Συνέδρια της Ελληνικής Επιστημονικής Ένωσης Τεχνολογιών Πληροφορίας & Επικοινωνιών στην Εκπαίδευση

Τόμ. 1 (2004)

4ο Συνέδριο ΕΤΠΕ «Οι ΤΠΕ στην Εκπαίδευση»

Designing Adaptive Instruction in the context of Adaptive Educational Hypermedia Systems

Kyparisia A. Papanikolaou, Maria Grigoriadou

Designing Adaptive Instruction in the context of Adaptive Educational Hypermedia Systems

Kyparisia A. Papanikolaou* — Research Fellow — spap@di.uoa.gr

Maria Grigoriadou — Associate Professor — gregor@di.uoa.gr

Department of Informatics and Telecommunications
University of Athens
Athens, Greece

* K. A. Papanikolaou is also affiliated with the department of Technology Education and Digital Systems, University of Piraeus, Greece.

ABSTRACT

In this paper we focus on adaptive instruction and especially on the educational perspective that should underlie the development of web-based Adaptive Educational Hypermedia (AEH) systems used for Internet-based distance education. A design rational and guidelines are proposed for adaptive instruction in the context of AEH systems, which unify several processes that formulate system's adaptation such as structuring the domain knowledge, developing the content, planning individualised instruction and support, assessment, and learner control opportunities. The main aim of this approach is to incorporate a variety of pedagogical models and learning theories in order to accommodate the diversity needs and perspectives of learners and teachers. Paradigms of the way these guidelines have been implemented mainly in INSPIRE (INtelligent System for Personalized Instruction in a Remote Environment) as well as in other AEH systems, are provided. Finally results from an expert review of INSPIRE's instructional design are also reported.

KEYWORDS: Adaptive Educational Hypermedia Systems, adaptive instruction, instructional design, instructional strategies, learning style.

INTRODUCTION

The Internet offers distance education an opportunity to augment the traditional methods, content and strategies of teaching and learning. In this learning context, web-based learning environments can serve as centrally available systems that allow a user to learn transcending typical time and space barriers. The challenge posed for the education and the computer science communities is the exploitation of the innovative characteristics of the Internet for the development of web-based learning environments, flexible enough to accommodate learners' individual differences in a distance learning setting and provide learners control over instruction in a way that enhances learning. For pedagogical reasons, the effective design of flexible learning environments within the technologically rich medium of Internet demands understanding of: (i) the learning and instructional processes under the specific conditions of Internet-based distance education, (ii) the diversity of the audience which consists of learners with different backgrounds, preferences, goals, knowledge level, etc. (iii) the unique characteristics of the medium which encourage the development of learner-centered environments. Otherwise, course design may become technology driven rather than allowing technology to serve as a resource in support of learners needs (Trapp, Hammond & Bray, 1996).

Towards these directions there has been current research into the area of adaptive instruction (Federico, 1999; Magoulas et al., 2003), where the primary principle is that learners will be able to achieve their learning goals more efficiently, when pedagogical procedures accommodate their individual differences. In the area of adaptive instruction, Adaptive Educational Hypermedia (AEH) systems (Brusilovsky, 1996; 1999; 2001) emerged as an alternative to the traditional "one-size-fits-all" approach in the delivery of courseware. AEH systems possess the ability to make intelligent decisions about the interactions that take place during learning and aim to support learners without being directive. To this end, AEH systems build a model of the goals, preferences and knowledge of each individual learner and use this model throughout the interaction for adapting the content and the navigation to the needs of the particular learner (Brusilovsky, 1996).

The idea of developing web-based learning environments, in which learners are individually supported to accomplish their personal learning goals demands a cohesive instructional background to integrate system's functionalities that lead to the adaptation enhancing its educational potential. To this end, in this paper we focus on adaptive instruction and especially on the educational perspective that should underlie the development of web-based AEH systems used for Internet-based distance education. A design rational and guidelines are proposed for adaptive instruction in the context of AEH systems with the aim to accommodate a variety of pedagogical models and learning theories and enable the system (or the learner) to select the most appropriate approach following the individual characteristics of the current learner and context. Paradigms of the way these guidelines have been implemented mainly in the development of INSPIRE (INtelligent System for Personalized Instruction in a Remote Environment) as well as in other AEH systems, are also provided. Finally an expert review and two group evaluations have been conducted to evaluate the instructional design of INSPIRE and several of the proposed guidelines.

