Chapter V
Integrating Knowledge of Cognitive System and E-Learning Applications

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ABSTRACT

This chapter outlines key findings of cognitive and developmental psychology which could be used as a theoretical framework to guide the design and research of e-learning applications. The chapter consists of two main sections. The first section presents the basic cognitive mechanisms and their development, while the second part discusses how our knowledge of the cognitive system can guide the design of computer-based learning environments. It is proposed that the human mind is organized in three levels: two of them are general-purpose mechanisms and processes and one consists of domain-specific structures of knowledge representation and problem solving processes. These three levels are associated with an effective learning framework. The suggested framework describes the basic points that any designer of e-learning environments must consider. The second section of the chapter discusses e-learning, connecting it to knowledge about the human cognitive system. In this section, we first present the conceptual bounds of the e-learning construct and discuss how cognitive theories of learning should guide the design of technologically-enhanced learning environments. It is proposed that a synergy between the study of human cognition and the design of e-learning applications is required for effectively understanding both fields.
INTRODUCTION

In the last decades the world has witnessed an ‘electronic revolution’. It is widely argued that the transition from the ‘industrial’ to the so-called ‘information’ society has been made possible by the development of novel information and communication technologies (Castells, 2000). New technologies, and especially computers, have dramatically altered both thinking and acting in almost all fields of human activity (Gentile & Walsh, 2002). Hence, it is critical to understand the changes which are being brought about by the introduction of communication and information technologies in order to maximize their benefits and minimize their shortcomings.

Nowadays, we use computers for learning (e.g. educational software), entertainment (e.g. animations, cartoons), communicating (e.g. electronic mail), or performing complex tasks, such as calculations and graphing, storing multi-layer information, text reading and writing, special scientific tasks, etc. (Gentile & Walsh, 2002). It is estimated that nearly half (48%) of all children six and under have used computers and that more than one in four (30%) have played video games (Rideout, Vanderwater, & Wartella, 2003). The impact of computers on modern societies is so vast and multifarious that our age has arguably been called the ‘electronic age’.

Education is one of the fields of human endeavor most affected by the electronic revolution. The impact of computer technologies on children’s cognitive, social and emotional development has been the subject of systematic research in the last decades. This research produced a number of myths and debates concerning the possibilities and dangers resulting from the introduction and extensive use of computers and its related applications in education. Some scholars even go to the extreme by arguing that the use of computers is linked to numerous disadvantages like low self-esteem, low intelligence, exposure to undesirable material, aggression, and obesity (Rocheleau, 1995; Roe & Muijs, 1998), whereas others suggest the exact opposite and stress the importance of outcomes, such as higher academic achievement and cognitive skills (Healy, 1998). Some could attribute such apparent inconsistencies and contradictory findings to the complexity and novelty of the field. However, most researchers would entirely agree on the need for the development of a theoretical framework for understanding the effects of computers on human mind and society.

The present chapter aims to outline key findings of cognitive and developmental psychology which could be used as a theoretical framework to guide the design and research of e-learning applications. The chapter proceeds as follows. First, we describe the basic mechanisms of cognition and their development. Then we explore the concept of learning and how one could utilize theory and research results from cognitive psychology, in order to design and implement e-learning environments. The chapter will conclude with a synopsis of essential parameters that a designer of web-based environments must take into account when s/he plans the content, representations and interactional features for a computer-based learning environment.

THEORETICAL FRAMEWORK

Cognition, Metacognition and Problem Solving Skills

Cognition refers to the ability of human mind to acquire and manage information. The concept of cognition encompasses mental processes such as attention, perception, memory, learning and problem solving (Solso, MacLin & MacLin, 2005). The term also refers to the concept of cognitive architecture as it is used in the frame of cognitive science. According to Ritter and Young (2001) a cognitive architecture is an embodiment of a scientific hypothesis about those aspects of human cognition.
cognition that are relatively constant over time and relatively independent of task. This architecture is a product of systematic interaction between a biologically predetermined neurological development and experience gained by the actions of the architecture upon its environment. Cognition is usually analyzed at two levels: at a fundamental level which involves basic mechanisms or abilities, like perception, attention, and memory, and at a higher level which concerns cognitive functions and processes like comprehension, reasoning, decision-making, planning, problem-solving and learning.

