

Building an instructional framework to support learner control in Adaptive Educational Systems

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ABSTRACT

Recently there has been a growing appreciation concerning learner control over the learning/instructional process, leading to the development of mixed-initiative systems where learners are allowed to take varying levels of control. The design of Adaptive Educational Systems (AES) that provide such learner control opportunities through their adaptive and adaptable dimensions, is a challenging research goal that requires a certain understanding of the learning and instructional processes. To this aim, in this paper we focus on the educational background that should underlie the design of adaptation and learner-system interaction in the context of AES used for web-based education. We propose an instructional framework that supports a variety of instructional approaches and provides guidelines that unify several processes underlying adaptation such as structuring the domain knowledge, developing the content, planning individualised support – assessment – learner control opportunities. This framework incorporates a variety of approaches over instruction and assessment, in order to accommodate the diversity of learners' needs and preferences, and enable them to choose when, what and how to learn. The theoretical background underlying the design of the framework and the implications for web-based AES design are also discussed.

Keywords: Distance Learning, Internet-Based Instruction, Web-Based Education, Instructional Design, Web-based Instruction, Online Course, Human/computer interaction, Adaptive Educational Systems, Adaptive Instruction, Learner Control, Individual Differences

INTRODUCTION

In web-based education, centrally available systems are used to deliver instruction, allowing a user to learn transcending typical time and space barriers. In this context, a challenge posed for both the education and the computer science research communities is the exploitation of the innovative characteristics of the Internet for the development of educational systems, flexible enough to accommodate learners' individual differences and promote learners to take control over the instructional process. Instruction for learning is, and has always been, a complex and multifaceted challenge. Especially in web-based education where tutors are mainly facilitators rather than the main agents, the instructional approach adopted to guide the interactions taking place among the educational system, the learners and the educational content should aim to: (i) provide learners with

the appropriate resources and guidance towards the accomplishment of their goals accommodating their individual approach to learning, and (ii) stimulate and actively engage learners in learning providing them opportunities to take control over the instructional process. However, the sharing of control between the learner and the system is a critical issue as there is always the possibility that unrestricted control and lack of learning goals can dampen the power of learning (Lawless & Brown, 1997). Thus, issues of learning and didactics become more prominent for the development of web-based learning environments, and several critical questions are emerging, such as: (i) which instructional approaches are appropriate for incorporation in a web-based environment where learners are usually adults and where the variety of learners taking the same course is large, and (ii) how to design learner control opportunities that allow learners to decide when and how to take control over instruction, in a way that enhances learning, builds positive attitudes and heightens self-efficacy.

In the context of web-based education, Adaptive Educational Systems (AES) (Brusilovsky, 1996; 1999; 2001; Brusilovsky and Peylo, 2003) emerged as an alternative to the traditional “one-size-fits-all” approach in the delivery of instruction. AES possess the ability to make intelligent decisions about the interactions that take place during learning and aim to support learners without being directive. Taking into account that, learners will be able to achieve their learning goals more efficiently when pedagogical procedures accommodate their individual differences (Federico, 1991), and that learners appear to benefit from learner control opportunities (Jonassen et al. 1993; Federico, 1999), research in the area of AES has been focused on methods and techniques that integrate such functionalities in real systems.

Critical issues that affect the educational perspective of AES are, the instructional approach guiding system-learner interaction, and the type of adaptation, which depends on the amount of control a learner has over the adaptation (for a taxonomy of different types of adaptation see Kobsa et al., 2001). As far as the latter is concerned, lately there is a growing appreciation concerning the learner control over the learning process (Kay, 2001), leading to systems where learners are allowed to take varying levels of initiative. The development of web-based AES in which learners are individually supported in accomplishing their personal learning goals (adaptive dimension of AES) and at the same time they are allowed to control when, what and how to learn (adaptable dimension of AES), requires a certain understanding of the learning and instructional processes. In this direction, the design of a coherent instructional framework, which integrates instructional decisions that lead to the adaptation, is a challenging research goal motivated by the expected learning benefits.

In this paper we focus on the educational background that should underlie the development of AES used for web-based education. We propose an instructional framework that supports a variety of instructional approaches, allows learners to take control over the system and provides guidelines that unify several processes underlying adaptation such as structuring the domain knowledge, developing the content, planning individualised support - assessment - learner control opportunities.

INSTRUCTIONAL APPROACHES AND LEARNER CONTROL IN ADAPTIVE EDUCATIONAL SYSTEMS

Different instructional approaches have been used in AES providing the central concept of the interactions that take place between the learner and the system and/or the basis for designing their building elements, such as learner model, domain knowledge, instructional model, adaptive engine. In several cases, these approaches build on teaching expertise or on a theoretical background that reflects specific learning/instructional theories.

