Cognitive and Emotional Processes in Web–Based Education:
Integrating Human Factors and Personalization

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Chapter XII
Cognitive Learning Approaches to the Design of Accessible E–Learning Systems

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ABSTRACT

The creation of exciting, new, powerful and accessible e-learning systems depends upon innovations in cognitive science, human learning, e-learning implementation principles and derivative, technological e-learning solutions. The issues of user sensitive design and user diversity are central to such developments and so must be one of the focuses of any effective e-learning system. This chapter shows how a unique characterization of the interaction between e-learning requirements, accessibility and cognitive user modeling generates an inimitable set of solutions to current e-learning problems, through a simple and supportive conceptual framework. In so doing, the authors show how evidence and insights from diverse subjects such as cognitive science, computing science and social sciences can be integrated to provide a robust platform for the next generations of pedagogically enriched e-learning systems.

INTRODUCTION

In the emerging inclusive Information Society (Savidis & Stephanidis, 2004), the intended users of e-learning systems are becoming much more demanding, expecting systems that are fast and powerful, customized and accessible, intelligent and adaptive, effective and efficient for human learning (Adams & Granić, 2007; Granić, 2008).

Focusing on e-learning, i.e. an instructional content or learning experience delivered or enabled by electronic technology (Pantazis, 2001), it is the case that, despite so much publicity and activity, progress in the field has been unexpectedly slow. In order to improve the learning experience and effectiveness and increase an e-learning system's intelligent behaviour, interactive mechanisms merit additional consideration and enhancement.

There should be a synergy between the learning process and a user's/learner's interaction with the e-learning application (Squires & Preece, 1996), additionally taking into account the different ways users learn, so supporting their natural and flexible interactions with the host system. Most current e-learning applications are static and inflexible, designed with little or no consideration of users' preferences and abilities. It is vital to overcome this one-size-fits-all approach and provide users with individual learning experiences through e-learning systems with intelligent and adaptive user interface.

BACKGROUND

In this background section, we provide broad definitions of helpful concepts that form the basis of 21st century e-learning. They include, but are not limited to, such concepts as: learning environments, e-learning, accessibility, adaptability, adaptivity, ambient intelligence, system smartness and user modeling (Adams, 2008).

A *learning environment* is a setting that is arranged to enhance the learning experience. In order for learning to take place, according to Pulkinen and Peltonen (1998) there are three essential components of any learning environment: pedagogical and psychological functions (learning activities, teaching situations, learning materials, assessment, etc.), appropriate technologies (how the selected tools are connected with the pedagogical model) and social organization of education (time, place and community). From another perspective a learning environment can be defined as constructivist in nature, enabling the learners to engage in "sense-making" about extensive information. On this view, the learning environment comprises four components: an enabling context, resources, a set of tools and scaffolds (Hannafin, Land, & Oliver, 1999). In addition, realistic contexts motivate learners, and involve them in complex, real-world tasks.

Piccoli, Ahmad and Ives *(*2001) argue that learning environments are defined in terms of time, place and space. According to them, it is also possible to expand the traditional definition of learning environment to include three further dimensions: technology, interaction and control. However, their definition did not include the consideration of learning the system usage and the corresponding skills required. A simple definition of e-learning is instructional contents or learning experiences that are delivered or enabled by electronic technology (Pantazis, 2001). One of the most technically advanced form of e-learning can be seen as the virtual learning environment. In early versions (Pimentel, 1999) students learn through an interactive environment that deploys text, images, voice, video, touch and graphics. In later versions (Little, 2008) virtual reality applications such as Second Life™ can proffer virtual realities than can become almost totally immersive and offer enhanced learning opportunities, including social or inter-personal skills.

Accessibility is another of our key concepts. It can be defined as the absence of barriers that would stop or impede user exploitation of a learning system. Adams (2007) has identified at least six types of accessibility problem. The barriers identified are summarized as:

a. hardware barriers,
b. communications barriers,
c. sensory / perceptual problems,
d. cognitive barriers, particularly in navigational demands and comprehension of contents,
e. barriers to learning and performance objectives and
f. unrealistic response requirements (see further ahead in this chapter for more details).

Accessibility is an increasingly noteworthy concept and is more and more supported by punitive legislation. For example, in the UK the Special

Educational Needs and Disability Act (SENDA) was implemented in 2002 and means that UK educational institutions are no longer exempt from the Disability Discrimination Act (1995) and must provide equal access to resources and information in general and website accessibility in particular to people with disabilities. Equally, the USA has the Americans with Disabilities Act of 1990 (ADA). Whilst web accessibility is often defined to mean that "that people with disabilities can use the Web," it is important to point out that web accessibility can also benefit others, as discussed in http://www.w3.org/WAI/intro/accessibility.php (accessed May 15, 2008). In fact, in the context of the emerging inclusive Information Society, the aspiration of universal accessibility is to provide access to everyone who wants it (Savidis & Stephanidis, 2004).

Intelligent User Interfaces (IUIs), bringing the concepts of adaptability and adaptivity, have been recommended as means for making systems individualized or personalized, thus enhancing its flexibility and attractiveness. They facilitate a more natural interaction between users and computers, not attempting to imitate human-human communication, but instead aiding the human-computer interaction process (Hook, 2000). The intelligence in interface can for example make the system adapt to the needs of different users, take initiative and make suggestions to the user, learn new concepts and techniques or provide explanation of its actions *cf.* (Hook, 2000; Lieberman, 1997). A satisfactory framework for taking into account users' heterogeneity has provided (Schneider-Hufschmidt, Kühme & Malinowski, 1993):

- *adaptable systems* along with the concept of *adaptability*, by allowing the user to control the interface customization and
- *adaptive systems* with the concept of *adaptivity*, by adapting the interface behaviour to user's individual characteristics; adaptive interface generally relies upon the use of user models (UMs), a collection of information and assumptions about particular users which is needed in the adaptation process of the system to an individual (Kobsa, 1995).

Ambient Intelligence (AmI) is another important concept and is best understood as a pervasive and unobtrusive intelligence in the surrounding environment supporting the activities and interactions of the users. Increasingly AmI is used in combination with augmented reality in which scenes also have computer generated objects e.g. sound, graphics etc to enhance the user experience (Riva, Loreti, Lunghi, Vatalaro, and Davide, 2003).

System smartness is defined as the possession of functions and attributes by a system that would be judged to be intelligent in the case of a human operator. One example is such a system being able to pass a modern, cognitive version of the Turing Test. The term smart, as used here, does not necessarily imply true intelligence, merely a simulation or appearance of it (Adams & Russell, 2006; Adams & Granić, 2007).

Of course, significant interactions between these important factors are of growing interest too. For example, are ambient intelligent applications universally accessible? (Adams, Granić & Keates, 2008). These authors evaluated six AmI systems and found an analysis of the accessibility of such systems to be surprisingly more complex than they expected. Thus, whilst the systems were rated highly overall for accessibility and usability, there were a number of complications. All six were rated well for accessibility, all six were significantly less so for system smartness and user satisfaction. Usability was also rated higher than user satisfaction and system smartness. Clearly, there is much more work to do in this area.