Design Rational for Adaptive Instruction

The proposed design rational aims to provide a picture of how the content, assessment and instruction work together to build purposeful lessons that accommodate learners' individual differences and provide learner control opportunities. To this end, we propose a set of guidelines for designing adaptive instruction in the context of AEH systems that unify several processes underlying system's adaptation such as structuring the domain knowledge, developing the content, planning individualised instruction and support, assessment, and learner control opportunities.

The proposed design rational addresses the following issues: (a) *Instructional strategies* (b) *Content* (c) *Assessment* (d) *Individualized support* (e) *Learner control opportunities*.

Instructional strategies. A variety of methods of instruction are supported which are based on different pedagogical models/learning theories. Adaptive instruction aims to: (*i*) individually support learners to accomplish their goals in a way that matches their style of learning and knowledge level, and (*ii*) to become system independent by enabling them to manipulate and accommodate instructional approaches to their own needs and preferences.

Guidelines: (*i*) Define a set of instructional strategies, which differ in the amount of structure, learner control and support provided to learners. (*ii*) Provide learners the option to select an instructional strategy. For each one provide a brief overview of the main idea and the different functionalities of the strategy in order to support learners select the most appropriate for them. (*iii*) Design each instructional strategy so that to provide: (a) individualised content following learner's profile (b) individualised support following learner's profile (c) multiple assessment opportunities (d) meaningful tasks and activities in which learners undertake an active role (e) collaboration opportunities. (*iv*) Propose the most appropriate strategy for learners with specific profiles, e.g. the initial acquisition phase is better served by classical instructional design techniques while complex and constructivist environments serve advanced knowledge learners better (Jonassen et al., 1993).

Implementation Example. As different cases of instructional strategies can be considered those starting *from* a highly *constructive* approach, in which learners are basically on their own to figure

out where and how to acquire the knowledge, skills and attitudes, *to* a more *prescriptive* approach, in which structure and guidance are provided to help the learners acquire the knowledge, skills and attitudes accommodating their individual differences.
Case of *prescriptive* approach. INSPIRE generates a sequence of individualized lessons following learner's learning goals, progress and learning style. The educational material includes theory, multiple tasks and activities, assessment tests and self-assessment tasks. Moreover, several communication tools are provided to support collaboration.
Cases of *constructive* approaches. In KBS-Hyperbook (Henze et al., 1999) learners are able to 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 (White et al., 1999) learners undertake collaborative research projects and a community of software agents, such as a Planner, a Collaborator, and an Assessor, support them providing strategic advice and guidance.

Content. The main topics of the curriculum are presented as learning goals enabling learners to select the one they prefer or need to study. Learning goals are building elements of the content as well as of learners' interaction with the content. The educational content of each learning goal includes all the concepts important to the curriculum for the particular learning goal (declarative and procedural knowledge) and comprise of multiple independent modules, which can be re-used by different instructional strategies.
Guidelines: (*i*) Define a set of *learning goals,* which are fundamental topics of the domain that can be recognized and selected even by a novice learner independently of his/her previous selections. (*ii*) Provide learners the option to select the 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 to support learners select the one to study. (*iii*) For each learning goal build a *conceptual structure* based on design principles extrapolated from instructional theory. This structure should include all the necessary concepts comprising the goal and their interrelations (such as prerequisites, related). (*iv*) Develop *educational material* for each domain concept that supports learning/achievement of specific skills/performance levels. Develop multiple knowledge modules of different types of educational resources and authentic and meaningful tasks that cover a variety of learning/cognitive styles. (*v*) The modularity of the content allows the use of its different components - concepts, knowledge modules - by different instructional strategies for a variety of learners' profiles.
Implementation Example. In INSPIRE a set of learning goals is proposed to learners. The domain model of the system is based on the notion of learning goals that the learner can select and study, and provides learners with a plurality of learning activities and resources, to support them in accomplishing their goals.
All the concepts comprising a learning goal are organised in a *conceptual structure* following the elaboration sequencing (Reigeluth, 1999). Other taxonomies that may be used for organising the conceptual structure for a learning goal are the Hierarchical sequencing, Procedural sequencing, Simple-to-complex sequencing.
The *educational material* provided for each concept is organised in different levels that correspond to specific skills or performance levels which learners are expected to develop/succeed following the taxonomy proposed by (Merrill, 1983) such as Remember, Use and Find levels of performance. At each level, the educational material includes multiple types of resources/activities such as questions, exercises, examples, activities, projects (knowledge modules in INSPIRE), aiming to cover a range of learning styles (Activists, Pragmatists, Reflectors, Theorists proposed by Honey & Mumford (1992)).