Human cognition is a dynamic system whose architecture is to a great extent predisposed biologically but its functioning is greatly determined by experience. This implies that the cognitive system can reach its final potential after a period of development. The term cognitive development refers to changes in cognitive architecture (structure) over time. After a rapid period of development the cognitive system is molded and operates in an adult-like fashion. In addition, it should be noted that recent approaches of cognitive development also emphasize individual differences in cognitive processes and its life-span character (Bjorklund, 2005).

However, three different paradigms regarding cognitive development have been put forth: empiricism, rationalism and socio-historic tradition (Case, 1998). Regardless of the particular research tradition there are some basic principles which crosscut and tie together the study of cognition and its development. These basic principles could constitute, and as such we will discuss them in this chapter, the needed theoretical base for the advancement of a cognitive learning theory of e-learning. First, the cognitive system becomes increasingly able to manage and comprehend successively and/or simultaneously more complex relationships of external or internal reality due to structural or functional reasons. In other words, the cognitive system becomes more flexible and efficient in using, storing and retrieving information in order to make sense and master its environment. Second, we progressively develop and apply self-regulatory processes which act upon our behaviour and cognition. Simply put, a metacognitive system gradually emerges, operating as a general manager of our cognitive and behavioural processes.

More specifically, our mind is organized in three levels, two of them comprising general-purpose mechanisms and processes -the information processing system and metacognition- and one comprising domain-specific structures of knowledge representation and processes of problem solving (Demetriou, Christou, Spanoudis, & Platissidou, 2002). These levels could be distinguished from each other on the basis of functional criteria. Each of the levels is itself a complex network of structures and processes organized across multiple dimensions and tiers. The most basic of these levels involves general cognitive processes and mechanisms that define the processing potential available at a given time. Therefore, the condition of the processes comprising this level constrains the condition and functioning of the systems included in the other two levels. The other two are knowing levels (Demetriou et al., 2002), in that they involve systems and functions underlying knowledge representation and problem solving. The duty of one of these two knowing levels is to process and represent the different aspects of the physical and social environments. The other knowing level is intended for monitoring, managing or regulating and storing knowledge concerning the self. That is, it pertains to all strategic processes underlying self-monitoring, self-representation, and self-regulation. Metacognitive skills emerge during the preschool period and fully mature during adolescence, playing an important role in many types of high-level cognitive processes like learning, reasoning and problem solving. Understanding, learning, or performing any task, at a particular point in developmental time, is a mixture of the processes involved at all three levels. In the section below we will briefly outline...
this architecture and present supporting empirical evidence.

Cognitive (Baddeley, 2007; Engle, 2002), and developmental psychologists (Case, 1998; Flavell, Miller, & Miller, 2004) agree that working memory is a core system of our cognition that has limited resources for representing and processing information concerning the environment and the self. The capacity of working memory to simultaneously process information defines the processing potential of our cognition. Three parameters have mainly been identified by cognitive and developmental research as primary indexes of processing potential: speed of processing, control of processing, and representational capacity.

The term speed of processing basically refers to the maximum speed at which a given mental act may be efficiently carried out. Usually, we measure speed of processing by asking individuals to recognize or choose a very simple stimulus as quickly as possible, such as locating or identifying a geometrical figure, a letter, or a word. Under these conditions, speed of processing indicates the time needed by the system to process the stimulus giving meaning to information. Traditionally, the faster an individual can recognize a stimulus, the more efficient information processor s/he is thought to be (MacLeod, 1991). It is deemed that these behavioral measures of speed of processing correspond to the attributes of our neural substrate. That is, the neural traces of stimuli encountered at a given moment tend to decay rapidly or to be overwritten by the traces of information encountered at the next moment (Nelson, de Haan, & Thomas, 2006). Therefore, fast processing ensures that the goals of a particular step of processing will be met before the initiation of a new step, which will, in turn, impose its own competing demands on the system (Salthouse, 1996).

