subject Descriptors

D.3.2 [**Computers and Education**]: Computer and Information Science Education – Information Systems Education.
D.3.3 [**Programming Languages**]: H.5.4 [Information Interfaces and Presentation]: Hypertext / Hypermedia;
D.1.2 [**Information Systems**]: User Systems (Human Factors);

General Terms

Human Factors

Keywords

Technology Enhanced Learning, Adaptive Educational Hypermedia Systems, Learning Styles

1. INTRODUCTION

Traditional Technology-Enhanced Learning (TEL) systems offer very few strategies for the personalisation of educational offerings. This limits the scope for providing tailored, effective TEL experiences to learners. However, adaptive educational hypermedia systems (AEHS) have been developed to address learner dissatisfaction by attempting to personalise the learning experience. Recent research in TEL has focused on the provision of adaptive educational experiences that are tailored to the particular needs of a learner. This adaptivity can be based upon various characteristics of the learner, including knowledge level, goals or motivation. The purpose of such adaptive educational offerings is to maximize learner satisfaction, learning speed (efficiency) and educational effectiveness [1].

This literature review and paper tackles the question of: "*What are the educational benefits afforded to the learners by TELE which adapt and personalize the learning experience; in particular AEHS that incorporate Learning Styles?"* For the purpose of this paper, an adaptive system refers to a system which tailors its output, using implicit inferences based on interaction with the user [2]. An adaptive hypermedia system (AHS) refers to any hypertext and hypermedia system which reflects some features of the user in a user model and applies this model to adapt various visible aspects of the system to the user [3]. In other words, an AHS should be able to satisfy three criteria: it should be a hypertext or hypermedia system; it should have a user model; and it should be able to adapt the hypermedia using this model. Many AHS exceed this basic stated criterion by adding multiple models (e.g. content model, navigation model, presentation model, device model etc). AEHS have been found to be useful in engaging the learner more in the educational experience.

The rest of this paper is structured as follows: Section 2 provides an overview of TEL and briefly introduces the mapping of educational theory to the design of learning environments; Section 3 introduces current AEHS; Section 4 introduces learning styles (LS) and provides a chronological taxonomy of recent research into learning style; Section 5 provides examples of AEHS which incorporate learning styles and also presents a list of potential

benefits, limitations and pitfalls of AEHS. Finally Section 6 concludes the paper and recommends future work.

2. TECHNOLOGY-ENHANCED LEARNING

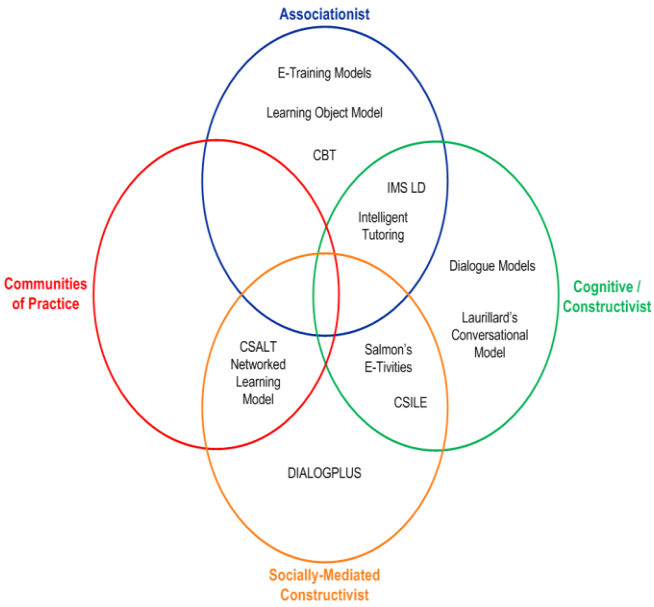
The process of learning in formal education no longer takes place solely in traditional, educator-centric settings. Interactive, learner-centric experiences are being used to support learner collaboration, knowledge acquisition and reflection. Learner enquiry, activity and engagement are key requirements in such experiences and TEL applications are being designed and utilised to meet these requirements [4]. TEL practices cater to students and teachers who use many different learning tools and environments and have experience of interaction derived with open, ubiquitous, and socially-oriented services. TEL is becoming well established in higher education institutes, most notably in blended or hybrid learning scenarios, which blend TEL and traditional approaches to teaching and learning [5]. TEL is expected to make a radical difference to education, specifically, the quality and effectiveness of the learning experience with one of its key contributions being 'personalised learning'. TEL methods have been known to change the deployment of the most important resource in the education system: teachers' and the learners' time [6]. Learning content should be reusable and accessible to everyone (with the author and originating institutions permission); however knowledge about individual learners should certainly not be accessible to everyone. Major benefits of TEL identified in literature range from cost savings to performance and strategic benefits [7]. In most cases learners using these technologies are able to receive instant and personalised feedback, active engagement, reusable learning materials and a safe environment where one can learn from one's mistakes and be able to access huge amounts of beneficial material on-demand. These technologies make learning more flexible in terms of time, space and place.

One of the main goals of the TEL development is to enable interoperability between different systems. Technology enhanced learning systems (TELS) that deal with learning styles are a special category of adaptive educational systems (AES), that focus on students' learning preferences as the adaptation criterion.