COGNITIVE LEARNING APPROACHES TO THE DESIGN OF ACCESSIBLE E-LEARNING SYSTEMS: ISSUES, CONTROVERSIES, PROBLEMS

It is clear from the background information presented earlier in this chapter that there are a number of issues, controversies and problems that relate strongly to our theme of cognitive learning approaches to the design of accessible e-learning systems. They include:

a.   a better appreciation of the pedagogical principles underlying e-learning,

b.   the psychology of human learning,

c.   the development of better learning environments, including e-learning, virtual realities and augmented realities,

d.   design for accessible and usable e-learning systems,

e.   the development of ambient intelligence and smarter systems as well as

f.   the appreciation of the synergy between cognitive and emotive factors in human learning.

A Better Appreciation of the Pedagogical Principles Underlying E-Learning

Pedagogic principles point to the sound and effective development of human learning environments based on well established guidelines. For example, consistency between learning objectives, learning and assessment methods might be helpful for effective human learning (Biggs 2001). Additionally, it is important to take into account individual differences between different learners.

Current research in this field is beginning to acknowledge that understanding users' needs is at the core of successful designs for Information Society Technologies (IST) products and services.

This naturally leads to *user-centered design* approaches, a philosophy which places the users at the centre of design (Norman & Draper, 1986) and a process that focuses on cognitive factors (such as perception, memory, learning, problem-solving, and alike) as they come into play during users' interactions with applications (Zaharias, 2005; Adams, 2007a). However, we are far from achieving the goal of user-centered design for systems that support effective human e-learning.

In order to "make people more effective learners", i.e. to take into account the unique needs of users as learners, a shift from user-centered to *learner-centered design* is needed (Soloway, Guzdial & Hay, 1994). It can range from attempts to design with the needs of the learner at the forefront, towards involving the learner at various stages of the design process (Good & Robertson, 2006). Such an approach entails understanding and considering who is the user, what are her/his needs, what we want her/him to learn, how is (s) he going to learn it and how are we going to support her/him in achieving the learning objectives. Accordingly, a variety of learners' types must be considered due to characteristics revealing user individual differences such as personal learning styles and strategies, diverse experience in the learning domain, as well as previously acquired knowledge and abilities. Many authors have attempted to provide comprehensive lists of additional needs for specific educational domains, but (Soloway, Jackson, Klein, Quintana, Reed, Spitulnik, Stratford, Studer & Jul, 1996) concisely summarize them under broad categories of universal applicability. This work begins to provide a foundation for matching the nature of the learning experience to the differentiated requirements of diverse learners. Such a foundation will be increasingly useful when meeting learner diversity. The role of an intuitive user interface and a flexible interaction suited to different needs, preferences and interests becomes even more important for the users' success, as users with a wide variety of background, skills, interests, expertise, goals and

learning styles *cf.* (Benyon, Crerar & Wilkinson, 2001; Egan, 1988) are using computers for quite diverse purposes, including for learning purposes. If so, this points to the need for effective learning tools with which practitioners can develop and deliver their own learning environments.

The Psychology of Human Learning

The field of *human learning in psychology* is developing fast. This presents a significant problem for practitioners who wish to apply the best and most relevant findings to improve e-teaching and e-learning. Psychological theories are intended to capture and integrate such findings into coherent bodies of knowledge. However, current theories are often too complex for the practitioner to deploy, though they can offer potential benefits for those who are willing to climb a steep learning close.

Complex and powerful theories of human learning and cognition include ACT-R (Adaptive Control of thought–Rational; Anderson & Lebiere, 1998), SOAR (not an acronym; Newell, 1990), COGENT (not an acronym; Fox, 1980; Fox & Cooper, 1997) and ICS (Interacting Cognitive Subsystems; Barnard, 1999; Barnard, May, Duke & Duce, 2000). A full review of such models is beyond the scope of this chapter or any one chapter, but these models all appear to share a number of important qualities and they deserve attention within the context of the psychology of human learning.

Consider ACT-R briefly (Anderson, 1983). It has a long and distinguished career in psychology and provides a powerful architecture of human cognition. The aim is to help us better understand and simulate human cognitive processes. The long term goal is to develop a fully grown system that can explain the full range of human cognitive activities, including working with interactive systems and, of course, human learning. Further information is available from the ACT-R web site (see URL in references list). ACT-R based research has generated over five hundred publications (as shown in the above web-site) and this count does not include publications about earlier versions of ACT-R and predecessor models. Clearly ACT-R is a powerful and complex theoretical framework but can present difficulties when being applied to practical problems because of that complexity.

Another approach to applying modern psychology to practical problems such as e-learning is to develop "simplistic theories" (Adams, 2007a). Such theories are deliberately designed both to capture relevant and current findings but also to be simple enough to guide practitioners. In the words of Einstein (1934) "Everything should be made as simple as possible, but no simpler." The Model Human Processor (MHP) is an alternative to complex cognitive theories and can be seen as a cut-down psychological theory, one that can be used by designers and other computer scientists, but without the over-powering complexities of a fully-fledged theory. The Model Human Processor (Card, Moran & Newell, 1983) is one outstanding theory that deliberately takes this tactic. MHP has the dual advantages of being simple enough to be applicable and also being developed directly to solve IT design problems. Over the years, the status of MHP as a psychological process has been strongly criticized. Such criticisms have been due, in part, to a failure to appreciate that MHP was never intended as a full psychological theory, but rather an application of then current cognitive psychology to act as a guide to system design and evaluation.

Some subsequent research has attempted, with some success, to develop MHP further (Liu, Feyen & Tsimhoni, 2006). They developed the Queuing Network-Model Human Processor (QN-MHP) in an attempt to integrate the queuing network and the symbolic approaches as a basis for cognitive modeling. The overall aim was unify theoretical and methodological aspects of cognitive modeling and the development of usable, HCI simulation methods. This theory was never intended as a full theory of human cognition but as a tractable guide for system designers and evaluators, provid-

ing a simple but coherent model of the intended users. Whilst this approach has been criticized for its incompleteness, it was never intended to be complete, merely to capture and apply the main relevant points of then current theories in cognition (Dix, Finlay, Abowd & Beale, 2004). MHP is clearly useful for personal computer based interfaces but may not be so applicable to the emerging, new types of technology (Byrne, 2001). A number of major paradigm shifts have occurred in system design and in the issues considered important in this field. So MHP perhaps is best seen as a brilliant trail blazer which should encourage us to develop new ways of dealing with interactive technology in all its forms, with user supportive architectures and with adaptable and self-adaptive new systems. However, it has considerable value as both a teaching aid and to inspire new approaches. For example, consider the inclusive design approach (Keates & Clarkson, 2003) that draws explicitly on MHP to construct the inclusion cube.

Broadbent's Maltese cross provided a further, conceptual advance, affording a well defined executive function and the two-way flow of information. This memory-store model has been based upon a considerable volume of high quality research and presented in a seminal paper (Broadbent, 1984). There are four memory stores and a well delineated executive function, i.e. input memory, output memory, working memory, long-term memory and a linking executive function and was presented as a simplistic model of human memory. However, it has the potential to be a cohesive architecture of human cognition. It has been compared with a powerful von Neumann machine.

The concept of the simplistic theory is now relatively well established, the search is now on for such a theory that captures more recent advances in the psychology of human learning that will guide the development of the next generation of e-learning applications.