The term control of processing pertains to the decision processes which allow human cognition to focus on specific aspects of a stimulus at all times. Given that our cognitive system is flooded by complex stimuli, our ability to process any stimulus would be widely restricted without the existence of decision processes. These processes are assigned with the work of, at a first step, discriminating the relevant features of stimuli being processed against non-relevant and, at a second step, directing attention to relevant ones. Efficient processing requires a mechanism that would allow cognition to keep control of processing, filtering out interfering and goal-irrelevant information and shifting focus to the selected information, if this is required (MacLeod, 1991). Control of processing is usually tested under conditions which include competing dimensions that force cognition into selecting one dimension over another, such as the well-known Stroop phenomenon. In this test, words denoting color are written with a different ink color (e.g., the word “red” written with blue ink), and the individual is asked to name the ink color as quickly as possible. These conditions accurately test control of processing, because the individual is required to inhibit a dominant but irrelevant response (to read the word) in order to select and express a weaker but relevant response (name the ink color) (Demetriou, et al., 2002; Dempster & Brainerd, 1995).

Representational capacity is defined as the maximum amount of information and mental acts that our cognition can efficiently activate and process simultaneously at a given moment. In current psychological literature, working memory capacity is regarded as the functional manifestation of representational capacity. According to Baddeley (2003) the working memory system is a multifaceted structure which consists of two kinds of systems, i.e., fluid and crystallized. In turn, the fluid systems consist of three discrete mechanisms, i.e., a central executive mechanism, a phonological loop, and a visuo-spatial sketchpad. The central executive is a limited capacity attentional mechanism which has a supervising role on storing and processing incoming information, and coordinates the interaction of fluid and crystallized systems through phonological and visuo-spatial subsystems. The phonological loop specializes
in the temporary storage of phonological-verbal material and is divided into two subsystems, one for storing and one for subvocally rehearsing the phonological information. The subvocal subsystem emerges during the first school years and serves the transportation of visual information to the phonological loop for storing and refreshing decaying phonological representations within the phonological store. The visuo-spatial system maintains temporary visual or spatial information. Further, the crystallized systems are constituted by three components: visual semantics, episodic long-term memory and language. The capacity of the working memory systems develops steadily until late adolescence.

The second general-purpose system pertains to metacognitive knowledge and processes. To understand the necessity of such a supervisory system, we have to bear in mind the complexity of environment, the multilevel functioning of cognition and, especially, the need for deliberate action of our mind on its environment. Our cognitive system must be able to record its own cognitive experiences (self-mapping) and keep knowledge of them that can be used in the future (self-regulation), if the need arises (Demetriou, 2000). Metacognition can be thought of as a second-order level of knowing and acting. The input to this system is information coming from the action of cognition and can roughly encompass knowledge about persons, tasks and strategies (Flavell et al., 2004). This information is organized by the mind into categories or models of mental activity and is used to guide the monitoring and controlling of cognitive processes. Thus, the metacognitive system consists of two sub-systems, one responsible for monitoring and regulating the functioning of cognitive system (working metacognition), as it operates, and one for storing and retrieving the knowledge which is produced by the action of working metacognition (long-term metacognition).

Working metacognition revolves around a strong monitoring, planning and executing function responsible for setting mental and behavioral goals, and pursuing them until they are attained. Specifically, working metacognition includes processes enabling the person to (i) monitor the current situation and compare it with the mind’s current goal, (ii) plan the steps needed to attain the goal, and, finally, (iii) execute the planned actions, constantly monitoring them and taking corrective actions, if and when these are required (Demetriou, 2000).