2.1 Mapping educational theory to the pedagogical design of learning environment

Recent developments in technology, coupled with the growing availability of low-cost or no-cost educational materials of high-quality (e.g., open content) have made it possible to develop powerful, yet potentially widely available technology enhanced learning environments (TELE). These environments have been increasingly studied as a way to provide a rich, supportive instructional system to students [8]. The TELE environments deliver instructional content and provide an array of scaffolding designed to support student learning. To ensure that the activities offered by learning environments can achieve the desired learning outcomes, there must be some mapping between the learning theories and the pedagogical design of learning environments. Each environment must provide specific functionality which reflects the approach to knowledge acquisition of the learning theory, or theories, which are being used. Mayes et al (2004) and Lawless (2009) provide categorization of learning at a theoretical level by dividing the[1] process of learning into three broad and overlapping perspectives: i) the associationist / empiricist perspective, which defines learning as an activity, ii) the cognitive perspective, which defines learning as achieving understanding and iii) the situative perspective, which defines learning as a social practice. Each environment must provide specific functionality which reflects the approach to knowledge acquisition of the learning theory, or theories, which are being used [4, 9]. Figure 1[1] below presents a display of a sample mapping of some approaches to TEL onto the pedagogical strands [9].

Figure 1[1] TEL models by pedagogical category



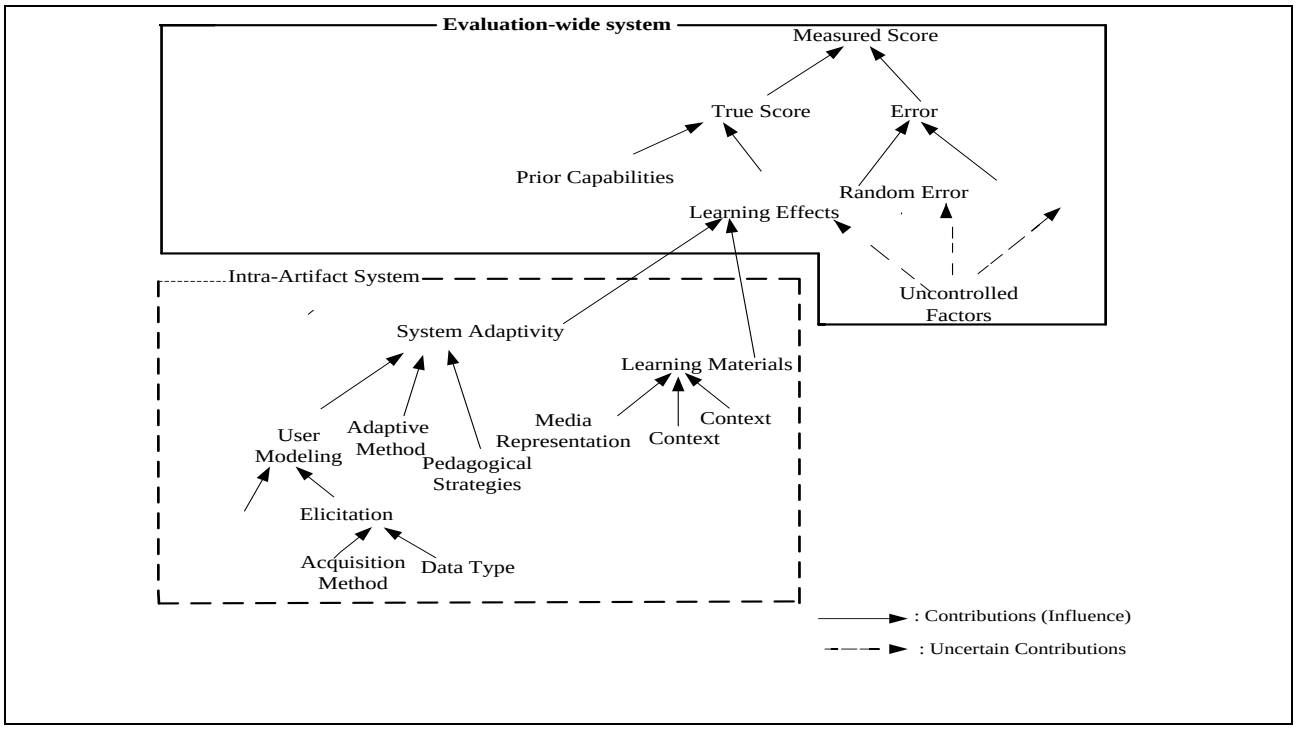
3. Using adaptive hypermedia systems for education

A hypermedia application offers its learners much freedom to navigate through a large hyperspace. Adaptive hypermedia (AH) offers its learners personalized content, presentation, and navigation support. Knutove et al (2009) provide a comprehensive overview of AH methods and techniques since their introduction 12 years ago. The researchers presented a survey of adaptive hypermedia (AH) architecture, defined a new taxonomy of adaptation techniques and also introduced a set of requirements and a modular structure that can be used to update the first generic AH model adaptive hypermedia application model (AHAM) that was introduced 10 years ago [10].

Adaptive hypermedia systems are being increasingly employed for educational purposes, especially with the advent of distance and distributed learning. One of the fundamental tenets of

[1] This diagram was taken from http://www.scss.tcd.ie/seamus.lawless/papers/thesis.pdf

Figure 2[2] the Hierarchy of Underlying Factors of AEH



education is that students are different and hence learn in a variety of different ways [11]. In most cases some of these differences may be due to preferences for certain ways of working. The material used for pedagogical purposes should be adaptive (or adaptable), in order to cater for these differences. AH is a technique used to provide a personalised learning experience that draws on computer-driven intelligent tutoring systems (ITSs) and student-driven virtual learning environments (VLES).