The Development of Better Learning Environments

Here we include a range of *environments for e-learning*, including the MUD (Multi-User Dimension), the MOO, (MUD Object Oriented or Multi-user Object Oriented), WOO (WEB Object Oriented or 'W3 + MOO'), virtual reality (VR) applications and augmented reality applications. MUDs and MOOS are different from other virtual reality systems since they are primarily text-based virtual realities intended for multi-use and accessible by the Internet. MUDs started as multi-user interactive role-playing games on the Internet but soon developed into communication and collaboration environments where diverse groups of people can meet online. The MOO provides a powerful programming language to support create entirely new objects, building the MOO virtual-world. It is, of course possible to add a graphical front end such as a 3D VR environment; one such example is "Diversity University". However, the potential of the MOO support individual and group learning has yet to been fully appreciated by e-teachers (Fanderclai, 1995).

Turning to more recent developments in VR, current computer technology allows us to create a striking range of imagery, displays, real-time computer graphics multi-sensory environment and virtual worlds that have the potential for a new generation of e-learning. The technology can vary from simple screens and keyboards to head-mounted audio-visual display, position sensors and tactile interface devices. In this way, learners can enter computer-generated environments that are limited only by the imagination of the designers and end-users. For example, Sloodle combines "Second Life", a VR application, with Moodle, a course management system. It promises to open up new opportunities for a social, immersive, e-learning experience, though it is still at an early stage of development (Kemp & Livingstone, 2006). At this stage it is clear that, exciting though these developments may be, they still have to

pass several crucial tests. They include; how best to develop such systems without recreating old mistakes, how to keep costs to acceptable levels, accessibility, usability, personalization, adapt-ability, adaptivity and acceptability (Adams and Granić, 2007; Adams, 2007b; Granić and Ćukušić, 2007; Adams, Granić & Keates, 2008).

Design for Accessible and Usable E-Learning Systems

In the deservedly exciting developments in new and immersive learning environments, it is clear that they tend to be technology-driven rather than learner-driven. If so, there are at least three serious risks. First, their potential may not be realized or realizable given state-or-the-art current technolo-gies and budgets. Second, they may fail to capture the requirements of their intended students and third, they may so easily be functionally exciting but fail to be either usable or accessible. This third point will be developed in more depth later on, but for now it is sufficient to say that technology-driven system solutions can often fail to be rel-evant, *accessible* or *usable* (Adams and Granić, 2007; Adams, 2007b; Granić and Ćukušić, 2007; Adams, Granić & Keates 2008). Earlier sections of this chapter show how accessibility comprises both a complex and a vital issue for designers of e-learning systems to tackle, if their offerings are to be acceptable to their intended users.

The Development of Ambient Intelligence and Smarter Systems

As discussed above, current work that conducted expert evaluations of six *ambient intelligence* (AmI) systems found that the chosen measures of accessibility, system smartness, user satisfaction and usability were not related to each other in simple ways. We found that ambient intelligence was not always appreciated by users. It was almost as if it acted as a background resource that is not always brought to the foreground and, if so, not always appreciated as much as it should. In addi-tion, we also found that, whatever the explanation, user satisfaction could not be assumed to auto-matically accompany high levels of accessibility and usability and so cannot be taken for granted by developers and other practitioners (Adams, Granić & Keates, 2008). Riva, Vatalaro, Davide and Alcañiz (2001) set out the basic requirements for ambiently intelligent systems as follows. They argue that it should seamless connectivity, efficient network support and effectively accessible and usable interfaces. As they put it, AmI systems should "not involve a steep learning curve". Thus it should act as if it were aware of (a) the presence of the users, (b) their requirements and prefer-ences, (c) be responsive in apparently intelligent ways to our attempts at communication and to our behaviour, (d) capable of intelligent dialogue, (e) be unobtrusive, even invisible when appropriate and (f) enjoyable.

Synergy between Cognitive and Emotive Factors in Human Learning

Stanford-Smith (2002) has concluded that much current e-learning is dull and boring. He calls it "little more than electronic page turning" or "Click & Yawn"! Yet virtual reality application and other modern solutions offer a learning environment that respects both cognitive and affective learn-ing, providing a student learning experience that is logical and emotive, practical and quirky, or-ganized and spontaneous. Traditionally, research on human cognition has been held at a distance from research on human emotions. For example, recent theories such as ACT-R (Anderson, 1983) and Simplex-One (Adams, Langdon & Clarkson, 2002) focus very much on cognitive processes that contribute to human information process-ing. However, more recent findings show how *cognitive* (information processing) and *emotive processes* interact. For example, Adams and Rus-sell (2006) compared user performance on two, functionally equivalent websites. However, one

of the websites was designed to be more irritating than the other website which, hopefully, was less irritating (one website required repeated log-ins, so the irritation level was quite mild). It turned out that performance on the less irritating website was significantly better than the more irritating website, all else being equal. Therefore more recent theories allow for the interaction between cognition and emotion (e.g. Simplex Two; Adams 2007a), though this forwards step has yet to be reflected in mainstream textbooks.

SOLUTIONS, RECOMMENDATIONS AND FUTURE TRENDS

In the context of the emerging knowledge society for all, the focus of research in this area has been set on applications of technologies for user-centered learning, building on the concept of learning and on sound pedagogical principle. The main objective is to increase the efficiency of learning contributing to a deeper understanding of the learning process by exploring links between human learning, cognition and technologies. What is becoming more evident as we explore advanced learning technologies is that holistic and systemic views of learners and their environments are necessary if we wish to make progress (Spector & Anderson, 2000).

In order to support the improvement of both, the learners' subject matter knowledge and learning strategy application, the e-learning environments should be designed to address learners' diversity in terms of learning styles, prior knowledge, culture and self-regulation skills (Vovides, 2007).

Compatibility of cognitive styles and technology directly impact perceptions of learning effectiveness, motivation and performance. When cognitive styles and technology are compatible, individuals are better equipped to attend to and interpret relevant information, which are important to learning and learning outcomes (Workman, 2004).

Individualized learning and reflective learning are two important ingredients that can enhance an e-learning system that supports learning and instruction offering the necessary scaffolds for the development of meta-cognitive and self-regulatory skills. In essence, the scaffolds within an e-learning system need to be adaptive in order to foster student self-regulation in these open-ended learning environments, *cf.* (Azevedo, 2005).

To achieve a better understanding of cognitive learning approaches for the design of accessible and efficient e-learning systems requires us to declare the systematic framework of learners and their environments that underpins our work. This will enable the well-informed reader to judge if it is adequate or if a better framework is necessary. Our framework is based upon the following, relevant six dimensions of accessible e-learning: profiles of the intended users, the context of use, the tasks to be undertaken, the technological platforms, cultural environment and principles of human learning (see Figure 1).

An essential starting point in effective and accessible e-learning design includes a clear understanding of the intended pedagogical aims and a determination of the pedagogical model or strategy underlying what is being attempted. The selection of technologies will be performed within the context of these pedagogical choices. Hence "pedagogy first, technology second" approach to e-learning is the key to understand both the potential of learning and the development of successful e-learning resources.