Long-term metacognition pertains to knowledge or models relative to past cognitive experiences resulting from the functioning of working metacognition. These models are broad descriptions of the general functional characteristics of the mind, suggesting the existence of different cognitive functions, such as perception, attention, and memory. Moreover, these models include a wide range of information about the efficient use of the psychological functions by the person itself, for instance, that detailed information requires organization to be retained in memory, or knowledge about the level of one’s own mathematical skills. In other words, our long-term metacognition encompasses general knowledge about psychological functions common to all human beings, and specific knowledge about the psychological functions relative to the individual experiences of the person.

Working metacognition could be part of, and use, the resources of fluid systems, while long-term metacognition could be part of crystallized systems as they are respectively described in Baddeley’s (2007) model. It is worth noting that the incorporation of metacognitive sub-components in corresponding fluid and crystallized systems creates a parsimonious architecture which offers a simple solution to the issue of self-regulation. Specifically, in the context of that architecture the metacognitive system can efficiently cooperate with and supervise the cognitive system, so that the former can be the general manager and the latter the accurate executive tool. Having in mind the form and function of the metacogni-
tive system, metacognition becomes a tool of wide application for solving many practical and theoretical problems.

The third domain-specific level of mind comprises of specialized processes oriented to aspects of the environment and of domain knowledge. These specialized processes are problem solving skills suitable for managing different types of information and kinds of problems. These processes allow the mind to choose and process particular types of representations between environmental stimuli. Additionally, they involve specialized operations that are appropriate for the specific type of representation and relations. In a sense, the operations and processes of a specific domain of thought are the mental analogues of the type of relations concerned. Moreover, they are biased to a particular symbol system that is better appropriate than other symbol systems to represent the type of relations concerned and facilitate the execution of the operations.

Each of the specialized domains involves two types of processes: core processes and mental operations and processing skills. The functioning of these processes produces domain-specific knowledge and skills. Core processes are fundamental processes that ground each of the domains into its respective environmental realm. During development, core processes are the first manifestations of the systems, and they are predominantly action and perception bound. If a minimum set of conditions is present in the input, they are activated and provide an interpretation of the input, which is consistent with their organization. In other words, core processes are inferential traps within each of the systems that respond to informational structures with core-specific interpretations that have adaptive value and “meaning” for the organism.

Operations and processing skills are systems of mental (or, frequently, physical) actions that are used to deliberately deal with information and relations in each of the domains. From the point of view of development, core processes constitute the starting points for the construction of operations and skills included in each of the domains. That is, at the initial phases of development, operations, skills, and knowledge arise through interactions between domain-specific core processes, the environment, and the executive and self-monitoring and self-regulation processes of the metacognitive system. That is, the systems of operations and processes within each domain emerge as a process of differentiation and expansion of the core processes when these do not suffice to meet the understanding and problem solving needs of the moment. In other words, the initial inferential traps are gradually transformed into inference that is increasingly self-guided and reflected upon.

Learning

Clearly, the way that we view learning has changed dramatically in the last fifty years due to the ‘cognitive revolution’, the intellectual movement that led to the birth of cognitive science by integrating psychology, linguistics, philosophy and anthropology against behaviorism. For the first half of the 20th century, psychology was dominated by behaviorism that attempted hard to reveal the general laws of learning. Learning was viewed as a primarily passive activity, concerning the formation of simple associations governed by reinforcements. Learning of complex behaviors was explained as cases of extension, generalization or combination of simple associations. After the cognitive revolution the way of viewing the concept of learning was, to a great extent, transformed. This transformation revolved around two issues: learners’ cognitive characteristics and the context of learning. The first issue was introduced by Piaget’s theory of cognitive development and information processing theories (Flavell et al., 2004), while the second by Vygotsky’s theory of social cognition (Rogoff, 1998). In this sense, learners are now viewed as active constructors of their knowledge, while learning is seen as
a multi-component dynamic procedure rather than simply a state. Important components of the learning procedure are deemed to be the learning environment, features of cognitive architecture, prior knowledge and motivation. We examine each of these four components next.