Assessment. Multiple assessment opportunities are provided that aim to support learners identify their own progress and provide the system with the necessary information about learners' level of performance in order to be able to adapt accordingly.
Guidelines: (i) Provide self-assessment opportunities 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 (formative assessment). (ii) Provide formal assessment aligned with the content provided in order to assess retention of learning following specific criteria given in terms of objectives and competences which state what learners must achieve (summative assessment - criterion-referenced assessment). (iii) Provide feedback to learners' answers in order to support the learning process, provoke reflection on and articulation of what was learned.
Implementation Example. In INSPIRE self-assessment opportunities are provided through assessment tasks included in the content such as, questions, exercises, activities, and projects. Moreover, INSPIRE uses automatically corrected assessment tests for the main topics of the domain in order to get the necessary information about learners' knowledge/level of performance and adapt accordingly. Assessment questions included in the tests are grouped in several categories that correspond to specific abilities that the learner should demonstrate. Different types of feedback that can be provided are (Mory, 1996): *suggestive feedback* which follows learners' wrong answer 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 *reinforcing feedback* which follows learners' right answer to justify the correctness of the particular answer.

Individualized support is provided aiming to advice and not direct learners. The amount of support and guidance provided is mainly dependent on learner's characteristics such as knowledge level, learning style, preferences.
Guidelines: (*i*) Support learners in undertaking control over the learning process and the adaptation. Provide learners with information about the different functionalities of the system that lead to the adaptation and of the influence of their actions on the system's functions. (*ii*) 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 restricted to follow system's suggestions.
Implementation Example. In several AEH systems such as ELP-ART, INSPIRE, AES-CS, the externalisation of the learner model is used as a means of communication between the learner and the system. For example, in INSPIRE the learner model is open to the learners providing information about the system adaptation, the instructional decisions of the system, and the opportunities they are provided to intervene in the instructional process. Moreover, different adaptation technologies such as adaptive presentation, adaptive navigation support, curriculum sequencing, are used to provide individualized content, support, navigation advice following learners' knowledge level, progress, and learning style.

Learner control opportunities. Learners undertake an active role in the learning process and are allowed to take varying levels of initiative. Learners are informed about the internal workings of the system and they are provided with opportunities to control the learning process and undertake control over the system. As system adaptation is mainly based on the learner model, an open learner model is a fundamental part of learner control (Kay, 2001).
Guidelines. Provide learners with the options to: (a) decide what to learn; (b) decide how to learn; (c) decide when to learn; (d) control the adaptation; (e) control the amount of control.
Implementation Example. In INSPIRE learners select the learning goal to study and the content is presented in a hypermedia form enabling learners to follow their own navigational paths (what to learn). Also, in INSPIRE learners select the type of content to study whilst in SCI-WISE learners

select their learning peer / teacher / companion (how to learn). In INSPIRE learners have the option to intervene in the adaptation process by modifying their model and to deactivate the system's adaptive functionality (Control over adaptation). Moreover, learners may follow system's suggestions, or intervene and guide the instructional process through modifying their characteristics in the learner model, or deactivate adaptation and take full control over the system (Control the amount of control). Lastly, cases of systems where learners select "When to learn" can be considered Ecolab (Luckin and Du Boulay, 1999) and I-Help (Bull and McCalla, 2002). In both systems learners ask for support when they need to and in Ecolab, a more able learning partner assists a learner as s/he attempts to complete an activity, whilst I-Help supports the interaction of a network of peers that help each other out. 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 (see Lemore group at http://www.eee.bham.ac.uk/bull/lemore/).