3.1 Adaptive hypermedia in educational systems

AEHS systems offer an alternative to the non-individualized instruction approach, by providing various services adapted to the learner profile. These systems are based upon user models which characterise each individual and can use these models to offer learners educational experiences which fit their needs. To achieve this, AEHS are comprised of several sub-components which have their own distinct behaviours and properties. Figure 2[2] conceptually depicts the hierarchy of this scenario. For example the AEHS as the intra-artifact system shown in Figure 2 can be decomposed by considering the influence of sub-components on the performance of ones at higher levels. The dashed arrows are edges representing uncertain influence. In this model the uncontrolled factors are identified and linked to other sub-components in the system with dashed arrows. For example sub-components inside the intra-artifact system can play the role of uncontrolled factors in the evaluation. On the other hand, the hierarchy of the evaluation task is shown by the evaluation-wide system.

A typical architecture of the state of the art of AEHS is fully decoupled and consists of five complementary models: i) The domain model which specifies what is to be adapted ii) The user and context models which indicate what parameters the content can be adapted and iii) the instructional and adaptation models which express the pedagogical approach the learning process should be based on, as well as the forms of adaptation to be performed [12]. In a review conducted by Karampiperis et al (2005), the authors identified the current state of the art adaptive hypermedia systems as AHA! [13], OntoAIMS [14], the Personal Reader [15], WINDS [16], ACCT [17]. These systems are based on the AHAM. This model builds upon the Dexter model, that is, a common model for hypertext-based systems that was designed for general purpose adaptive web application. The model consists of two main layers: i) the run-time layer which contains the adaptation engine that performs the actual adaptation and ii) the storage layer, which stores information about the media space, the domain model, the user model and the adaptation model [12].
The main components of the AHAM model and their structural interconnections are illustrated by Figure 3 below. The dashed lines represent a logical connection between the linked models. The student model maintains an accurate representation of a student's current state of knowledge, which allows the system to perform some adaptation based on the knowledge acquired during

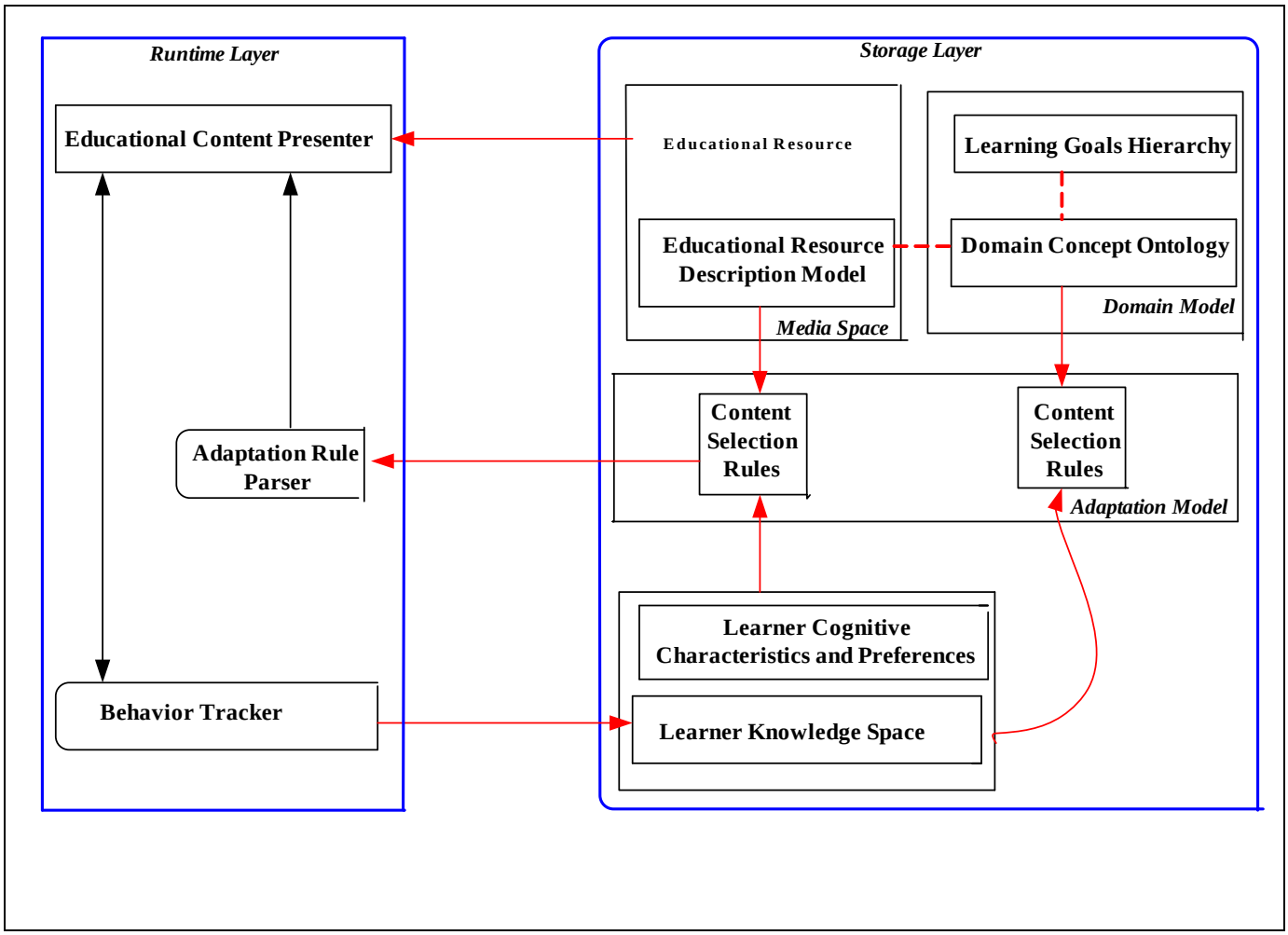
[2] This diagram is taken from the educational wide society (http://nccur.lib.nccu.edu.tw/bitstream/140.119/14993/1/52.pdf)