Requirements of an Effective E-Learning System

This section proposes that an effective e-learning system must be based upon the cognitive skills of the intended users in general and in the learning skills and preferences of the users in particular. However, such a system must also be accessible, adaptable, adaptive and acceptable, keeping in step with current trends in mobile computing and

Figure 1. Framework for accessible and efficient e-learning
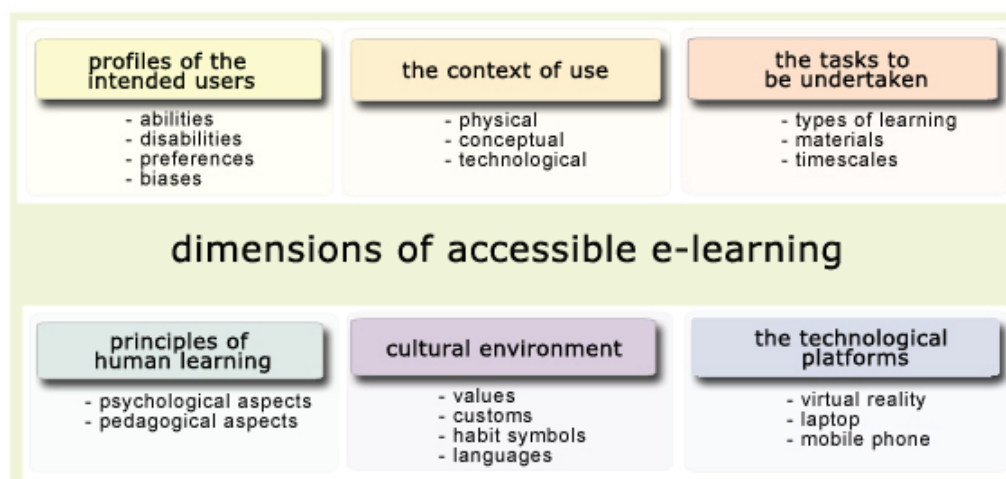
ambient intelligence. If so, then it is important to consider the key issues that include, inter alia, user sensitive design, individualized approaches, adaptability and adaptivity (see Figure 2).

User Sensitive Design

User sensitive design can be advocated as one of the most appropriate methodologies developed out of user centered design for the creation of effective e-learning (Gregor, Newell & Zajicek, 2002; Newell & Gregor, 2000). User sensitive design is a natural development from user-centered design. The central concept of user sensitive design is an equal focus on user requirements and the diversity of such requirements in the population of intended users. If so, it follows that it may be beneficial to consider not only typical users but also "outliers" i.e. those users whose needs are more significant than the average user. Designing for these users may provide design insights that benefit all. Why should the average user have to make do with a minimalist solution, when others receive a more customized product or service?

We bring together the *user sensitive approach* with learner-centered design to create a robust approach to learner inclusion in the design process,

learner performance and to the learner experience of twenty-first century e-learning. It is aiming to explore the creation of successful e-learning systems able to increase users' learning outcomes and advance their personal learning experience. First, the hypothesis that the solution is to be found in systems that comply with nine specific factors was explored (Adams, 2007a). Accessibility and learner modeling turned out to be the weakest points. Second, an empirical study was conducted, aiming to investigate the influences of user individual characteristics on users' learning outcomes in e-learning environment (Granić and Nakić, 2007). The experiment indicated that motivation to learn, in addition to expectations about e-learning significantly impacts on users' learning achievements. Third, an enhancement of the designed methodology with user sensitive research issues enabled us to outline improved experimental procedures. Moreover, further experiment results will provide us better insight into arguments needed to carefully assess benefits of developing and involving a user model into an e-learning system.

Figure 2. Effective e-learning
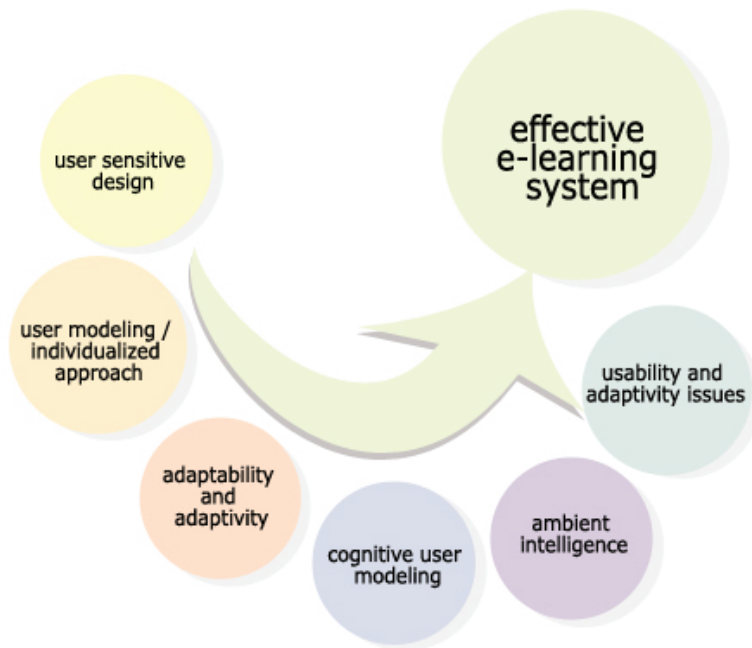
Individualized Approaches

Progress in the field of e-learning has been surprisingly sluggish and "… although technology is often touted as the great salvation of education – an easy way to customize learning to individual needs – it rarely lives up to this broad expectation" (Healey, 1999). It seems that too much of the research may be driven by technical possibilities, while paying inadequate attention to the area of application. Huge resources were spent for e.g. courseware development and not enough was left to improve the actual quality of learning (Nielsen, 1993; Nielsen, 2001).

Additionally, *user modeling* has not yet succeeded in addressing the variety and richness of the educational environment, even in the terms of individual user profiles or characteristics. Learners are diverse and have different requirements such as their individual learning style, their actual level of learning in the learning process and their individual background knowledge. For quite a long time these issues were out of the focus of research in the hope that new technology will somehow resolve the lack of real progress. However, experience has proved so far that these issues can not be avoided as they determine the type and scope of e-learning systems that are likely to succeed. In this context, a satisfactory framework for taking into account users' heterogeneity have provided adaptable systems, by allowing the user to control the interface customization and adaptive systems, by adapting the interface behaviour to user's individual characteristics (Schneider-Hufschmidt, Kühme & Malinowski, 1993).

Adaptability and Adaptivity

Adaptability refers to changes made to a system or its interface before run-time to accommodate the requirements and preferences of its learners. Clearly, adaptability is a potentially very useful approach to custom e-learning, but it does presuppose the existence of a well validated user

profile or model. A simple profile may contain a brief list of learner preferences and past learning experiences. A learner model may capture a more complex account of an individual's strengths and weaknesses. Whilst it is usually the case that the more reliable information the better, there will always be a trade off between information obtained and the costs required to gather it. There are, of course, ethical and practical issues raised by disclosure of information to a system and on the Internet (Adams & Russell, 2006; Adams & Granić 2007).