EMPIRICAL STUDY

In this section we present the current evaluation results of specific aspects of the proposed design rational. Especially the study presented below concentrated on INSPIRE's instructional design (this is briefly presented in the different sections of the questionnaire – see Table I) with the aim to verify the instructional approach adopted and guide further development and improvement. The current version of INSPIRE adopts just one prescriptive instructional strategy, according to which learners are provided with structured content in a specific sequence matching learners' knowledge level and/or learning style, and individualised study guidelines. After learners have succeeded a level of competence the system proposes them a project to work with. Note that the provided structured content includes specific cases in the form of activities that lead learners to deal with different perspectives of the project, aiming to support them to gradually acquire the necessary level of competence to deal with the whole project. A constructivist strategy, which will be fully problem-based, will be included in the next version of the system, which is currently under development. In more detail, INSPIRE (Papanikolaou et al., 2003), is a prototype web-based AEH system designed to support Web-based instruction as well as traditional classroom-based teaching as a supplementary resource. Based on learners' learning goals, INSPIRE plans a sequence of lessons aiming to support learners to gradually achieve each of their goals. With regards to the adaptive dimension of INSPIRE, it supports the selection of the lessons contents following learners' knowledge level (the curriculum sequencing technology (Brusilovsky, 1996) is adopted), and provides guidance over learners' navigation and study (the adaptive navigation support and adaptive presentation technologies (Brusilovsky, 1996) are adopted) following learners' knowledge level and learning style. However, learners are not restricted to follow system suggestions, as they are always able to navigate through the hyperspace or to intervene in the adaptive behaviour of the system by modifying their model (the learner model that INSPIRE stores and updates for each learner during their interaction) or by deactivating system's adaptive behaviour. As an application domain we selected a quite demanding subject from the area of Computer Architecture, "Cache Memory".

As far as the evaluation of INSPIRE's instructional design is concerned, both learners and instructors were involved as they are the main stakeholders of a virtual classroom. In more detail we conducted an expert review (described in this section) and two group evaluations (Tessmer, 1993) in which 33 students participated (Papanikolaou et al., 2002; Papanikolaou et al., 2003). In the expert review, a group of eight experts-instructors acted as evaluators who reviewed the instructional design that underlie system's functionalities. They attended a brief presentation of INSPIRE and were asked to rate its functions (in a questionnaire where each of the functions was briefly presented) by assigning to each of them a qualitative characterization: {Useless, Almost

Useless, Rather Useful, Useful, Very Useful}. The mean ratings for each function are shown in Table I, in particular 1 stands for {Useless}, 2 for {Almost Useless}, 3 for {Rather Useful}, 4 for {Useful}, and 5 for {Very Useful}. The system functions were grouped in the questionnaire in different sections (see Table I). Each of the sections was accompanied with a free space for comments, suggestions, likes and dislikes, problems identified, etc.

It is important and rather encouraging the fact that all the described functions were considered by instructors as at least {Rather Useful} (the lowest mean rating was 3.25, while 3 stands for 'Rather Useful'). However, instructors were more restrained in their ratings when it comes to the type of automatically corrected assessment tests, and on specific issues of learner control, such as the usefulness of providing information to learners about their learning style & knowledge level and of providing learners with control over the content presentation and the selection of the educational material.