the learning process [18]. It includes information referring to the specific knowledge that the system judges that the user possesses on the domain, known as the domain dependent data (DDD).

In the past, AHS systems have attempted to customize courses to a learner's prior knowledge, goals and personal preferences without taking into account any form of pedagogy. As a result, such systems neglect the entire body of research that exists in the educational field and fail to take advantage of the benefits that the application of pedagogy has for the learning experience [19]. The researchers' emphasize the significance of iClass (iClass, 2004) which is an open learning system which utilizes pedagogical strategies to adapt to learners' needs, both intelligently and cognitively.

Jovanovica et al. (2009) discuss the three generations of AEHSs. The first generation comprised stand-alone systems with adaptation rules and content entwined in a single model. They used this model together with the user model to offer personalised content (e.g. AHA! and ELM-ART). However, as adaptation rules and content were intertwined, there was little scope for content or model reuse or the use of externally developed content in the generation of learning offerings.

Figure 3 Generalized architecture of adaptive educational system



The second generation attempted to overcome some of the problems encountered by the first generation by pursuing a multi-model approach. This approach assumed decoupling of content and the adaptation rules of the system [20]. The third generation is moving towards a service-oriented architecture and the complete decoupling of different kinds of knowledge [21]. Peter Brusilovsky (2004) provided a subjective overview of research in adaptive educational hypermedia and summarized the current state of the art of the three generations [22]. He admitted that there were problems encountered while using the AEHS and accepted that several research teams had recognized the problems of static hypertext in different application area and had begun to explore various ways to adapt the behavior of hypertext and hypermedia systems to users. For example he accepts there are problems which are related to hypermedia such as, navigation in hypermedia, inefficient navigation or the problem of being lost in hyperspace; that had been discovered when the field of hypertext reached relative maturity at the end of the 1980's [23].

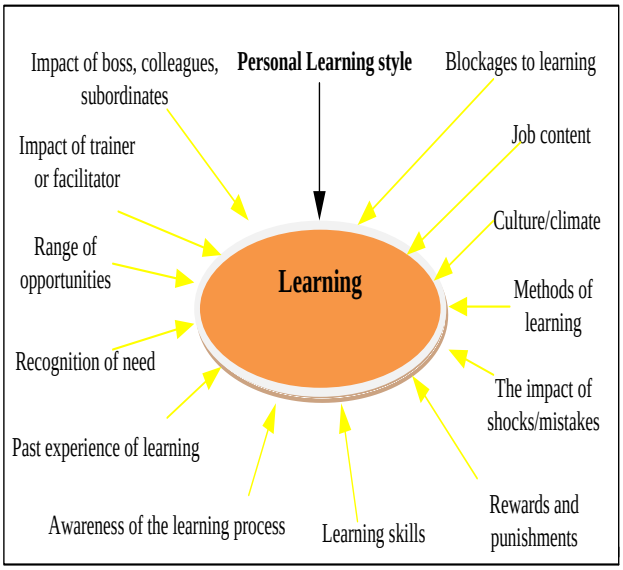
3.2 Evaluations of AEHS

Evaluation of any system is important and should ensure the correct methods are used. In particular it is very significant to evaluate the entire AEHS both from a technological perspective and from a user-centered perspective. This is emphasized more from our earlier research on system evaluation [24]. The evaluation of learner and tutor feedback is essential in the production of high quality personalised TEL services. There are a few evaluations available in the AH domain relative to the amount of research interest this domain is attracting. Majority of the research in this domain focuses on the technological design and performance of systems without justifying the designs through the lessons learned from evaluations [25]. In order to provide the best support for learners, a user-centered evaluation approach for enhancing and validating the student model of AEHS has been proposed, that combines adaptive hypermedia (AH) and information retrieval techniques [26]. User-centered evaluation (UCE) can serve three goals: verifying the quality of an AEHS, detecting problems in the system functionality or interface, and supporting adaptivity decisions. These functions make UCE a valuable tool for developers of all kinds of systems, because they can justify their efforts, improve upon a system or help developers to decide which version of a system to release. The benefits of the user-centered approach are savings in terms of time and cost, ensuring the completeness of system functionality, minimizing required repair efforts, and improving user satisfaction. This may lead to higher adoption of the AEHS, ease of use and a more enjoyable student experience. Student model performance is usually measured in terms of actual and expected accuracies, where actual accuracy is a model's probability of a correct response averaged across all users. For example, Corbett and Anderson (2008) used correlation, mean error and mean absolute error to quantify model validity [27].