The ideal learning environment for effective learning is one that stimulates individuals to engage in active learning and provides several opportunities to make sense of the various aspects of the concepts being learned. Such environments are learner-centered as they emphasize the learner’s ability to interpret and construct meaning based on their own experiences and interactions. Learners are actively engaged in meaningful projects and activities that promote exploration, experimentation, construction, collaboration, and reflection of what these learners are studying (Marton & Booth, 1997). The learner’s engagement and active involvement in the learning procedure are achieved when the context is characterized by specific properties. First, the context should allow for a structured interaction between learners with the same or different levels of understanding. The term structured refers to the presence of a mediator, for instance, teacher, software or peers, or a combination of these. The mediator facilitates interaction and engagement in meaningful activities. In the case of learners with different levels of understanding, the work of the mediator is to scaffold the knowledge transfer from the more competent to the less competent learner. Second, the context should enable learners to control the flow of information and rate of learning, and experience the learning procedure as an enjoyable and meaningful experience.

Concerning the features of the learners’ cognitive architecture, as mentioned before, there are two levels of cognition that play an important role in learning: information processing system and metacognition. During learning the learner’s mind has to handle a cognitive load effectively (Kirschner, 2002). The extent to which the mind manages the cognitive load efficiently depends on its features, more specifically, on the speed, control, and the representational processing capacity. Given that working memory is a limited capacity system, it is apparent that speed and control of processing could define the quantity and quality of stored representations. We could imagine our working memory as a workbench continuously receiving information coming from our senses (sensory), or our specialized knowledge domains (mental). This information must be processed very quickly because other information is waiting for processing. At the same time, processing must be targeted to a specific object and not be spread out. Simply put, the ability to learn is dependent on our working memory capacity.

On the other hand, our cognitive system as we grow older is supervised by metacognitive processes. This implies that effective learning could be achieved through acting upon or ‘instructing’ metacognition. A learner who has learned to manage her cognitive load effectively could be a better learner. Also, a learner who has learned to organize material into easily accessible chunks, or work strategically in problem solving, could acquire deeper understanding of the learning material, or perform better on problem solving tasks.

Research has shown that a learner’s prior knowledge plays a crucial role in learning. A large body of findings demonstrates that prior knowledge acts as a framework through which the learner filters new information and attempts to make sense of what is learned. We tend to organize and understand new information in terms of what we already know. As mentioned before our mind has specialized processes which strive to package information into coherent domains of knowledge utilizing core processes and mental operations and skills. This well-connected domain knowledge allows our cognitive and metacognitive system to understand, retrieve and apply new knowledge very efficiently. Without a basis of prior knowledge characterized by these properties, learning new material would be very
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laborious and time-consuming (Van Merriënboer & Sweller, 2005).

Based on what we have presented thus far, one can conclude that the prerequisites of learning are the ability of the cognitive system to quickly select and focus on the incoming information, to make sense and organize it aided by prior knowledge and to integrate it into the domain-specific representational systems. Additionally, our metacognitive processes supervise and, if necessary, redirect a part or the whole process of learning. But who should be responsible for activating metacognitive thinking? Given that research has shown that many learners are not particularly metacognitively aware (Collins, Brown, & Newman, 1989) pedagogical design needs to raise student awareness of themselves as learners and adopt strategies for training to engage in metacognitive thinking. In other words, it is necessary to motivate learners to the extent that her or his metacognition can effectively manage the learning process.

Scientific fields like cognitive and developmental science have grown up rapidly and matured to the point where they can definitely contribute to learning theory and its application in educational settings and practice. Nowadays, cognitive psychology is developing and suggesting models of cognition, challenging human-computer interaction and investigating expert performance, in an attempt to illuminate cognitive processes of competence.

Our review of cognition and learning, thus far, outlines the basic points that any designer of e-learning environments must take into consideration. In recent years, designers of e-learning environments started incorporating ideas, findings and methods originating from the area of cognitive and developmental psychology. The convergence of theory and research regarding both e-learning and cognitive and developmental psychology is necessary. The latter will be helpful for both, as e-learning will acquire the needed theoretical framework, while cognitive and developmental psychology will have a new scientific field for applying ideas and models.