For example, AST (Specht et al., 1997) adopts a variety of instructional strategies, which simulate strategies used by teachers when teaching different types of concepts in statistics: learning by example, learning by reading texts, learning by doing. These strategies are responsible for deciding how to sequence the educational material in relation with specific learning outcomes, and thus they imply the type of educational material to be developed. In the Dynamic Course Generation (DCG) system (Vassileva, 1997) courses are generated dynamically depending on the learning goal that learners select. These courses can be dynamically changed, following specified teaching rules and strategies of the Generic Task Model (GTE) (Van Marke, 1998), to suit better to learner's individual goals, progress and preferences. GTE provides an instructional model that reflects the instructional knowledge and expertise underlying human teaching. In Arthur (Gilbert and Han, 1999), alternative styles of instruction are used, which differ in the type of media they utilize. The implementation of these alternative styles of instruction requires the development of multiple types of educational material that use different types of media for each particular section of the course. In AES-CS (Triantafillou et al., 2003) adaptation is based on the Field Dependent - Field Independent cognitive style model. Several instructional strategies have been incorporated in the system that accommodate learners' cognitive style in relation to: the approaches (global versus analytical), the control options (program versus learner control), the contextual organizers (advance organizer, post organizer), the study instructions (provide minimum or maximum instructions), the feedback, and the lesson structure. The domain in which these functions build is a set of concepts designed by the expert-instructor. Lastly, in INSPIRE (Papanikolaou et al., 2003), adaptation is based on a comprehensive instructional framework which builds on a combination of instructional design theories about planning the content and delivery of instruction, with the learning style theory, providing the basis for delivering individualized content that accommodates learners' knowledge level and learning style. This framework guided the development of the domain model and the educational material, the representation of learner's knowledge and learning style, and the design of pedagogical rules guiding the system's adaptive behaviour. In the KBS Hyperbook system (Henze et al., 1999), learners work with projects and the system adapts the project resources to their knowledge level and/or learning goals. Thus, learner-system interaction is based on activities, which have been developed according to the project-based learning theory.

Lately there is a growing appreciation of sociocognitive practices in which learners take control over the learning process and construct their knowledge through collaboration with peers and/or teachers. For example, Ecolab (Luckin and du Boulay, 1999) is an interactive learning environment, which assists children (aged 10 and 11 years) to learn about food webs and chains. Ecolab provides appropriately challenging activities to children to cope with, as well as the right quantity and quality of assistance. The theoretical framework on which Ecolab is based was inspired by Vygotsky's theory about ZPD (Zone of Proximal Development), which is an appealing idea about how to support learners to learn. Another interesting approach, which is based on sound theoretical principles, has been adopted in SCI-WISE (White et al., 1999). SCI-WISE supports learners to develop lifelong learning skills, i.e. to learn how to learn via inquiry and understand the sociocognitive and metacognitive processes that are involved. It houses a community of software agents, which give strategic advice and guide learners as they undertake collaborative research projects and as they reflect on and revise their inquiry process.

As far as learner control issues are concerned, in several AES different levels of adaptation have been adopted, depending on who takes the initiative, the learner or the system, ranging from system driven to learner driven adaptation. In particular, learner control can take several forms such as learner

controlling (Kay, 2001): choice of learning tools/teacher/learning peers, choice of time of learning (on-demand learning), their learner model, system's domain and teaching beliefs, the amount of control.

The I-Help (Bull and McCalla, 2002) system fits the model of on-demand learning. I-Help assists learners as they try to solve problems while learning a subject. To this end, I-Help supports a network of peers that help each other out, i.e. selects appropriate peers to assist a learner, and then sets up a one-on-one peer help session between the helper and the helpee based on a number of factors. User-adapted online documentation systems, which aim to assist users in learning what they want, are also closely related to the on-demand learning approach. For example, PUSH (Höök et al., 1996) aims at developing and testing intelligent help solutions to information seeking tasks. Höök et al. (1996) suggest that in order to give users a sense of control, the systems' internal workings should be transparent and their actions should be predictable to users.