4. LEARNING STYLES

To date no single definition of the term learning style (LS) has been identified, a widely accepted definition is given by Keefe (1979) who defines learning style as "the composite of characteristic cognitive, affective, and physiological factors that serve as relatively stable indicators of how a learner perceives, interacts with, and responds to the learning environment" [28]. Learning styles are preferences for information types (concrete vs. abstract), presentation styles (visual vs. verbal, written) and learning actions such as hands-on versus planning and reflecting about a concept [29]. Some researchers view learning styles as individual, stable and predictable [30] others view learning styles as the parts of personality that change over time [31-32] or that unconsciously adapt to match learning contexts [33]. Both views seem acceptable, as Cassidy stated; learning styles are regarded as comprising of three fundamental learning components: i) information processing, ii) instructional preference, and iii) learning. However other researchers disagree; Elizabeth Brown (2007) is quite negative about learning styles; a quote from her thesis "Overall no statistically significant benefits were found and these findings now shed doubt as to whether learning styles are indeed an effective mechanism for personalised learning" [11]. There is no doubt that adaptivity is a good thing, it comes down to i) what properties of a learner do you adapt on and ii) are learning styles a good and effective means of teaching / learning or iii) does adapting to learning style benefit the learner or iv) do we know how to successfully adapt to learning styles. The authors acknowledge personal learning style as being significant since it is one of the factors that influence learning. Other factors that influence learning are presented in Figure 4 below.

Figure 4 Factors that influence learning



In a review conducted by Penger & Tekav (2009), the researchers identified the most influential research studies and research construct within learning styles. The researchers categorized 32 studies from 2000 to 2008 as shown in Table 1[4]. However of the 32 studies only 2 were on adaptive learning systems. In their review the researchers fail to identify which of these two adaptive systems were AEHS. This supports our point that there is limited research in area of AEHS and more research and publications is required.

4.1 Measurements for Learning Styles

Hsieh et al (2007) acknowledge that measurements can be used as a decision making tool. The researchers also admit that learning styles measurements are like foundations for predicting how the student will perform. The students' different learning styles should be measured along with different information processing stages (e.g. sensory-term memory, short-term memory and long-term memory). For instance during the sensory memory stage which is affiliated with the transduction of energy (i.e., change from one energy to another), in the process of transduction a memory is created. It is critical that the learner initially process the information at this beginning stage in whole learning process (from sensory register, working memory to long -term memory).[3] The students' different learning styles should be measured along with different information processing stages (e.g. sensory-term memory, short-term memory and long-term memory).

* Factors in TELE that influence learning

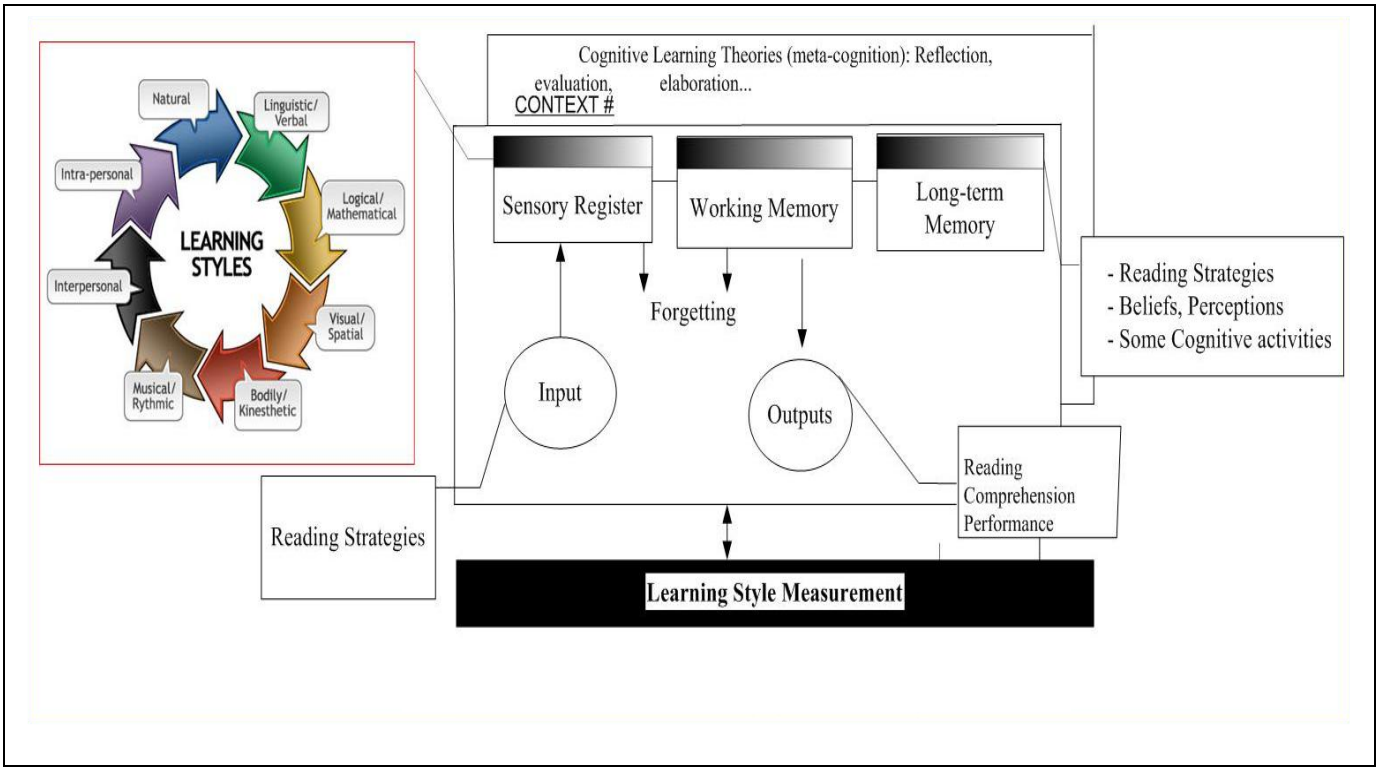
Table 1[4] Chronological taxonomy of recent research into learning styles and (organizational) learning