Adaptivity is a more subtle concept, referring to the ability of a system or website to change to adapt to meet user needs whilst running. For example, if an individual consistently fails to click properly on a series of small icons, the system may diagnose this as an error due to icon size and increase the size of the icons whilst running. Another individual may always select auditory feedback over visual feedback, so the system may ask if they want auditory feedback to be the default mode. As above, adaptivity raises significant ethical and practical problems of information disclosure, perhaps even raising problems of which the individual is unaware. It is also clear that machine learning and intelligence is an important component of an adaptive e-learning system (Adams & Russell, 2006; Adams & Granić, 2007; Granić & Nakić, 2007).

Cognitive User Modeling

The central importance of the concept of *cognitive user modeling* (Adams, 2008) is introduced, defined and refined. If it is easier to work with someone we know, then it may be the case that an e-learning system would be more effective if it also possessed the equivalent of such knowledge. The concept of cognitive user modeling is very important here, taking a cognitive approach to an understanding of the skills and knowledge of the learner. But how can the complexity of human thinking and performance be captured in a coher-

ent way that can be applied by users? As introduced above, complex theories such as ACT (Anderson, Bothell, Byrne, Douglass, Lebiere & Qin, 2004)) and SOAR (Jones, Lebiere & Crossman, 2007) require a considerable learning curve before they can be applied. Simpler theories such as the Model Human Processor (MHP) (Card, Moran & Newell, 1983) and Broadbent's (1984) Maltese cross theory provide a parsimonious capture of then current state-of-the-art theories of human performance. Consequently, then such theories can be created to capture current knowledge and allow it to be applied by practitioners to user modeling and interactive e-learning system design.

To distinguish between these two types of theories, we refer to the former as full theories, whilst the latter are entitled simplistic theories. A full theory is defined as a theory that aims to provide a full account of human cognition. A simplistic theory is defined as a theory that seeks to capture current findings in such a way as to allow practitioners to apply the theory to solve practical problems.

A consideration of all possible simplistic theories is beyond the scope of this chapter; here we use one representative theory to demonstrate current knowledge. Simplex Two (Adams, 2007a) is derived from Broadbent's Maltese cross. He started with four types of memory store (input, output, working memory and long term memory) controlled by an executive function that processes information and transports that information. The separation of memory and processing is a key feature of this theory. Novel features (compared with MHP) are the introduction of the flow of information in all directions and the provision of an executive function to control the memory stores. Simplex Two is introduced and its dual role as a user model and a theory of human cognition is explained with examples.

Usability and Accessibility Issues

The deployment of user sensitive design within the e-learning context promotes individualization

and end-user acceptability, ensuring that usability and accessibility should be design concerns, thus avoiding the need for post-hoc adaptations. Unfortunately, studies have regularly shown that the *accessibility* of web-based applications in general falls short of an acceptable level (Sloan, Kelly, Heath, Petrie, Fraser & Phipps, 2006) and most of existing efforts related to accessible e-learning ones propose guidelines that primarily address technical accessibility issues (De Marsico, Kimani, Mirabella, Norman & Catarci, 2006)

Furthermore, when considering e-learning applications it has been claimed that *usability* assessment needs further consideration of learning perspective e.g. Squires and Preece (1999), although some authors propose applying heuristics without further adjustment to the e-learning context e.g. (Parlangeli, Marchigiani & Bagnara, 1999). In the line with the first approach are the results of the study reported in (Granić, 2008). The experience indicated that useful usability assessments with a significant identification of interface limitations can be performed quite easily and quickly. On the other hand, it raised a series of questions that require further comprehensive research, the more so if the employment of universal design within e-learning context is considered. Consequently, when designing an accessible and easy to use e-learning system, system which attempts to address the needs of all potential users, it is important to consider the key issues that include learner-centered design paradigm, context of use approach, individualized approach, pedagogical framework as well as guideline framework. If so, then such an approach will be in accordance with the claim that in e-learning we do not need user interfaces that support "doing tasks", but interfaces that support "learning while doing tasks", *cf.* (Hsi & Soloway, 1998).

While some authors consider accessibility as one of usability's components, e.g. (Zaharias, 2005; Adams 2007a), others point out potential conflicts in including accessibility guidelines alongside usability ones, e.g. (Phipps and Kelly, 2006). This may be due, in part, for a focus of accessibility concerns on the lowest level of design, namely standards for coding in a programming language on in a mark-up language such as HTML or XHTML. One solution offered here is to develop the concept of accessibility into a taxonomy of different types of accessibility. Defining inaccessibility as the presence of barriers to stop or impede user exploitation of a learning system, Adams (2007a) identified different types of accessibility problems. Any of these problems can place the intended user on the wrong side of a digital divide or "haves" and "have-nots". The barriers identified are:

a. hardware barriers i.e. having inadequate or inappropriate hardware,
b. communications barriers i.e. being unable to make reliable contact with system for reasons such as poor signal strength,
c. sensory / perceptual problems such as poor visibility or sound relative to the population of intended users,
d. cognitive barriers, where the cognitive demands made on the user are excessive, given their known cognitive skills levels, particularly in navigational demands and comprehension of contents and
e. barriers to objectives and aims, such that the user cannot achieve their objectives.

A sixth barrier can be created with respect to the learner's abilities to respond appropriately. For example, a touch pad may be too sensitive or a system may require a speed of response that is barely attainable. This simple framework enables accessibility and usability issues to be considered together in a constructive and complementary manner. Whilst Adams (2007b) referred to the "user" this reference should be read as the "learner" in the present context, as it allows for the inclusion of the user's learning objectives.

Brain Computer Interfaces

So far, in our discussion we have focused on relatively familiar methods by which the learner can interact with the system. However, technologies, such as psycho-physiological measurements in general and electroencephalograms (EEG) in particular, are emerging and improving. Future generations of technologies indicate a revolution in the emerging Information Society through the development of *brain-computer interfaces* (BCI) and *augmented cognition solutions*. Ideally, such systems would make e-learning environments more accessible to a range of users, including those with psychomotor disabilities and anyone who cannot use a keyboard or mouse dependent system with facility. Adams, Bahr and Moreno (2008) reviewed some critical psychological and pragmatic factors are to be understood before these technologies can deliver their full potential. They examined a sample (n = 105) BCI papers and found that the most studies provided communication and control resources to people with disabilities or with extreme task demands. Surprisingly, they found that issues of usability and accessibility were rarely considered. They concluded that there is a need for an increased appreciation of these issues and the related large research literatures, if BCI are to contribute significantly to the development of accessible and usable learning environments.

Ambient Intelligence

The role of the concept of *ambient intelligence* (AmI) is introduced, defined and refined above. We are all familiar with the relatively unintelligent systems on most personal computers and laptops. Some of us may also be aware of the increasing "smart" or apparently intelligent systems that are emerging (examples). They are probably best seen as not truly intelligent, thinking systems, but they offer the possibility of sensible responses to learner needs. If intelligence or at least "smart"

systems are emerging in the office or home, there is also the emergence of systems that are located more widely in the environment. For example, when you observe a bus stop or airport display, the system may detect your e-ticket and display information that is relevant to you, in your own language. Such systems are captured by the descriptive title "ambient intelligence" (ISTAG, 2001). Again, there is a trade-off between functionality and convenience on the one hand and information disclosure, willingly or unwillingly of the other.