Different approaches have been adopted in AES for introducing adaptability and providing learner control opportunities. ELM-ART (Weber and Brusilovsky, 2001) provides learners with the option to access their model and modify the assumptions of the system about their knowledge level on the different pages of the educational content, their preferences concerning the screen design and the adaptation technologies used. ELM-ART uses multiple sources of information about the learning status of each page of the course, such as the learners' estimation of their knowledge level and the knowledge of the system about learners' assessment results in solving exercises, tests, or programming problems. In AST as well as in Hypadapter (Hohl et al., 1996) when learners first log on the system they submit an introductory questionnaire to initialise their own learner model. Questionnaires provide learners with a means of controlling and customizing various aspects of these systems at the beginning of the interaction as well as during the learners' interaction with the system (Hypadapter). In DCG, learners take control over the system depending on their aptitudes. For example, if the learner is considered as "motivated" and "success-driven" then s/he is allowed to select what to study next, and how (i.e. the task and method of instruction); in case s/he is considered as "unsure" and "not confident" then the system takes on the initiative to decide what s/he should do next. In AES-CS learners are allowed to intervene in the instructional process by modifying the status of the corresponding instructional strategies through their model and/or appropriate interactive features of the system. Lastly, INSPIRE supports several levels of adaptation, allowing the learners to decide on the level of control they wish to exercise. It offers opportunities to learners to deactivate adaptation and undertake full control over the system, or to let the system generate individualised lessons, or to intervene in the lesson generation process reflecting on their own perspective. As far as the latter is concerned, learners have always the option to access their learner model, reflect upon its contents (learner's knowledge level on the concepts of the domain and learning style) and change them in order to guide system's instructional decisions.

The adaptable dimension of many AES is based on providing learners the option to check and update their characteristics stored in their learner model. This approach enables learners to see how the system models their individual characteristics relative to standards set by the system and update them. As system adaptation is mainly based on the learner model, an open learner model is a fundamental part of learner control (Kay, 2001). Open learner modeling is a broad issue in the learner modeling area focusing on the use of open learner models (OLM) as a learning resource. To this aim a variety of approaches have been proposed concerning the contents, interaction and form of OLM in AES (Kay, 1995; Bull et al. 1995; Mitrovic and Martin, 2002; Dimitrova, 2003). At this point we should mention the LeMoRe group, which has members from all around the world and one of its main aims

is to advance the theoretical study and the application of approaches to opening the learner model to learners and others involved in the learning process, such as teachers and peers (visit <http://www.eee.bham.ac.uk/bull/lemore/> for more information).

THEORETICAL FOUNDATIONS

The theoretical foundations for the proposed instructional framework come primarily from the instructional science and cognitive science, drawing on the view of learning as an active process of knowledge construction and of instruction as anything that is done to facilitate purposeful learning.

The purpose of designed instructional interventions is to activate and support learning. Towards this direction, alternative instructional/learning theories and approaches have been proposed as to how it should be done (Jeroen et al., 2001). Jonassen et al. (1993) propose that the initial acquisition phase is better served by classical instructional design techniques while complex and constructivist environments serve advanced knowledge learners better. Along this line, Ertmer and Newby (1993) argue that the instructional approach adopted for novices may not be efficiently stimulating for a learner who is familiar with the content. Moreover, recently there is an increased interest on collaborative learning which is supposed to lead to deeper level learning, critical thinking, shared understanding, and long term retention of the learned material, providing opportunities for developing social and communication skills, and developing positive attitudes towards co-members and learning material. In this context instructional interventions should aim to enhance social interaction among the group members in ways that encourage elaboration, questioning, rehearsal, and elicitation (Kreijns et al., 2003).

Following this line of research, a learning-focused instruction paradigm should better exploit the diversity of perspectives and methods proposed (Reigeluth, 1999a, Jeroen et al. 2001). In this direction, an important issue that should also be considered is learner control, which is assumed as an alternative procedure for accommodating instruction to the dynamic characteristics of learners (Federico, 1999). In the context of a web-based educational system, learner control can cause problems as well as offer benefits. Learner control is intuitively appealing because it is assumed that learners will be more motivated if allowed to control their own learning (Lin & Hsieh, 2001; Steinberg, 1989). Along this line Kay (2001, pg. 122) suggests that 'given the importance of cooperation by the learner if learning is to be achieved, we have no choice but to trust the learner with control'. However, it is also argued that the effectiveness of learner control depends to a large extent on how well each learner can decide which instructional/learning strategy is optimal for him/her at any one moment (Federico, 1999). This raises the important issue for web-based education as to whether all types of learners appreciate being given control over instruction. Thus, the challenge posed for adaptive instruction and personalisation in order to succeed to their educational potential, is to provide alternative approaches to learners enabling them to: (i) adapt instruction to their learning needs and individual differences, which as several studies reveal have significant effects on learning (Chen and Paul, 2003; Papanikolaou and Grigoriadou, 2004), and (ii) take control over instruction when they wish to.