2000 - 2004	2005 - 2006	2007	2008
Alban & Metcalfe (2002) -disorder type behavior among undergraduates **Dart et., al** (2000) -students' conceptions of learning **Duff & Duff** (2002) -Kolb's learning style questionnaire, academic performance -Honey & Mumford's learning style questionnaire **Dunn & Griggs** (2003) -Synthesis of the Dunn and Dunn learning style model research **Kayes** (2002) -experiential learning theory and its critics: the role of experience in management learning and education **Lhori-Posey** (2003) -determining learning style preferences of students **Loo** (2004) - Kolb's learning style and learning preferences	**Cuthbert** - double loop learning in a classroom setting **Champoux** -experiential learning in the online environment **Laureano-Cruces, Ramrez-Rodrguez, de Arriaga & Escarela-Perez** - intelligent learning styles - computer-based educational systems **Yannibelli, Godoy & Amandi** - a genetic algorithm approach to recognize students' learning styles - computer-based educational systems	**Argyris** - double loop learning in a classroom setting **Champoux** -experiential learning in the online environment **Demirbas & Demirkan** - learning style and academic performance -using Kolb's experiential learning theory (ELT) **Garcia, Amandi, Schiaffino & Campo** - detecting students' learning styles - web based education **Hornyak, Green & Heppard** - implementing experiential learning **Herbert & Stenfors** - management education and experiential learning methods **Kayes** - power and experience - management education - conversational learning **Reynolds & Vince** -experiential learning and management education **Skerlavaj & Dimovski** - network perspective of intra-organizational learning **Skerlavaj, Indihar-Stemberger, Skrinja, & Dimovski** - organizational learning culture in Slovenian companies **Verpoorten, Poumay & Leclercq** - eight Learning Events Model - pedagogical framework **Welsh, Dehler & Murray** - learning about and through aesthetic experience	**Armstrong & Mahmud** - experiential learning and the acquisition of managerial tacit knowledg - Kolb' learning style inventory **Alkhasawneh, Mrayyan, Cocherty, Alashram & Yousef** - problem-based learning (PBL): assessing students' learning preferences **Dimovski, Skerlavaj, Kimman & Hernaus** - organizational learning process, Slovenia, Croatia, Malaysia **Duff, Dobie & Guo** - the use of case studies and learning styles in New Zeland - use of business case studies (BCS) *** Filippidis & Tsoukalas** -Felder-Silverman learning style model - adaptive educational system **Graf, Lin & Kinshuk** - relationship between learning styles and cognitive traits - Felder-Silverman's learning style model - working memory capacity **Li, Chen & Tsai** - learning styles in Taiwan (higher educational) - using Myrers-Briggs Type Indicator **Metallidou & Platsidou** - the psychometric properties of Kolb's LSI-1985 in a Greek sample - meta-cognitive knowledge - problem-solving strategies **Peters, Jones & Peters** - preferred learning styles' and their relationship with grades for students undertaking *** Tseng, Chu, Hwang, & Tsai** - adaptive learning system computer-assisted learning

Source: authors; adapted from the research papers and publications indicated in the figure, 2008 * Pure adaptive (educational & Learning system[4]

[4] Table taken from http://www.cluteinstitue-onlinejournals.com/PDFs/1611.pdf

Figure 5[5] Possible Locations of Learning, Learning Measurements & Information processing stages



This process is demonstrated clearly in Figure 5[5] above. Actually in the past thirty or more years, the outcomes of the learning style measurement have encouraged teachers to understand students' learning style so that they know how to enhance the students to conclude that they need to find the relationship between learning style and varied instructions, so that they can develop customized materials for students who have different learning styles **[32, 34-35]**. Figure 5[5] is the assumption where possible location of learning styles and measurements might be located.

5. AEHS INCORPORATING LS

Learning styles with other means of adaptivity (e.g. user goals, prior knowledge) provide some improvements in learner satisfaction and knowledge gain. However there are very few studies in adaptive e-Learning which limit the adaptivity to just learning style adaptivity. From the results of around 2009, both of the researchers (Brown and Kelly) came to similar conclusions which seemed to indicate that the aspects of specific learning style adaptation have no significant impact on the learners performance [36-37]. One reason for this might be that adapting to learning styles means adapting to only one feature of the learner and that the real power and benefit of AEHS systems is the dynamic personalisation of the content and the navigation based on multiple contextual influences (e.g. prior knowledge).