E-LEARNING

Historically, e-learning has developed concurrently with information and communication technologies (ICTs), which have shattered conventional ideas about the limitations on human communication imposed by physical location and geographic proximity and re-defined learning. The inception of the first network technologies in the early 1960’s was related to the Cold War, in an attempt to re-establish the United States’ technological lead and as a response to the USSR’s launching of Sputnik. It was not until a few decades later that the internet had reached a maturity level that would allow exploring its possibilities in educational settings.

The construct of e-learning includes any electronic means that facilitates learning. According to Wentling et al. (2000):

E-learning is the acquisition and use of knowledge distributed and facilitated primarily by electronic means. This form of learning currently depends on networks and computers but will likely evolve into systems consisting of a variety of channels (e.g., wireless, satellite), and technologies (e.g., cellular phones, PDA’s) as they are developed and adopted. (p.5)

It is frequently observed that media outlets, lay people, and many academics do not consistently differentiate between different e-learning categories, putting the emphasis rather on the medium of delivery as the most important common denominator amongst e-learning applications. Thus, often, e-learning is reserved solely for online, distance applications (e.g. Huffaker & Calvert, 2003), even though the definition by Wentling et al. allows for a variety of delivery media, which
do not all require network access. The lack of ontological clarity propagates the confusion as to what exactly constitutes e-learning (Ally, 2008); in turn, this holds the field back, since it complicates the development of a sound theoretical basis that would distinguish the field from others, could promote community building, and would enhance knowledge sharing about principles that should be guiding the development and instructional delivery of e-learning environments.

It is true however, that web-based e-learning applications share important benefits as compared to stand-alone computer applications (Kyza, 2005). Web-based environments are accessible from anywhere and anytime thus offering opportunities for learning at a distance and enhancing lifelong learning opportunities and just-in-time training. Such web-based learning environments share many innovative features that offer multimodal experiences to learners: for example, they feature synchronous and asynchronous communication capabilities, embed technologies for customizing and personalizing learning, and employ multiple tools for facilitating online collaboration. These features, whether used only online or as part of a blended learning model, have expanded educational horizons to specifically include informal learning settings.

Harasim (2006) identified three educational models in e-learning applications: a) online collaborative learning, which emphasizes collaboration and group work, b) online distance education, which most often refers to a new way of delivering distance learning while still relying on similar conventional pedagogical methods such as the ones employed in traditional distance learning, and c) online computer-based training, which relies on human-computer interaction through software tutoring programs. Anderson (2008) further distinguishes e-learning as intending to cater to two types of learning settings: collaborative or independent.

**COGNITIVE MODELS UNDERLYING E-LEARNING**

The development of learning materials is influenced by the specific tradition about human learning that their developers subscribe to, whether these beliefs are made explicit or not. Even though the three main schools of thoughts about learning (rationalist, empiricist, and sociohistorical) have influenced educational design (Greeno, Collins & Resnick, 1996), they have not systematically touched educational technology design, with most e-learning discussions being driven by practice rather than by theory (Ravenscroft, 2001). It is, perhaps, no exaggeration to say that many of the online environments described as e-learning do not reflect any truly transformative practices, such as those denoted by Harasim’s first educational model cited earlier. Furthermore, in spite of discussions about e-learning practices abounding in the literature, the theoretical basis of these discussions, and most notably the theory driving e-learning development and application, seems weak and murky, to say the least.

In an attempt to contribute towards a theory of e-learning, Anderson (2008) discusses the similarities and differences between face to face learning (f2f) and online (distance) learning. Accepting that e-learning is a subset of learning, Anderson goes on to argue that as long as one develops rich learning experiences and as long as some basic presuppositions are met, learning can be experienced in both f2f and online environments; he goes on to identify the presuppositions as building learning environments that support interaction between students, teachers, and content (student-to-student, student-to-teacher, and student-content) and which are learner-centered, content-centered, community-centered, and assessment-centered (Bransford, Cocking & Brown, 1999).