The proposed instructional framework builds on the above-mentioned ideas adopting a variety of approaches over instruction and assessment, aiming to enable learners to choose when, what and how to learn. To this end, the instructional design and the constructivist perspectives are used to design alternative opportunities for learning in a Web-based educational context. The instructional approaches proposed differ in the amount of structure, control and support provided to learners

including highly *constructivist* approaches that build on the on-demand learning theory, as well as more *prescriptive* approaches. In the former approaches, learners are basically on their own to figure out where and how to acquire the knowledge, skills and attitudes, and the system provides them with individualised support when they ask to. In the latter approaches, structured educational material and guidance are provided to help learners acquire the knowledge, skills and attitudes, accommodating their individual differences, with the aim to advise but not directing them.

A FRAMEWORK FOR DESIGNING INSTRUCTION

The proposed instructional framework provides guidelines for the design of aligned learning opportunities. It draws a picture of how the content, assessment and instruction work together to build purposeful lessons that provide learner control opportunities. The main aim is to provide researchers with an educational background, comprehensive enough to support a variety of instructional decisions that underlie the design of adaptation and learner-system interaction in the context of an AES. To this end, we propose a set of guidelines, accompanied by representative examples and alternative theories which could be adopted for the implementation of a real system (see Table I).

The proposed framework comprise of the following elements (see Table I):

- (a) *Learning goals*. Learners select what to study. Learning goals focus on the topics that are important to the curriculum, defined in a way that can be recognised and selected by learners.
- (b) *Instructional approaches* . Learners select among alternative instructional approaches that reflect different pedagogical perspectives.
- (c) *Assessment*. Multiple assessment opportunities are provided. Assessment aims to support learners in identifying their own progress (self-assessment) and provide the system with the necessary information about the learners' level of performance.
- (d) *Content*. Learners are provided with structured content comprised of independent modules. It includes critical objectives, declarative and procedural knowledge on all the concepts that learners need to know.
- (e) *Individualized support*. It aims to help learners accomplish their goals and take more responsibility for their own learning .
- (f) *Learner control opportunities*. Learners are informed about the internal workings of the system and they are provided with opportunities to control the instructional process.

Table I. The main elements of the instructional framework. Each element is accompanied by a set of guidelines, and by representative examples and alternative theories proposed for the implementation of a real system.

Framework elements	Design guidelines	Examples
<p>Learning goals <i>The main topics of the curriculum are presented as learning goals enabling learners to select the one they prefer or need to study</i></p>	<p>Define a set of <i>learning goals</i> from the fundamental topics of the curriculum in a way that can be recognized and selected even by a novice learner independently of his/her previous selections.</p> <p>Provide learners with the option to select a learning goal to study according to their needs and preferences. For each goal provide relevant learning outcomes, information about its fundamental concepts, and a brief overview, in order to support learners in selecting the one to study.</p>	<p>In DCG and INSPIRE a set of learning goals are proposed to learners.</p> <p>In KBS-Hyperbook learners can define their own learning goals or can request new goals from the hyperbook.</p>
<p>Instructional approaches <i>Different instructional approaches are provided to learners enabling them to select the one most appropriate to their knowledge and preferences</i></p>	<p>Define a set of instructional approaches, which differ in the amount of structure, learner control and support provided to learners.</p> <p>Provide learners with the option to select an instructional approach. For each one provide a brief overview of the main idea and its functionality, in order to support learners in selecting the most appropriate.</p> <p>Design each instructional approach so as to provide:</p> <ul style="list-style-type: none"> – individualised content following learner’s profile – individualised support following learner’s profile – multiple assessment opportunities – meaningful tasks and activities in which learners take an active role – collaboration opportunities 	<p>Samples of representative instructional approaches adopted by different systems are presented below.</p> <p>INSPIRE generates a sequence of individualized lessons following learner’s learning goals, progress and learning style. The lesson contents, the sequencing and the presentation of multiple types of educational material (e.g. theory, examples, exercises, activities) are adapted to learners’ profile.</p> <p>In KBS-Hyperbook learners work on projects and the system supports them by providing appropriate material and guidance. Project results are used to represent and to assess learners’ knowledge. In SCI-WISE learners undertake collaborative research projects and a community of software agents, such as a Planner, a Collaborator, and an Assessor, supports them providing strategic advice and guidance.</p>