Most of the AEHS which incorporate learning styles are based on the notion that matching the learning strategies with learning styles improves learner's performance. Examples of these systems include AEHS which address learners' diverse needs to assimilate and comprehend information or content [18, 38-39]. Table 2 provides a summary of examples of AEHS systems, their approach to determining learning style, the type of learning styles incorporated in these systems and a brief overview of how the AEHS system achieves its learning style and adaptivity[5]

[5] Some parts of the diagram were extracted from P.H. Hsieh et al. 2007

Table 2Adaptive educational hypermedia systems considering learning styles

System	Year	Learning Style	Student modeling approach	System Description
CS383	Carver et al. 1999	visual/verbal, and sequential/ global	Inventory of Learning Styles questionnaire	It considers learning styles as the basis for the user model and uses multiple types of resources differing in the media the system utilizes
MANIC	Stern & Woolf, 2000	Applies preferences for graphic versus textual information	Automatic approach by using a Naïve Bayes Classifier and population data	Uses machine learning techniques in order to identify learners' preferences by observing his/her interactions with the system
IDEAL	Rodriguez et.al., 2002	----	Questionnaire of the considered learning style model	This is an adaptive and intelligent agent-based system used to support active learning
MASPLANG	2002	---	Index of Learning Styles questionnaire for initializing and a case-based reasoning process for fine-tuning	This system is focused on the utilization of intelligent agents which are available in online learning environment
LSAS	Bajraktarevic et al., 2003	Global-sequential dimension of the Felder Silverman learning style model	Index of Learning Styles questionnaire	-
iWeaver	2003	auditory, visual, kinaesthetic, impulsive, reflective, global, analytical styles of Dunn and Dunn learning style model	Building Excellence Inventor; automatic approach is planned	It is a web-based interactive adaptive learning environment, which aims to create an individualized learning environment that can accommodate specific individual learning styles
INSPIRE	Grigoriadou et al., 2001	Honey & Mumford categorization of activists, pragmatists, reflectors and theorists based on Kolb	Questionnaire by Honey and Mumford or initializing/ updating the student model manually	It allows learners to select their learning goal and accordingly generates lessons that correspond to specific learning outcomes.
TANGOW	Carro et al., 1999	Sensing-intuitive dimension from the Felder-Silverman learning style model	Index of Learning Styles for initializing and an automatic student modeling approach for revising the information in the student model	An interactive hypermedia e-Learning system which supports basic adaptive features. It tracks a student progress through the course and enables links to other pages as the student learns the previous concepts.
AHA!	2005/2006	Determined by the teacher	Manually initialized and updated by determined instructional meta-strategies	This is an adaptive website framework, which has been used in implementing some adaptive website in education
ARTHUR	-	visual-interactive, auditory-lecture and text styles	-	This is a web-based instruction system that provides adaptive instruction
CS388	Carver et al., 1996	Felder-Silverman LS model-global-sequential, visual-verbal, sensing-intuitive, inductive-deductive styles	The Felder-Silverman Index of Learning Styles	Uses multiple types of resources differing in the media they utilize
AEC-ES	Triantafilou et al., 2002	Field-dependent (FD) and Field-independent (FS) cognitive styles	Witkin and Goodenough FI/FD	Uses navigational support tools & adaptive presentation techniques. It provides users with instructional strategies that suit their cognitive preferred style with an option to switch to a non-preferred version
MOT	Cristea et al. 2003	Diverger/ converger	Kolb's experiential learning	It is a generic delivery system that is based on the LAOS framework. Also a powerful and simple authoring system.
OPAL	Conlan et al., 2002	Abstract/concrete, active/reflective	-	It delivers content personalized to the learner's cognitive and presentation learning preferences using aggregation models based on AOL SCORM
ILASH	-	Summarizing, questioning	Summarizing and questioning	This system uses adaptation to provide a representation of an appropriate strategy for students while learning

The process of building and updating the student model (i.e., classified into collaborative and automatic) is known as student modeling. The student model aid and forms a very significant role in AEHS systems. In all the systems reviewed in Table 2, they all store the learning style information in student model. The model includes all relevant information that the AEHS has gathered about the learner. This data is then used as a basis for providing suitable adaptivity. The authors acknowledge that most AEHS systems research focuses on adapting to user features such as goals / tasks, knowledge, background, hyperspace experience, and interests[5].

Papanikolaou and Grigoriadu (2004) acknowledge that the most important thing in exploiting different learning style categorization in AEHS is their potential to support and enhance adaptation providing appropriate guidance for AEHS developers [34]. The authors admit that there is need for an investigation on how learning style categorization could assist the design of different adaptation technologies. For example in ARTHUR, iWeaver, CS388 and MANIC the adaptation is achieved by providing different media representations for each learner. On the other hand ARTHUR and iWeaver are very similar in choice of learning styles representation. While AEC-ES provides field-dependent learners with navigational support tools and guide them through the learning material via adaptive navigation support and enables learners to switch between different instructional strategies [35]. This shows that different systems can adapt based upon learning styles using techniques such as: content adaptation, navigation paths and use of multiple navigation tools.

5.1 Potential Benefits, Pitfalls and Limitations of AEHS

5.1.1 Potential benefits of AEHS

Many benefits can be attached to AEHS. For example adaptive educational games (AEG) like the adaptive learning in games through non-invasion (ALIGN) [40] can encourage learner participation, improve motivation and experiences and reinforce these with a personalised learning experience. Following is a list of examples of current benefits:

- These systems provide specific navigation aid,
- Selection of content,
- Metadata cognition and
- Provide results of the learning style tests [24].
- Change learning explicitly and provide scrutability.