Especially, two instructors proposed that adaptive guidance should be provided to learners for the selection of the learning goal to study, based on their knowledge level and their interaction with the system. Instructors' suggestions on the assessment framework inspired several future plans. They suggest that the system should provide multiple assessment approaches such as peer and collaborative assessment. Another interesting suggestion concerns the feedback provided which in the current implementation has been designed to lead learners towards the right answer depending on their answers without taking into account their individual differences. Thus adaptive feedback is an issue that is worthwhile to reconsider. Lastly, the issue of providing learners with support in order to undertake control over the instructional process should be investigated more thoroughly.

SYSTEM FUNCTIONS	MEAN RATING
Section A: ***General Aspects***	
A1. Learners have the option to select a learning goal to study from a set of predefined goals. A learning goal corresponds to a fundamental topic of the subject matter and it is described in an easy to follow way in order that it can be recognized and selected even by a novice learner.	4,50
A2. Learners are able to select and study any learning goal according to their preferences, independently of their previous selections. To this end, all the educational material necessary for studying each particular goal is provided when the goal is selected.	4,63
Section B: ***Content***	
B1. The content of each lesson generated for a particular learning goal is organized around specific outcome concepts, i.e. concepts that are fundamental to the accomplishment of the goal. More specifically, a conceptual structure is built for each learning goal including outcome concepts, prerequisite concepts of the outcomes and related concepts.	4,50
B2. Learners are informed about the relevant learning outcomes associated with each concept. Also, a special kind of overview of the simplest and the most fundamental ideas that are covered for each concept is provided, which summarizes the ideas that follow.	3,88
B3. Educational material provided for an outcome is organized in three levels: (*i*) *Remember*, material that targets the ability of students to understand and recall the provided theory and specific instances presenting a concept, (*ii*) *Use*, material that aims to strengthen the ability of students to apply theory to specific case(s), and (*iii*) *Find*, material that aims at enhancing/cultivating students ability/skills to propose and solve original problems.	4,50
B4. A variety of learning resources that differ in their interactivity level and format is provided for each goal, so that they can be reused for learners with different preferences.	4,38
B5. An outcome concept is introduced through multiple types of educational material (Remember level): a *theoretical presentation* of the concept, an *introductory* or *self-assessment question* that motivates learners to use their prior knowledge and think about the new-presented concepts or supports learners to assess their knowledge on the concept, and an *example* or *analogy* of the concept.	4,25
B6. Learners are supported to apply the presented concepts through multiple types of	4,38

educational material (Use level): *hints from theory* that highlight specific useful issues of the concept, *exercises* (usually accompanied by their solution), *examples*, and *activities*.	
B7. Learners are stimulated to propose and solve original problems through (Find level): specific *activities*, *case studies*, *projects* and/or *collaborative activities,* and *assignments* that should be submitted to the tutor.	4,13
B8. Learners are provided with a *summary* for each particular outcome concept that reviews the content already presented.	3,88
B9. Learners are provided with self-assessment opportunities through specific automatically-corrected tests and exercises for which the correct solution is also provided.	4,38
B10. Learners may select the educational material they prefer to study on each lesson as the presentation of the lesson contents in a hypermedia form facilitates the process.	3,63
Section C: ***Assessment***	
C1. The system infers learners' knowledge level based on their performance on the assessment tests they submit. Moreover, learners submit assignments to the tutor.	4,25
C2. *Assessment tests* are part of the educational material of each outcome concept and are available to learners during studying the particular concept. These tests, addressing the learning outcomes of the outcome, evaluate learner's knowledge level on the outcome and its prerequisite concepts.	4,50
C3. Assessment questions included in the tests are grouped in several categories that correspond to specific abilities that the learner should demonstrate: (*i*) questions that test learners' ability to recall the presented concepts; (*ii*) questions that test learners' ability to apply the provided information to specific case(s); (*iii*) questions that test learners' ability to propose and solve original problems;	4,13
C4. Automatically corrected assessment questions included in the tests are mainly of multiple-choice type.	3,63
C5. The system provides feedback to learners' answers on the assessment questions, i.e. in case of a: (*i*) *wrong answer*, the system provides feedback that refers to the consequences of learner's answer aiming this way to stimulate him/her think towards the right answer; (*ii*) *right answer*, the system provides additional comments that justify the correctness of the particular answer;	4,13
C6. The assessment process is based on three qualitative criteria that correspond to the three levels of performance that learners should achieve in order to cover the concept In this way we aim to assess learners' knowledge level following the structure of the educational material. Different weights are assigned by the tutor to the above criteria expressing their relative importance with respect to learner's knowledge level at the time of assessment, i.e. novice, mediocre, advance, as well as to the type of the concept under consideration, i.e. theoretical concept, procedure, etc.	4
Section D: ***Prescriptive Instructional Strategy - Individualised Support***	
D1. The system informs learners about their knowledge on the different domain concepts (estimated by the system or defined by the learner). This is visualized in the lesson contents by annotating the links of the corresponding concepts.	3,88
D2. The system, based on learners' knowledge level, provides individual advice about the pages that they are ready to study next. This is visualized in the lesson contents through graphical annotation of the corresponding pages.	4,38
Individualizing educational content -based on learners' knowledge level	
D3. The system based on learners' knowledge level generates a sequence of lessons for each particular learning goal. Content planning (selection of outcomes included in the lesson) of each lesson depends on learners' progress.	4,75
D4. The domain concepts are gradually presented to learners, from the general to the specific ones or in other words from the simple to complex ones, following their layered structure, i.e. outcome concepts of a learning goal are organized into layers, each of which includes a subset of them. The outcome concepts proposed to the learner for study are determined based on learner's knowledge level on the outcome concepts of the previous layers, i.e. in order to go on to the next layer the learner should be "Advanced" on the outcome concepts of the previous layer. However, the concepts of each subsequent layer enrich those of the previous	4,50