<p style="text-align: center;">Assessment Multiple assessment opportunities are provided aiming to (i) stimulate learners to assess the quality, quantity and retention of their learning, and (ii) support the system's adaptation by providing data for the learners' progress</p>	<ul style="list-style-type: none"> – Provide <i>self-assessment opportunities</i> in the educational content through a plurality of assessment tasks that actively engage learners and stimulate them to assess and record their own progress and study accordingly (<i>formative assessment</i>). – Provide formal assessment aligned with the content in order to assess retention of learning following specific criteria given in terms of objectives and competences which state what learners must achieve (<i>summative assessment - criterion-referenced assessment</i>). – Provide feedback to learners' answers in order to support the learning process, provoke reflection on and articulation of what was learned. <i>Feedback</i> to learners' answers might include different types of information such as comments on the correctness, precision, and timeliness of the answers, learning guidance, motivational messages, lesson sequence advisement, critical comparisons, learning focus (Sales, 1993; see also the chapter "An Adaptive Feedback Framework to Support Reflection, Guiding and Tutoring" in this book). 	<p>Self-assessment opportunities can be provided through a variety of tasks included in the content such as, questions, exercises, activities (INSPIRE), and projects (INSPIREKBS-Hyperbook).</p> <p>ELM-ART and INSPIRE use automatically corrected assessment tests for the main topics of the domain in order to get the necessary information about learners' knowledge and adapt accordingly. In KBS-Hyperbook, project results are used to represent and to assess what topics / concepts a learner has successfully applied or learned.</p> <p>Different types of feedback that can be provided are (Chi, 1996; Mory, 1996): <i>suggestive feedback</i> which follows learners' wrong answers aiming to alert the learner that there is a problem (e.g. INSPIRE provides feedback that refers to the consequences of learners' answers aiming to redirect their thinking), and <i>reinforcing feedback</i> which follows learners' right answer so as to justify the correctness of the particular answer (INSPIRE).</p>
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<p>Content <i>The educational content includes all the concepts important to the curriculum and comprise of multiple independent modules which can be re-used by different instructional approaches</i></p>	<ul style="list-style-type: none"> - Define a set of <i>learning goals</i> derived from the fundamental topics of the domain (see above for a more detailed description). - For each learning goal build a <i>conceptual structure</i> based on design principles extrapolated from instructional theory. This structure should include all the necessary concepts comprising the goal and their interrelations. - Develop <i>educational material</i> for each domain concept to support learning/achievement of specific skills/performance levels. Develop multiple knowledge modules of different types of educational resources as well as authentic and meaningful tasks may support multiple instructional approaches. - Organise and present the content in hypermedia form 	<p>All the concepts comprising a learning goal may be organised in a <i>conceptual structure</i> following a specific sequencing such as the elaboration sequencing (Reigeluth, 1999b) used in INSPIRE, hierarchical sequencing, procedural sequencing, simple-to-complex sequencing (learning-prerequisite, topical, spiral, subsumptive, web sequence).</p> <p>The <i>educational material</i> may be organised in different levels that correspond to specific skills or performance levels which learners are expected to develop/succeed following a specific taxonomy such as those proposed in (Merrill, 1983) used in INSPIRE, (Mayer, 2002), (Reigeluth & Moore, 1999), (Jonassen et al., 1993). At each level, the educational material may include multiple types of resources/activities such as questions, exercises, examples, activities and projects aiming to cover a range of learning styles (knowledge modules in INSPIRE, AST). The above modularity of the content allows the use of its different components - concepts, knowledge modules - by different instructional strategies.</p> <p>AST adopts a variety of instructional strategies, such as learning by example, learning by reading texts, learning by doing. The educational material is reused by these strategies, which are responsible for deciding how to sequence the educational material in relation with specific learning outcomes.</p>
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<p>Individualized support <i>Individualized support is provided following learners' individual differences and needs, aiming to advice instead of directing learners</i></p>	<p>Support learners in taking control over the process and the adaptation. Provide learners with information about the different functionalities of the system that lead to the adaptation and about the influence of their actions on the system's functions.</p> <p>Support learners in accomplishing their tasks by providing individualized content, support, and navigation advice. Learners should be allowed to decide on their next steps and not be restricted to follow system suggestions.</p>	<p>The externalisation of the learner model can be used to provide learners with information about the system's adaptation and the opportunities they are offered to control it (ELM-ART, INSPIRE).</p> <p>Different adaptation technologies such as adaptive presentation, adaptive navigation support, curriculum sequencing, problem-solving support, adaptive collaboration can be used for providing individualized content, and navigation advice following learners' individual differences (ELM-ART, DCG, AST, INSPIRE, AES-CS)</p> <p>In SCI-WISE, a community of software agents give strategic advice and guide learners as they undertake research projects reflect on and revise their inquiry processes.</p>
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<p>Learner control opportunities <i>Learners undertake an active role in the learning process and they are allowed to take varying levels of initiative</i></p>	<p>Provide learners with the options to:</p> <ul style="list-style-type: none"> – decide what to learn; – decide how to learn; – decide when to learn; – control the adaptation; – control the amount of control; 	<p><i>What to learn:</i> Learners select a learning goal to study (DCG, INSPIRE) and the content is presented in a hypermedia form enabling learners to follow their own paths (ELM-ART, INSPIRE)</p> <p><i>How to learn:</i> Learners select their learning peer / teacher / companion (SCI-WISE), the type of content to study (INSPIRE).</p> <p><i>When to learn:</i> In Ecolab and I-Help, learners ask for support when they need to. In Ecolab, a more able learning partner assists a learner as s/he attempts to complete an activity. I-Help supports a network of peers that help each other out.</p> <p><i>Control over adaptation:</i> In ELM-ART and INSPIRE learners have the option to intervene in the adaptation process by modifying their model. Oppermann (1994) suggested the usage of adaptive tips that the system provides to learners in order to lead them through the adaptation and explain its use. Höök et al. (1996) suggest that adaptation should be inspectable, controllable and predictable by users and propose the glass box approach.</p> <p><i>Control the amount of control:</i> The expertise and behavior of the different types of advisors that SCI-WISE provides to learners are easily modifiable by learner designers. Moreover learners have the option to switch roles from time to time, so that each gets an opportunity to be in charge of the different components of cognitive and social expertise. In INSPIRE learners may follow system's suggestions, or intervene and guide the instructional process, or deactivate adaptation and take full control over the system.</p>
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Example of Implementation