In this chapter, we argue that there is a strong need to use learning theories in designing e-learning environments; however, we need to look
no further than existing theories of cognition. Theories about individual cognition and collaborative learning can guide the design of such environments according to the goals of each design effort; we discuss this topic next.

**COGNITIVE THEORIES OF LEARNING AND THE DESIGN PROCESS**

At the onset of each principled design effort, designers have to answer questions about the target audience, the learning goals and expected learning outcomes, and the learning context. The answers to these questions will provide the design framework. For example, the age of the learners will help the designers examine research and experience, in order to provide the initial postulations about what could be cognitively feasible and accessible by this audience, and will suggest what a common baseline of knowledge might be. Setting learning goals will help focus the design while describing the expected learning outcomes will bootstrap the design activity. The design of efficient e-learning environments requires knowledge about human cognitive architecture, the learners' prior knowledge and motivation, and the learning environment. We examine each one of these next.

**HUMAN COGNITIVE ARCHITECTURE**

Design efforts need to take into account the architecture of the human cognitive system and existing knowledge about how people learn and how the mind develops. One of the most important contributions of cognitive science is the constructivist framing of learning. Even though e-learning environments have the capacity to allow active engagement with ideas, this is not an inherent property of this type of learning, as it is often, quite optimistically, being portrayed. Rather, designers need to make concerted efforts and build upon knowledge about human cognition, motivation, and social interaction in order to produce environments that afford, but do not guarantee, active learner engagement.

Two other important findings from cognitive science research is the importance of attending to cognitive load during the design process and of creating opportunities for metacognitive engagement. Several strategies have been proposed to help overcome the cognitive load that can result from the well-established processing and storing limitations of human working memory. Applying strategies to overcome these memory limitations becomes increasingly important, as pedagogical designs of domain-specific educational technology applications increasingly place emphasis on problem-based learning and making sense of complex data (Hmelo-Silver, 2004; van Merriënboer & Ayres, 2005). Chandler and Sweller's theory of cognitive load (1996) suggests that instructional design is most critical in situations of high interactivity between intrinsic cognitive load, which is content-related, and extraneous cognitive load, which is dependent on the instructional representation method. High extraneous cognitive load and, especially, high interaction between the two types of cognitive load increase the demand on working memory and may negatively influence the learning outcomes. Thus, designers of complex, information-rich e-learning environments should strive to reduce extraneous cognitive load and increase germane cognitive load, which can lead to the integration of new information into the long-term memory which does not share the limitations of working memory.

Intentional learning requires the deployment of metacognition. In the case of personalized, self-paced e-learning environments, metacognition is crucial in supporting the learner in planning and monitoring their learning activity, as well as in understanding their strengths and weaknesses as learners and engaging in appropriate and effective
help-seeking. According to Lin (2001) researchers have used the following two approaches to support metacognition in instructional interventions: a) strategy teaching, to facilitate the working metacognition and self-regulated learning, and b) creating a supporting social environment to facilitate long-term metacognition.

As a construct, self-regulation is important in that it regulates cognitive, motivational, and behavioral states of the learner (Azevedo, 2005). Metacognitive engagement in e-learning environments can be supported through either software or human mediation (e.g. the teacher as a facilitator of learning). Software mediation can take a variety of forms, such as being embedded in the representations of the learning environment or constructed on the fly from computational agents who monitor the user actions and provide advice as needed. However, technological solutions for dynamic metacognitive support, tracing the learners’ process and providing on-demand support have only been possible in very constrained problem-solving situations, such as intelligent tutoring systems (e.g. Cognitive Tutors, Koedinger, Anderson, Hadley, & Mark, 1997), while even in these environments there have been reports of ineffective use of the software. Because of the lack of adaptive, technology-based scaffolding, non-adaptive scaffolds (e.g. metacognitive prompts) have been used to support ongoing metacognition (Azevedo, 2005).