ones, augmenting the domain presented to the learner.	
D5. The system provides individual navigation advice following learners' progress, without restricting the educational material and limiting learners' freedom to browsing. To this end, all the educational material is available to learners for the outcomes included in the lesson contents, the educational material pages that are proposed for study are determined, and accordingly annotated, based on specific instructional strategies that take into account the type of each concept (outcome or prerequisite) and the knowledge level of the learner on the particular concept. Thus, in case that the learner is a novice on an outcome concept, i.e. his/her knowledge level is characterized as "Inadequate", then the pages of the Remember level for the particular concept and all its prerequisites will be proposed. Following learner's progress, the system proposes the pages of the Use level (when his/her knowledge level becomes "Almost Adequate") and finally of the Find level (when his/her knowledge level becomes "Adequate").	4,50
Individualizing educational material presentation based on learners' learning style	
D6. Learners' learning style is initialized by the learner him/herself or through the submission of the corresponding questionnaire developed by Honey and Mumford (1992).	3,75
D7. Based on learners' learning style, which reflects their preferences of instructional material, the *sequencing* of different types of educational material is adapted. In particular, the various types of educational material constituting the pages of the outcome concepts (questions, theory presentations, examples, exercises, activities, case studies, see questions B5, B6, B7 for more details on the contents of the educational material pages) are joined together in various ways following alternative instructional strategies according to the learning style of the learner. Thus, all learners are provided with the same educational material which is presented in a way that focuses on different perspectives of the presented topic depending on the learning style of the learner.	4,00
D8. For Activists, who are more motivated by experimentation and challenging tasks, the adopted instructional strategies for sequencing the educational content in both the Remember and Use levels of performance are of high interactivity level. Thus, at the Remember level of performance, educational material pages are built following an *Inquisitory presentation* strategy, i.e. a Introductory Question is embedded on the top of the page that motivates learners to use their prior knowledge and think about the new-presented concepts and below an Example and Theory appear as links. At the Use level of performance, educational material pages are built following an *Activity-based* strategy, i.e. an Activity is embedded on the top of the page and below an Example, Hints from Theory & an Exercise, appear as links;	4,00
D9. For Reflectors who tend to collect and analyze data before taking action, the adopted instructional strategies for sequencing the educational content in both the Remember and Use levels of performance are of low interactivity. Thus, at the Remember level of performance, educational material pages are built following an *Expository presentation* strategy, i.e. theory presenting the concept is embedded on the top of the page, and then an Example and a Self-assessment Question appear as links. At the Use level of performance, educational material pages are built following an *Example-based* strategy, i.e. an Example is embedded on the top of the page and below Hints from Theory, an Exercise and an Activity, appear as links;	4,13
D10. For Theorists who prefer to explore and discover concepts through more abstract ways, the adopted instructional strategies for sequencing the educational content in both the Remember and Use levels of performance are of medium interactivity. Thus, at the Remember level of performance, educational material pages are built following an *Inquisitory presentation* strategy, i.e. a Question is embedded on the top of the page that motivates learners to use their prior knowledge and think about the new-presented concepts and below Theory and an Example appear as links. At the Use level of performance, educational material pages are built following a *Theory-based* strategy, i.e. Hints from Theory are embedded on the top of the page and below an Example, an Exercise and an Activity appear as links;	3,63
D11. Pragmatists who are keen on trying out ideas, theories and techniques, the adopted instructional strategies for sequencing the educational content in both the Remember and Use levels of performance are of medium interactivity, Thus, at the Remember level of	4,13