Researchers and teachers that have embraced the idea of building lessons based on an instructional framework recognize the depth of decision making that exists with each framework space. In this section, aiming to improve the understandability of the proposed framework and facilitate its application, we provide an example for implementing the aforementioned guidelines.

Learners are provided with a set of *learning goals* and two *instructional* approaches, a prescriptive and a constructivist one, from which they may actively and continuously (during the interaction) select the one most appropriate to their needs and preferences. In particular, the prescriptive approach provides structured content in a specific sequence matching learners' knowledge level and/or learning style, as well as individualised study guidelines. The constructivist approach provides learners with a project to accomplish, accompanied by supportive content & resources (web and human resources). In both approaches, projects are used as a building element in organizing learners' study: learners select a learning goal from a set of meaningful ones, independently of their previous selections, and then they have the option to start working on a project (constructivist approach) or start studying the provided content and then continue with a project (prescriptive approach). Moreover, learners may work on a project alone or by collaboratively participating in a group. In such groups learners undertake specific roles, they conduct research and share knowledge in the pursuit of a meaningful, consequential task using different communication tools provided by the system such as discussion lists, e-mail, and chat.

The *content* is comprised of units, such as concepts and educational material modules that can be reused by the different instructional strategies. The notion of learning goals is used in order to build a hypermedia structure that provides learners with an overview of how all the relevant information fits together. To this end, each goal is associated with a project and a conceptual structure that includes all the necessary concepts and their relationships – outcomes, prerequisites, related concepts. The conceptual structure of a learning goal is organized following the elaboration sequence (Reigeluth, 1999b) which starts with the broadest, most inclusive and general concepts and proceeds to narrower, less inclusive, and more detailed concepts, until the necessary level of detail has been reached. The educational material of each outcome concept consists of a variety of knowledge modules which aim to support learners in achieving three levels of performance (Merrill, 1983): (i) the Remember level includes theory presentation of the concept, introductory or self-assessment questions/tasks, and instances of the concept, (ii) the Use level includes hints from the theory, application examples, exercises, activities, self-assessment questions/tasks, and (iii) the Find level includes specific cases in the form of small projects (see in Figure 1 the structure of the educational material of an outcome and in Figure 2 the different knowledge modules comprising an educational material page of the Use level). *Assessment* tests are provided for each concept including different types of questions that correspond to the three levels of performance (Remember, Use, Find). *Self-assessment opportunities* are provided through automatically corrected assessment tests, and different tasks, such as exercises, activities and projects, included in the educational material as described above.

In case learners select a learning goal to study and the *prescriptive approach*, then the system generates a sequence of individualised lessons. These lessons are organized around specific outcome concepts that learners should study in order to successfully accomplish their goal. In particular, the system provides *individualised support* to learners by:

- generating a sequence of lessons which gradually reveal the conceptual structure of the learning goal following learners' progress (as the learner progresses, more detailed concepts appear following the conceptual structure of the goal – see above how the content is organised),

- providing individualised navigation advice by annotating the lesson contents (use of visual cues) reflecting learners’ competence on the different concepts (see Figure 1),
- providing individualised presentation of the educational material following learners’ learning style, e.g. Activist, Reflector, Theorist, and Pragmatist proposed by Honey and Mumford (1992) (see Figure 2).