Relating Human Learning Requirements and E-Learning Solutions

Based upon the work reported above, it is now possible to present a relatively simple taxonomy of types of human learning and a range of e-learning solutions. The relationship between cognitive learning factors and e-learning is developed below. Consider the following table that attempts to set out types of human learning, based on the Simplex Two theory (Adams, 2007a) and related forms of e-learning (see Table 1). The different components of the Simplex theory (column one) are related to different types of human knowledge acquisition (column two) and the different types of related skills attainment (column three). This approach makes the following, testable predictions. For each type knowledge (column two) or skills (column three), there is a corresponding form of e-learning environment, as shown in column four (knowledge acquisition) and column five (skills attainment).

Relating Cognitive User Modeling to E-Learning

Current evidence from cognitive user modeling supports the development of accessible e-learning solutions. In addition to the six levels of accessibility discussed above (hardware barriers,

Table 1. Linking types of human learning to e-learning solutions

Aspects of human learning	Types of knowledge	Types of process skills	e-Learning knowledge	e-Learning skills
Input (I)	Learn New Patterns	Perceptual Skills	Multimedia	Multimedia / VR
Feedback (F)	New Feedback	Manage Feedback	Multimedia	Multimedia / VR
Working Memory (WM)	Add New Items to WM	Improve WM Skills	Mainly Text	Mainly Text
Long Term Memory (LTM)	Add New Items to LTM	Improve LTM Skills	Mainly Text	Mainly Text
Executive Functions (ExF)	Add New Task Structures To ExF	Improve ExF Skills	Task Simulation	Task Simulation / VR
Emotional Evaluation (EE)	Learn New Evaluations	Improve EE Skills	Virtual Reality (VR)	VR
Mental Models (MM)	Learn New Mental Models	Learn New Modeling Skills	Virtual Reality (VR)	VR
Output (O)	Learn New Responses	Learn New Response Skills	Response Learning	Task Learning / VR
Complex Output Sequences (COS)	Learn New Output Sequences	Learn To Create Better Output Sequences	Task Simulation	Varied Task Learning / VR
Episodic Memory (EM) (In WS)	Add New Items To EM	Learn Better EM Skills	Biographical Information	Biographical Tasks / VR
Social Context	New Social Knowledge	Learn New Social Skills	VR	VR

communications barriers, sensory/perceptual problems, cognitive barriers, barriers to learning and performance objectives as well as unrealistic response requirements), the Simplex Two framework identifies those locations within human cognition where accessibility problems can hit. There are two types of accessibility problem, namely problems with memory capacity and second problems with processing capacity.

Changing the Ways E-Learning Environments are Constructed

We have given a general description of the new requirements for the design of effective e-Learning systems. But how will the presented cognitive theories have a significant effect on the presentation of information, the learner navigation, the structure of an e-learning lesson and the complexity of the environment? The key to the answer is that these cognitive theories will enable e-educators to get to know their students better, more objectively and more systematically. The theory Simplex Two has been designed to provide e-educators with an accessible and usable way to profile their students in terms of only nine aspects of human cognition (see above). These nine components have all been validated in a recent, major study. So, we are confident that they capture the bigger picture of the strengths and weaknesses of our students. E-educators can readily familiarise themselves with the simple structure and contents of Simple Two. (It does not require the substantial learning overhead of more complex theories such as ACT-R.). E-educators can then address questions about their students' abilities and disabilities. This can

be done in several ways. One method is to judge the strengths and weaknesses of each student. Simply, is this a strong area or not for the student? Then look critically at the e-learning materials. Will the materials overload the student's known weaknesses or stimulate their known strengths? Other ways to collect useful evidence would be for you to evaluate each student's strengths and weaknesses yourself on ten point scales and use these profiles indicate that they will be able to use your e-learning materials well. Or, you could ask the students to evaluate their own strengths and weaknesses. Finally, you could use psychometric tests to evaluate your students' requirements. This is a much more objective approach. All of these approaches enable you to look at the overall e-learning requirements of your students and also you can identify their differing needs and adapt your system to reflect individual differences. Once you have student profiles, you can use them to evaluate the suitability of your systems. For example, if you are concerned about the best ways to present information, your student profiles should contain valuable information about their sensory and perceptual requirements. Effective learner navigation requires the student to have adequate skills in working memory, attention and concentration. The appreciation of the structure of an e-learning lesson reflects the student's abilities to create mental models. The complexity of the environment should support the student's executive skills, not being too complex as that will cause overload, not too simple as they might be boring. The complexity of the environment should also match the learning skills of the student. It should be neither too difficult not too easy. In each case, the demands of the e-learning systems can be matched against the strengths, weaknesses and requirements of your students. If you wish to apply Simplex Two to an evaluation of your students' requirements and the design of your e-learning systems, the present authors would be willing to answer any questions that you might have.

Simplex Two can also explain how different technological innovations can impact e-learning, by relating their features to the different factors of human cognition, as follows. A brain computer interface (BCI) will revolutionise e-learning. A BCI can enable students with limited physical movement to engage with an e-learning system without the requirement for gross physical movements such as required by using a mouse or a keyboard. Signals from the electroencephalogram of the student (due to cognitive events in their brain or due to their slight psychomotor movements e.g. finger flexion) can be relayed as signals with which to communicate and control an external system such as an e-learning system. But this approach will be the cure, par excellence, for the accessibility problems faced by any students who are unable or unwilling to interact with physically demanding systems because of physical or cognitive disabilities (Simplex: psychomotor and cognitive responses). Virtual reality (VR) applications will also revolutionise e-learning. Virtual worlds can now be created relatively easily. In such virtual worlds, students can enter much richer learning environments than ever before and learn new skills in realistic settings that can be repeated or modified on demand (Simplex: executive and memory functions). If BCI and VR can be combined one day, students with accessibility problems could also benefit from richer and more realistic learning environments. In contrast, a MOO (*MUD, object oriented*) system is a text-based, online and virtual reality system to which multiple users (learners) connect at the same time. Such systems can bring e-learning to widespread or technologically limited communities, where more advanced options are not accessible. Blind users can also use screen readers to interact with such a system. Finally, ambient intelligence (AmI) technologies are those technologies that can detect the presence of people and respond smartly to significant aspects of them (perhaps with use of an RFID tag). For example, a student can enter a room or a study space and be identified by an e-learning system

that can adapt to her requirements, for example changing the language, mode of presentation or choice of lesson. If so, this opens the possibility of e-learning that is portable or is adaptive.

DISCUSSION AND CONCLUSION

In this chapter, we have been able to address the research issues and practical questions associated with the design of accessible e-learning systems by taking a cognitive learning approach. Whilst this is a complex and developing field, we have identified some of the key issues that support the development of theory and practice. Such issues include; a better appreciation of the pedagogical principles that underlie e-learning, the development of a more advanced psychology of human learning, the development of better learning environments, the design of accessible and usable e-learning systems, the development of ambient intelligence and smarter systems, a greater appreciation of the potential synergy between cognitive and emotive factors in human learning. Our solution to the problems associated with these issues is based upon: setting requirements for effective e-learning, adopting a user-sensitive design approach, building in both adaptability and adaptivity, basing user requirements on cognitive user modeling, taking usability and accessibility factors into account and making better use of ambient intelligence in e-learning environments. On this basis, we have been able to show how human learning requirements can be used to identify the most appropriate e-learning solutions. Lastly, we have been able to use a cognitive user modeling perspective to support the creation of e-learning applications that are both usable and accessible. In this way, we have shown how evidence and insights from diverse subjects such as cognitive science, computing science and social sciences can be integrated to provide a robust platform for the next generations of pedagogically sound e-learning systems.