LEARNERS’ PRIOR KNOWLEDGE AND MOTIVATION

As mentioned earlier, learners’ prior knowledge frames and constraints any new learning that takes place. Increasingly, e-learning environments have the capacity for customizing and personalizing the learning experience, allowing the learners to draw from their own experience, set their pace of learning according to their background, and seek additional information to complement what they already know. For example, an e-learning environment may be easily customized for different age learners, or learners from different cultural contexts, thus making the material to be learned more accessible by the target users of the e-learning application.

Learner motivation to actively participate can be detrimental to the successful outcomes of any e-learning approach. When learning is completely self-paced and online, managing to capture and sustain the learners’ motivation is what will eventually support the learner’s cognitive engagement. Keeping learners motivated at a distance is difficult to achieve (Keller & Suzuki, 2004); some strategies to increase learner motivation include building learning environments that involve authentic learning, drawing from problems that connect to the learners’ experiences and real-life issues, inviting active participation, and providing systematic feedback and customization. Keller & Suzuki (2004) have proposed a model for achieving learner motivation. According to this model, the following criteria have to be met for an environment to support motivation: a) the learning environment needs to attract and sustain the learner’s attention; this can be achieved by a variety of techniques, such as personalization to address personally meaningful learning opportunities, building upon natural curiosity, placing the learner in a problem-solving situation, varying the approach to avoid boredom, etc.; b) the learning environment needs to be relevant to the learners’ lives. Learners need to understand why they are engaging in this e-learning task and share the goals of the designers, transforming them into their own personal goals; c) tasks have to be designed at an appropriate level of difficulty, so that the learners gradually build confidence in what they are doing and increase their self-efficacy about engaging in the task; d) the environment needs to evoke positive affective reactions, balancing intrinsic and extrinsic motivation. Learner motivation and self-efficacy beliefs can then, in turn, impact upon
their self-regulation strategies and interact with metacognitive engagement (Pintrich, 1999).

THE LEARNING ENVIRONMENT

The design of the learning environment is another very influential factor contributing to the effectiveness of e-learning. Psychological research has indicated that contextual factors can influence the impact of e-learning applications. The context of learning can be defined as consisting of all factors contributing to the learning activity, which are external to the learner. Examples of these are interactions between the learner, the teacher and other peers. Knowledge about peer interaction processes and the role of tools and inscriptions as extending the individual cognition capabilities can greatly enhance the design of electronic learning environments. Exactly because interaction is key to learning, e-learning applications need to maximize possibilities for interaction, while structuring them to avoid unnecessary cognitive load.

While in the previous section we discussed the principles for supporting cognitive and motivational engagement, the focal point in considering the learning environment is on capitalizing on the interactional elements. New technologies can support this interaction, both in asynchronous and synchronous modes. For example, forums, an example of an asynchronous technology and a component of many web-based environments, can help sustain the dialogue between members of a learning community, even when these learners are not physically or temporally co-located.

CONCLUSION

In this chapter we have described how cognitive theory is prerequisite to integrating theory, data, and knowledge concerning human and computer interaction. Current psychological research provides a clear image of how and under which conditions we could achieve efficient learning. Learners are seen as cognitive and socio-emotional creatures able to learn effectively when are granted specific conditions. The learners’ cognitive and motivational characteristics, in combination with an appropriate learning context, are deemed as necessary conditions to achieve learning (Huffaker, & Calvert, 2003). Models of learners’ cognitive and motivational features, as well as learning theories, would constitute a sound and well-elaborated framework which can be utilized in improving the usability of e-learning applications and user interfaces. Designers of e-learning applications should be aware of current learning and cognitive theories, as such knowledge would allow them to take into consideration basic psychological principles about learning and apply them into e-learning environments. If the inherent features of e-learning as a flexible, enjoyable and creative medium are coupled with the cognitive and learning principles that were mentioned before, the future of e-learning would be very promising. In addition, adopting a cognitive and developmental psychology framework to e-learning research would benefit both fields, as e-learning applications provide a creative and flexible applied area for testing the theories and data produced from cognitive and developmental studies.

REFERENCES


Integrating Knowledge of Cognitive System and E-Learning Applications


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