After learners have reached a level of competence, the system proposes to them a project to work with. Note that the provided content includes cases (see above the educational material modules developed to support the Find level of performance) that lead learners to deal with different perspectives of the project, aiming to support them to gradually acquire the necessary level of competence.

Even in the prescriptive approach, learners are provided with *opportunities to take control* over the system. They are provided with the option to change their individual characteristics, i.e. knowledge level on the concepts of the goal and learning style, and in this way to intervene in different stages of the lesson generation process reflecting on their own perspective. In this process the system supports learners by providing appropriate information about its functionalities and the options provided. In any case, learners are allowed to follow the system’s advice or deactivate adaptation and work on their own.

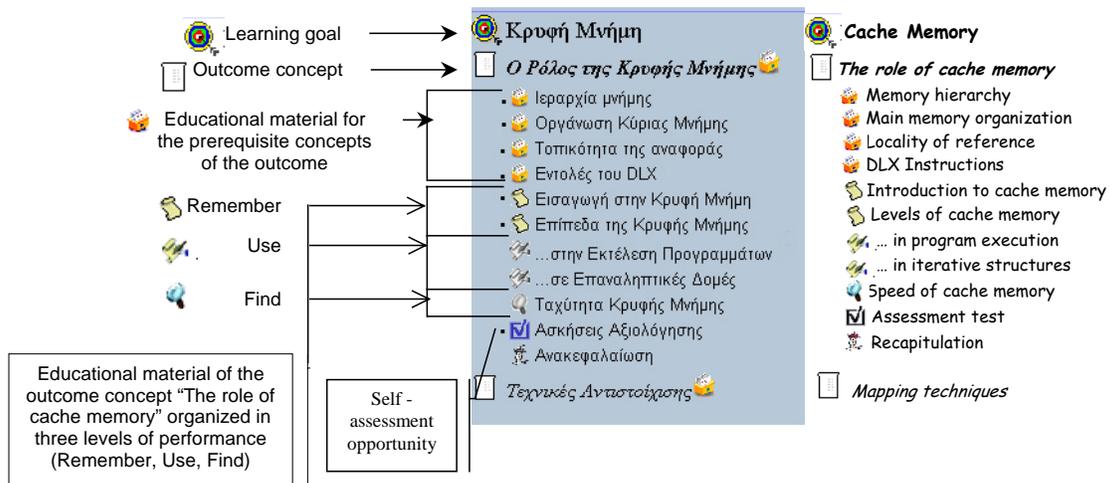


Figure 1. The contents of the first lesson generated for a novice who selected the learning goal “Cache Memory” include two outcome concepts “The role of cache memory” and “Mapping techniques”. The educational material of prerequisite concepts accompanies each outcome. The educational material of the outcomes is organized in three levels (Remember, Use, Find). The structure of the lesson contents is denoted by means of different icons. The colored icons (marked with a bullet) accompany pages that are proposed to the learner for study (navigation advice) following his/her knowledge level.

In case learners select a goal to study and the *constructivist approach*, then the system proposes to them a project to work with. Project presentation includes three integrated components (Jonassen, 1999): project context (the project statement presents all the contextual factors that surround the problem as well as the role of the learner(s) in this context), project representation (engage learners in activities which present the same type of cognitive challenges as those in the real world) and problem manipulation space (where learners generate a hypothesis and search for appropriate information in order to argue for it). Also, an assessment pre-test is provided with each project, so as to assess

learner's prior knowledge on the different concepts involved in the project. Based on this information the system will be able to provide *individualised support* in the problem manipulation space, i.e. provide the appropriate concepts (those on which the learner has insufficient knowledge), suggest web resources, peers to ask for support (peer selection process is also based on learners' knowledge level and learning style). In more detail, in the project manipulation space, the content includes all the available educational material (corresponding to the Remember, Use and Find levels) for the proposed concepts graphically annotated. Thus, individualised navigation advice is provided through annotation of the proposed content based on learner's learning style, e.g. Activists, who are motivated by experimentation and attracted to challenging tasks, are advised to start studying the small projects included in the Find level of each concept, whilst Reflectors, who prefer to collect and analyse data before acting, the material included in the Remember level. Lastly, apart from the support provided in the project manipulation space, learners have always the option to go back to the structured content and study following system's suggestions (prescriptive approach) or search within the content for the information they need.