Finally, looking to the future, exciting new systems like Second Life and Sloodle learning systems for virtual environments (Kemp & Livingstone, 2006) are emerging to offer new technological platforms upon which to build accessible, new learning environments. However, it is also clear that technology alone is necessary but not sufficient for functional systems to be smart, usable and accessible. That will depend upon system designers being able to call upon expertise in such areas as user modeling, cognitive science, computing science and social sciences to do so. It will be the biggest challenge to technology enhanced e-learning in the future.

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REFERENCES

ACT-R. (2002). *Welcome to ACT-R*. Retrieved October 12, 2003, from http://act-r.psy.cmu.edu/

Adams, R. (2007a). Decision and stress: Cognition and e-accessibility in the information workplace. *Universal Access in the Information Society, 5*, 363-379.

Adams, R. (2007b). User modeling for intelligent interfaces in e-learning. In *Universal access in human-computer interaction, application and services* (LNCS 4556).

Adams, R. (2008). User modeling & monitoring: A universal access perspective. In C. Stephanidis

(Ed.), *Universal access handbook*. Mahwah, NJ: Lawrence Erlbaum Associates Inc.

Adams, R., Bahr, G. S., & Moreno, B. (2008). Brain computer interfaces: Psychology and pragmatic perspectives for the future. In *AISB Proceedings*, Aberdeen.

Adams, R., & Granić, A. (2007). Creating smart and accessible ubiquitous knowledge environments. In C. Stephanidis (Ed.), *Universal access in HCI, part II, Proceedings of HCII 2007* (LNCS 4555, 3-12). Berlin, Germany: Springer-Verlag Berlin Heidelberg.

Adams, R., Granić, A., & Keates, L. S. (2008). Are ambient intelligent applications universally accessible? In *Universal Access to Novel Interaction Environments: Challenges and Opportunities, Proceedings of the 2nd International Conference on Applied Ergonomics AE International 2008) with the 11th International Conference on Human Aspects of Advanced Manufacturing (HAAMAHA)*, Las Vegas, NV, USA.

Adams, R., Langdon, P., & Clarkson, P. J. (2002). A systematic basis for developing cognitive assessment methods for assistive technology. In *Universal Access and Assistive Technology, Proceedings of the CWUAAT, Cambridge Workshop for Universal Access and Assistive Technology*.

Adams, R., & Russell, C. (2006). Lessons from ambient intelligence prototypes for universal access and the user experience. In *Universal access in ambient intelligence environments* (LNCS 4397, pp. 229-243). Berlin, Germany: Springer.

Anderson, J. R. (1983). *The architecture of cognition*. Cambridge, MA: Harvard University Press.

Anderson, J. R., & Lebiere, C. (1998). *The atomic components of thought*. Mahwah, NJ: Lawrence Erlbaum Associates.

Anderson, J. R., Bothell, D., Byrne, M. D., Douglass, S., Lebiere, C., & Qin, Y. (2004). An integrated theory of the mind. *Psychological Review, 111*(4), 1036-1060.

Azevedo, R. (2005). Using hypermedia as a meta-cognitive tool for enhancing student learning? The role of self-regulated learning. *Educational Psychologist, 40*(4), 199-209.

Barnard, P. J. (1999). Interacting cognitive sub-systems: Modelling working memory phenomena with a multi-processor architecture. In A. Myake & P. Shah (Eds.), *Models of working memory*. Cambridge, UK: Cambridge University Press.

Barnard, P. J., May, J., Duke, D., & Duce, D. (2000). Systems interactions and macrotheory. *Transactions on Computer Human interface, 7*, 222-262.

Benyon, D., Crerar, A., & Wilkinson, S. (2001). Individual differences and inclusive design. In C. Stephanidis (Ed.), *User interfaces for all: Concepts, methods, and tools* (pp. 21-47). Mahwah, NJ: Lawrence Erlbaum Assoc.

Biggs, J. B. (2001). *Teaching for quality learning at university: What the learner does*. Open University Press.

Broadbent, D. E. (1971). *Decision and stress*. London: Academic Press.

Broadbent, D. E. (1984). The Maltese cross: A new simplistic model for memory. *Behavior and Brain Sciences, 7*, 55-94.

Byrne, M. D. (2001). ACT-R/PM and menu selection: Applying a cognitive architecture to HCI. *International Journal of Human-Computer Studies, 55*, 41-84.

De Marsico, M., Kimani, S., Mirabella, V., Norman, K. N., & Catarci, T. (2006). A proposal toward the development of accessible e-learning content by human involvement. *Universal Access in Information Society, 5*. 150-169

Dix, A., Finlay, J., Abowd, G., & Beale, R. (2004). *Human-computer interaction* (3rd ed.). London: Prentice Hall.

Egan, D. (1988). Individual differences in human-computer interaction. In M. Helander (Ed.), *Handbook of human-computer interaction* (pp. 543-568). Elsevier Science B.V. Publishers North-Holland.

Einstein, A. (1934). On the method of theoretical physics. *Philosophy of Science, 1*(2) 163-169.

Fanderclai, T. L. (1995). MUDs in education: New environments, new pedagogies. *Computer-Mediated Communication Magazine, 2*(8).

Fox, J. (1980). Making decisions under the influence of memory. *Psychological Review, 87,* 190-211.

Fox, J., & Cooper, R. (1997). Cognitive processing and knowledge representation in decision making under uncertainty. In R. W. Scholz & A. C. Zimmer (Eds.), *Qualitative theories of decision making* (pp. 83-106). Lengerich, Germany: Pabst.

Good, J., & Robertson, J. (2006). CARSS: A framework for learner-centred design with children. *International Journal of Artificial Intelligence in Education*, 16(4), 381-413.

Granić, A. (2008). Experience with usability evaluation of e-learning systems. *Universal Access in the Information Society*, 7, 209-221.

Granić, A., & Nakić, J. (2007). Designing intelligent interfaces for e-learning systems: The role of user individual characteristics. In *Universal access in human-computer interaction. Applications and services* (LNCS 4556, pp. 627-636).

Granić, A., & Ćukušić, M. (2007). Universal design within the context of e-learning. In *Universal access in human-computer interaction. Applications and services* (LNCS 4556, pp. 617-626).

Gregor, P., Newell A. F., & Zajicek, M. (2002). Designing for dynamic diversity - interfaces for older people. In J. A. Jacko (Ed.), *Proceedings of the ASSETS 2002. The Fifth International ACM Conference on Assistive Technologies*, Edinburgh, Scotland (pp. 151-156).

Hannafin, M., Land, S., & Oliver, K. (1999). Open learning environments: Foundations, methods, and models. In C. Reigeluth (Ed.), *Instructional design theories and models* (pp. 115-140). Mahwah, NJ: Lawrence Erlbaum Associates.

Healey, D. (1999). Theory and research: Autonomy in language learning. In J. Egbert, & E. Hanson-Smith (Eds.), *CALL environments: Research, practice, and critical issues* (pp. 391-402). Alexandria, VA: Teachers of English to Speakers of Other Languages, Inc.