performance, educational material pages are built following an *Expository presentation* strategy, i.e. an Example is embedded on the top of the page, and then Theory and a self-assessment Question appear as links. At the Use level of performance, educational material pages are built following an *Exercise-based* strategy, i.e. an Exercise is embedded on the top of the page and below an Example, Hints from Theory and an Activity appear as links;	
Section E. *Learner control opportunities*	
E1. Learners are informed about the different learning style categories and on the influence that this characteristic has on system's decisions that guide the content presentation.	3,25
E2. Learners are informed about their performance on the assessment tests that they submitted, on the way their knowledge level was evaluated and on the influence that learners' knowledge level has on system's instructional decisions about the lessons contents and the "ready to study" educational material proposed to learners.	3,75
E3. Learners have the option to check and update their learning style.	4,63
E4. Learners have the option to check and update their knowledge level on the various domain concepts.	4,38
E5. Learner control is supported on the presentation of the educational material.	3,88
E6. Learner control is supported on the contents of each lesson and on the "ready to study" educational material.	4,13
E7. Learners have the option to deactivate system's adaptive features and select the contents of the next lesson.	4,50

Table I. Instructors' mean ratings for different aspects of the instructional design of INSPIRE

CONCLUSIONS

The development of web-based learning environments that accommodate learners' individual differences is the real challenge for distance education taking into account the diversity of its audience as well as the issue that an instructional approach that benefits one category of learners may create obstacles for other categories. A critical issue in the development of such systems is the pedagogical background underlying the adaptation.

The design rational presented in this paper focuses on the educational perspective of AEH systems with the aim to support the development of learning environments built on sound pedagogic principles and rich enough to accommodate a diversity of instructional/learning approaches. From the technological perspective, the proposed guidelines provide the educational basis for modelling the domain knowledge of the system, the learner model (although in this paper this aspect of the framework has not been covered) and system's adaptation. In particular, modelling the domain is a critical issue in the area of personalized web-based instruction, as it should support courseware reusability. One of the major goals of courseware 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 (*The instructional use of learning objects*, On-line edition, URL: http://reusability.org/read/).). Consequently, the decomposition of the content based on pedagogical principles enhances the educational perspective of its re-use under a variety of instructional situations and learners' profiles.

Moreover, the research described in this paper is towards the development of meta-adaptive hypermedia systems capable of selecting the most appropriate adaptation technology following the individual characteristics of the current users and context (Brusilovsky, 2003). Extending this research to the authoring process of AEH systems we intend also to accommodate the diversity of needs and perspectives of teachers who should be considered as a main target group of these systems playing a significant role in the development of the AEH area.