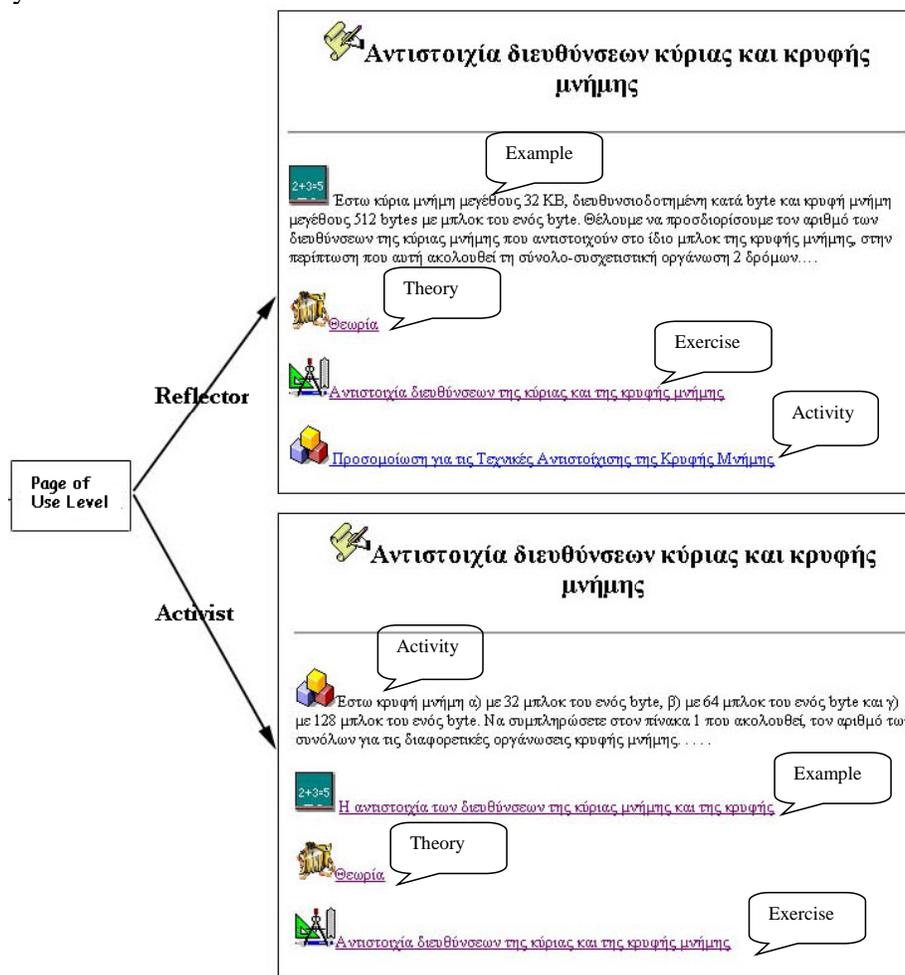


Figure 2. Learners with different learning styles view different presentations of the educational material: for Reflectors the presentation at the Use level of performance is “Example-oriented“ proposing the learner to start by studying an example, continue with hints from the theory, and then try to solve an exercise and undertake an activity, whilst for Activists, it is “Activity-oriented“, proposing the learner to start with an experimentation activity, and use the provided example, hints from the theory, and the solved-exercise in case s/he needs help.

CONCLUSIONS

The design of AES that allow learners to take varying levels of initiative is a challenging research goal focusing on the adaptable dimension of these systems. Research in this direction has a lot to benefit from the educational literature. Otherwise, adaptation design may become technology driven rather than allowing technology to serve as a resource that supports learners’ needs.

The instructional framework described in this paper unifies several processes that formulate the adaptation of an AES focusing on its educational perspective. Learner control is a critical issue in the proposed framework: the aim of adaptation is to suggest and advice learners on their study, navigation, etc., providing them with the option to decide on their steps. Learners select the learning goal they would like to study and they have the option to select the instructional approach to follow. Additionally, learners are provided with the option to decide on the level of guidance provided by the system and in any case, either to follow system advice or work on their own.

From the technological perspective, the proposed framework provides an educational basis for modelling the building elements of adaptive web-based educational systems: the domain knowledge, the learner model (although in this paper this issue has not been covered) and the adaptive engine (adaptivity and adaptability). In particular, modelling the domain is a critical issue in the area of adaptive instruction, as it should support content reusability. One of the major goals of content re-use is to support the generation of personalized courses enabling the production of several versions of the same course targeted to different audiences, from the same rich set of learning objects (IULO, 2000). Thus, the decomposition of the content based on instructional/learning theory aims to enhance the educational perspective of its re-use under a variety of instructional situations and learner profiles.

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