His, S., & Soloway, E. (1998). Learner-centred design: Addressing, finally, the unique needs of learners. In *Proceedings of the Computer Human Interaction '98, CHI '98*, Los Angeles, USA (pp. 211-212). ACM Press.

Hook, K. (2000). Steps to take before intelligent user interfaces become real. *Journal of Interaction with Computers, 12*(4), 409-426.

Information Society Technologies Advisory Group (ISTAG). (2001). *Scenarios for ambient intelligence in 2010* (Final Report,EC 2001).

Jones, R. M., Lebiere, C., & Crossman, J. A. (2007). Comparing modeling idioms in ACT-R and Soar. In *Proceedings of the Eighth International Conference on Cognitive Modeling*, Ann Arbor, MI.

Keates, S., & Clarkson, J. (2003). *Countering design exclusion: An introduction to inclusive design*. London: Springer.

Kemp, J., & Livingstone, D. (2006). Putting a second life "Metaverse" skin on learning management systems. In *Proceedings of the Second Life Education Workshop at SLCC*, San Francisco (pp. 13-18).

Kobsa, A. (1995). Supporting user interfaces for all through user modeling. In *Proceedings of the 6ᵗʰ International Conference on Human-Computer Interaction HCI International 1995*, Yokohama, Japan (pp. 155-157). Retrieved from http://www.ics.uci.edu/~kobsa/papers/1995-HCI95-kobsa.pdf

Lieberman, H. (1997). Introduction to intelligent interfaces. Retrieved from http://web.media.mit.edu/~lieber/Teaching/Int-Int/Int-Int-Intro.html

Little, B. (2008). Giving learning a 'second life' chance. *Human Capital Management*, (Jan/Feb).

Liu, Y., Feyen, R., & Tsimhoni, O. (2006). Queuing network-model human processor (QN-MHP): A computational architecture for multitask performance in human-machine systems. *ACM Transactions on Computer-Human Interaction, 13*, 37-70.

Newell, A. (1990). *Unified theories of cognition*. Cambridge, MA: Harvard University Press.

Newell, A. F., & Gregor, P. (2000). User sensitive inclusive design in search of a new paradigm. J. Scholtz & J. Thomas (Eds.), *Proceedings of the First ACM Conference on Universal Usability*, Washington, DC (pp. 39-44).

Nielsen, J. (1993). *Usability engineering*. London: Academic Press.

Nielsen, J. (2001, January 16). *Jacob Nielsen on e-learning. E-learning post*. Retrieved from http://www.elearningpost.com/features/archives/001015.asp

Norman, D., & Draper, S.W. (1986). *User centred system design*. Hillsdale, NJ: Lawrence Erlbaum Assoc.

Pantazis, C. (2001). *Executive summary: A vision of e-learning for America's workforce* (Report of the Commission on Technology and Adult Learning, ASTD). Retrieved from http://www.learningcircuits.org/2001/aug2001/pantazis.html

Parlangeli, O., Marchigiani, E., & Bagnara, S. (1999). Multimedia systems in distance education: Effects of usability on learning. *Interacting with Computers, 12*, 37-49

Phipps, L., & Kelly, B. (2006). Holistic approaches to e-learning accessibility. *Association for Learning Technology, 14*(1), 69-78.

Piccoli, G., Ahmad, R., & Ives, B. (2001). Web-based virtual learning environments: A research framework and a preliminary assessment of effectiveness in basic IT skills training. *MIS Quarterly, 25*(4), 401-426.

Pimentel, J. R. (1999). Design of net-learning systems based on experiential learning. *Journal of Asynchronous Learning Networks, 3*(2), 64-90.

Pulkinen, J., & Peltonen, A. (1998). Searching for the essential elements of Web-based learning environments. In *Proceedings of the 3ʳᵈ International Open Learning Conference*, Brisbane, Queensland, Australia.

Riva, G., Vatalaro, F., Davide, F., & Alcañiz, M. (Eds.). (2001). *The evolution of technology, communication and cognition towards the future of human-computer interaction*. Amsterdam, The Netherlands: IOS Press.

Riva, G., Loreti, P., Lunghi, M., Vatalaro, F., & Davide, F. (2003). 4 presence 2010: The emergence of ambient intelligence. In G. Riva, F. Davide, & W. A. IJsselsteijn (Eds.), *Being there: Concepts, effects and measurement of user presence in synthetic environments*. Amsterdam, The Netherlands: IOS Press.

Savidis, A., & Stephanidis, C. (2004). Unified user interface design: Designing universally accessible interactions. *Interacting with Computers, 16*(2), 243-270.

Schneider-Hufschmidt, M., Kühme, T., & Malinowski, U. (Eds.). (1993). *Adaptive user interfaces: Principles and practice*. North-Holland, Elsevier Science Publishers B.V.

Sloan, D., Kelly, B., Heath, A., Petrie, H., Fraser, H., & Phipps, L. (2006). Contextual Web accessibility - maximizing the benefit of accessibility guidelines. In *Proceedings of the WWW 2006,* Edinburgh, Scotland. Retrieved from http://www.ukoln.ac.uk/web-focus/papers/w4a-2006/

Soloway, E., Guzdial, M., & Hay, K. E. (1994). Learner-centred design: The challenge for HCI in the 21st Century. *Interactions, 1*, 36-48

Soloway, E., Jackson, S., Klein, J., Quintana, Ch., Reed, J., Spitulnik, J., Stratford, S., Studer, S., Jul, S., Eng, J., & Scala, N. (1996). Learning theory in practice: Case Studies of Learner-Centred design. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI96)*, Vancouver, British Columbia (pp. 189-196). New York: ACM Press.

Spector, J. M., & Anderson, T. M. (Eds.). (2000). *Integrated and holistic perspectives on learning, instruction and technology: Understanding complexity*. Dordrecht, The Netherlands: Kluwer Academic.

Squires, D., & Preece, J. (1999). Predicting quality in educational software: Evaluating for learning, usability and the synergy between them. *Interacting with Computers, 11*, 467-483

Squires, D., & Preece, J. (1996). Usability and learning: Evaluating the potential of educational software. *Computers Education, 27*(1), 15-22.

Stanford-Smith, B. (2002). *Challenges and achievements in e-business and e-work*. Amsterdam: IOS Press.

Vovides, Y., Sanchez-Alonso, S., Mitropoulou, V., & Nickmans, G. (2007). The use of elearning course management systems to support learning strategies and to improve self regulated learning. *Educational Research Review, 2*(1), 64-74.

Web Accessibility Initiative. (2005). *WAI: Strategies, guidelines, resources to make the Web accessible to people with disabilities*. Retrieved May 15, 2008, from http://www.w3.org/WAI/intro/accessibility.php

Workman, M. (2004). Performance and perceived effectiveness in computer-based and computer-aided education: Do cognitive styles make a difference? Computers in Human Behavior, 20(4), 517-534.

Zaharias, P. (2005). E-learning design quality: A holistic conceptual framework. In C. Howard, J. Boettcher, L. Justice, K. Schenk, P. L. Rogers, & G. A. Berg (Eds.), *Encyclopaedia of distance learning* (Vol. II). Hershey, PA: Idea Group Publishing.