In a survey conducted by Harrigan et al. (2009), the researchers identified some of the benefits as:

- Reusability,
- Provision of relevant learning materials which are personalised to specific learner,
- Efficiency of the AEHS systems which are user specific,
- Student motivation,
- Avoidance of information overload,
- Automation, flexibility and
- Monitory and temporal and spatial relevance.

5.1.2 Limitations and Pitfalls of AEHS

- It is difficult to find hard evidence for the impact of the new technologies on learning outcomes and
- Effective learner modelling, addressing personalisation for disabilities considering the time and evolving user context(s), including the user control and relating them to the issues of privacy,
- The complexity of environments in which learners work. Their attitudes, motivation, beliefs, knowledge and skills constitute just one important factor relevant to their learning achievements. Kay (2008) advocates that scrutability is an issue crucial not just for student models but all components of AEHSs.

Several researchers have identified some pitfalls encountered by developers of these systems [41-43]:

- Specification of control conditions, these occur when the control conditions of experimental settings for evaluation are defined. In many studies the adaptive system is compared to a non-adaptive version of the system with the adaptation switched off,
- Difficulty in attributing cause: is the adaptation causing the measured effect or another aspect of system functionality or design (e.g. system usability),
- Statistically insignificant results,
- Difficulty in defining the effectiveness of adaptation,
- Insufficient resources and allocation of these resources, in most cases the resources are underestimated and
- Too much emphasis on summative rather than formative evaluation.

Meccaway et al (2008) emphasized that the level adoption of AEHS into ‘real world’ teaching has being poor. The researchers agreed that one of the reasons behind this is due to their architectural design failing to answer the overall needs of Web-enhanced learning [44]. Majority of these systems are currently prototypic and experimental systems with basic graphical user interface (GUI). They are not designed for the modern e-Learning context which prompts services and reusability of learning context [45]

Table 3 Adaptive and Adaptive hypermedia variables identified in the studies

Variables	Brusilovsky 1996	Brusilovsky 2001	Kobsa , Koeneman & Pohl 2001	Rothock , Koubek, Fuchs , Haas & Salvendy 2002	Magoulas & Demakopoulos 2005	Lex Van Velsen, Thea, Van Der Geest & Michael Steehouder 2008
User goals	Y	Y	Y	Y	Y	
Knowledge of the domain	Y	Y	Y	Y	Y	
Background and Hyperspace experience	Y	Y			Y	
Preferences	Y	Y	Y		Y	
User interests		Y	Y		Y	
Individual traits (e.g. cognitive or learning style, user personality)		Y		Y	Y	
Environment (e.g. location, locale, software, hardware), (user situation awareness)		Y	Y	Y	Y	
Personal data			Y		Y	
User skills and capabilities			Y			
User performance				Y		Y
Usage data (e.g user history)			Y		Y	
User cognitive workload				Y		
Groups of users				Y		
Appreciation						Y
Trust and privacy issues						Y
User experience						Y
User Satisfaction						Y
Usability						Y
User behavior						Y
Intention to use						Y
Perceived usefulness						Y

The authors have identified existing adaptive variables variable (also known as concepts) that can prompt adaptivity, in the literature from 1996 to 2008. These variables make AEHS a variable tool for learners in TELE. By adaptive variables we refer to the features of the user that are used as a source of the adaptation (i.e. to what features of the user the system can adapt its behaviour). Table 3 above presents a summary of these variables, the researchers who identified them and the year [2-3].

6. CONCLUSIONS AND FUTURE WORK

Nowadays, the development of technology enriches the learning environment where the teachers can continuously monitor the appropriateness of their instructional delivery methods [42]. It remains to be seen if educators are willing to invest the significant time and effort required to initially integrate an AEHS systems into their teaching plans and to ensure that the learning offerings provided meet the curriculum. The teachers can review information processing theories and cognitive theories, and then examine the structure of learning style measurements.

The paper demonstrated how the use of TEL, particularly AEHS, can benefit learners and tackled our research question "*What are the educational benefits afforded to learners by technology-enhanced learning environments (TELE) which adapt and personalize the learning experience. More specifically it focuses on adaptive educational hypermedia Systems (AEHS) that incorporate learning styles?"* It emphasized the importance of incorporating learning styles into AEHS in order to provide a more personalised and effective learning experience although some researchers may disagree i.e.,[46] [11].
Adaptivity can only be provided in an efficient and effective manner if the needs of the students are known. The landscape of AEHS is rather rich in ideas and interesting solutions.

The authors came to conclusion that; learning styles with other means of adaptivity (e.g. user goals, prior knowledge) provide some improvements in learner satisfaction and knowledge gain. However there are very few studies in adaptive e-Learning which limit the adaptivity to just learning style adaptivity. Some researchers seemed to indicate the aspects of specific learner's performance; adaptation has no significant impact on learner's performance. One of the reasons for this might be that adapting to learning styles means adapting to only one feature of the learner and that the real power and benefit of AEHS systems is the dynamic personalisation of the content and the navigation based on multiple contextual influences (e.g., prior knowledge). AEHS incorporating learning styles are very significant to learners.

Further work is required to address the limitations of such systems and to:

- Investigate the weaknesses of the AEHS which incorporate Learning styles;
- Investigate how such systems have been evaluated and identify the most effective approaches;
- Compile a review of all existing AEHS;
- Examine the extent to which the decision to allow different levels of control over the student model is determined by the domain.

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