REFERENCES

Brusilovsky, P. (1996), Methods and Techniques of Adaptive Hypermedia, *User Modeling and User-Adapted Interaction,* 6 (2/3), 87-129

Brusilovsky, P. (1999), Adaptive and Intelligent Technologies for Web-based Education, In: C. Rollinger, C. Peylo (Eds.): *Kunstliche Intelligenz*, Special Issue on Intelligent Systems and Teleteaching, 19-25

Brusilovsky, P. (2001), Adaptive Hypermedia, *User Modeling and User-Adapted Interaction,* 11 (1/2), 111-127

Brusilovsky, P.: Adaptive navigation support in educational hypermedia: The role of student knowledge level and the case for meta-adaptation. British Journal of Educational Technology 34 (4) (2003) 487-497

Bull, S. & McCalla, G. (2002), Modelling cognitive style in a peer help network, *Instructional Science*, 30, 497–528

Federico, P.-A. (1999), Hypermedia environments and adaptive instruction, *Computers in Human Behavior,* 15, 653-692

Grigoriadou, M. & Papanikolaou, K.A. (2000), LEARNING ENVIRONMENTS ON THE WEB: The Pedagogical Role of the Educational Material, *Themes in Education*, 1(2), 145-161

Henze, N., Naceur, K., Nejdl, W. & Wolpers, M. (1999), Adaptive Hyperbooks for constructivist teaching,*Kunstliche Intelligenz,*26-31

Honey, P & Mumford, A. 1992, *The manual of Learning Styles*, Maidenhead: Peter Honey

Jonassen, D., Mayes, T. & McAleese, R. (1993), A Manifesto for a Constructivist Approach to Uses of Technology in Higher Education, In: T. Duffy, J. Lowyck and D. Jonassen (Eds.): *Designing Environments for Constructive Learning*, *NATO ASI Series F*, Vol.105, Berlin: Springer-Verlag

Kay, J. (2001) Learner control, *User Modeling and User-Adapted Interaction,* 11(1/2), 111-127

Luckin, R. & Du Boulay, B. (1999), Ecolab: The Development and Evaluation of a Vygotskian Design Framework, *International Journal of Artificial Intelligence in Education*, 10, 198-220

Magoulas, G.D., Papanikolaou, K.A. & Grigoriadou, M. (2003), Adaptive web-based learning: accommodating individual differences through system's adaptation, *British Journal of Educational Technology*, 34 (4), 511-527

Merrill, M.D. (1983), Component Display Theory, In: C.M. Reigeluth (Ed.): *Instructional design theories and models: An overview of their current status*, Hillsdale: Lawrence Erlbaum Associates

Mory, E.H. (1996), Feedback Research. In D.H. Jonassen (Ed.): *Handbook of Research for Educational Communications and Technology*, pp. 919-956, New York: Simon and Schuster Macmillan. Also available at: http://www.aect.org/intranet/publications/edtech/32/index.html

Papanikolaou K., Grigoriadou M., Kornilakis H. & Magoulas G.D. (2003), Personalising the Interaction in a Web-based Educational Hypermedia System: the case of INSPIRE, *User-Modeling and User-Adapted Interactio*n, 13 (3), 213-267

Papanikolaou, K.A., Grigoriadou, M., Magoulas, G.D. & Kornilakis, H. (2002), Towards New Forms of Knowledge Communication: the Adaptive Dimension of a Web-based Learning Environment, *Computers and Education*, 39 (4), 333-360

Reigeluth, C.M. (1999), The elaboration theory: Guidance for scope and sequencing decisions, In: C.M. Reigeluth (ed.): *Instructional-Design Theories and Models: A New Paradigm of Instructional Theory*, Volume II, Mahwah, NJ, London: Lawrence Erlbaum Associates

Tessmer, M. (1993), *Planning and conducting formative evaluations,* Kogan Page Limited.

Trapp, A., Hammond, N. & Bray, D. (1996), Internet and the support of psychology education, *Behavior Research Methods, Instruments, & Computers*, 28, 174 –1176

White, B.Y., Shimoda, T.A. & Frederiksen, J.R. (1999), Enabling students to construct theories of collaborative inquiry and reflective learning: Computer support for metacognitive development, *International Journal of Artificial Intelligence in Education*, 10,151-182