In Proceedings of the IADIS International Conference "Cognition and Exploratory Learning in Digital Age (CELDA 2005), **Porto, Portugal, 14 -16 December 2005**

LEARNING ACTIVITIES AND AIDS IN ADAPTIVE LEARNING ENVIRONMENTS

Kyparisia A. Papanikolaou, Maria Grigoriadou
Department of Informatics and Telecommunications, University of Athens
Panepistimiopolis, GR-15784 Athens, GREECE
{spap,gregor}@di.uoa.gr

Maria Samarakou
Department of Energy Technology, Technological Educational Institution of Athens
Ag. Spyridonos, GR12210 Egaleo, GREECE
marsam@teiath.gr

ABSTRACT

The Internet offers distance education an opportunity to augment the traditional methods, content and strategies of teaching and learning yielding to the development of innovative learning environments. In this paper we concentrate on the design of learning activities and aids in adaptive learning environments. In particular, we present learning activities and aids that reflect two alternative pedagogical design approaches of adaptive educational hypermedia systems. The first concentrates on the instructional design approach which focuses on the definition of specific outcome objectives, design of materials and procedures that are targeted on these objectives, and assessments that determine if learners have attained the desired objectives – adopted by the main stream of adaptive educational hypermedia systems, and the constructivist approach which focuses on in-context learning organized around authentic tasks. As representative examples of learning activities and aids designed on these approaches, we present learners' interaction with INSPIRE, which adopts an instructional framework that combines theories from the area of instructional design and learning styles, and ProSys which adopts a constructivist approach based on a combination of project-based and case-based learning theories. In particular, learners working with INSPIRE are progressively provided with structured content in a sequence that matches learners' knowledge level and progress, as well as individualised study guidelines based on learner's knowledge level and learning style. In the case of ProSys, learners work on projects, and the system proposes them a learning cycle to follow as well as individualised content and resources in the form of realistic cases in order to support learners deal with different perspectives of the project.

KEYWORDS

Learning activities, learning aids, adaptive learning environments, adaptive educational hypermedia systems, adaptation

1. INTRODUCTION

The Internet as a main technological advance has stimulated researchers and educators to expand their conceptions of learning as well as the design of learning environments (Land and Hanaffin, 2000). Recently, renewed interest in student-centered teaching and learning has yielded many approaches purported to provide flexible and powerful alternatives to the design of instruction, leading to the development of a variety of innovative and provocative learning environments. Especially for web-based education, the design of student-centered learning environments that support experimentation, manipulation, and idea generation, raises several issues. How can learners become engaged in active learning through a web-based learning environment? How can instruction be organized in order to support meaningful learning activities, self-learning and enhance reflection? Under what conditions does it help to provide learners with control over instruction and which forms of learning aids could support them in this process? Do all learners benefit from one pedagogical approach, especially in web-based education where the variety of learners is large? Towards these directions there has been current research into the areas of network learning/instruction, multimedia learning, collaborative learning and adaptive instruction/learning and it has already been suggested a number of new theoretical and methodological ways that address instruction/learning in the context of web-based learning environments. Especially, in adaptive instruction, the primary principle is that learners will be able to achieve their learning goals more efficiently, when pedagogical procedures accommodate their individual differences (Federico, 1999).

In the area of adaptive instruction, Adaptive Educational Hypermedia Systems (AEHS) (Brusilovsky, 1996; Brusilovsky and Peylo, 2003) emerged as an alternative to the traditional “one-size-fits-all” approach in the delivery of courseware. To this end, AEHS 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). In the area of AEHS, adaptation is based on learner’s discriminative characteristics and exploits the adopted domain model, which consists of knowledge elements usually mentioned as concepts, under the guidance of a specific pedagogical approach. Especially, different pedagogical approaches have been used in AEHS leading to the design of a variety of learning activities and aids, such as the instructional design approach focusing on the definition of specific outcome objectives, design of materials and procedures that are targeted on these objectives, and assessments that determine if learners have attained the desired objectives - adopted by the main stream of AEHS (DCG, ELM-ART, INSPIRE, AST, KnowledgeSea), and the constructivist approach which focuses on in-context learning organized around authentic tasks (KBS Hyperbook). Especially, in the first category of systems, the learning activities that learners perform are mainly practice-oriented including answering to questions, following examples, solving exercises, submitting assessment tests. Guidance provided is in the form of advices on the selection and/or sequencing and/or presentation of educational content using specific adaptation technologies (Brusilovsky, 1996). In the second category of systems, constructivist theories are used as a base for their development. The main characteristic of constructivist learning environments is that a specific problem drives the learning, rather than acting as an example of the concepts of the subject matter (Jonassen, 1999). For example, in KBS Hyperbook (Henze at al., 1999) that belongs to this category, learners work with projects and the system provides individualised navigation support to the project resources based on the learners’ knowledge level and/or learning goals. The content provided to support learners in accomplishing their project is in the form of lectures (sequence of text units such as information pages, examples showing the use of concepts, information pages in the WWW, e.g. Sun Java tutorial), former student projects, glossary etc. Recently, with the aim to investigate the design of adaptive educational systems based on constructivist theories, we have developed ProSys (Papanikolaou et al., 2005). In ProSys learners are engaged in authentic tasks in order to accomplish a learning goal. Through the interaction with the system, learners are proposed to follow a sequencing of learning activities that assist them in understanding the issues implicit in the problem they have to face, whilst they are provided with access to a set of related experiences - cases -. The innovation in this research is the type of the learning aids offered including a library of realistic cases that surrounds the outcome concepts of each learning goal, as, following Jonassen (1999), a main characteristic of meaningful learning is mindful activity and in such activities the lack of experience is especially critical.

The paper is organized as follows. At first we present alternative learning activities and aids that reflect the instructional design and constructivist approach (Section 2). Both approaches are accompanied by paradigms of learners’ activity through their interaction with INSPIRE and ProSys. Moreover, evaluation data for both systems are briefly presented, whilst a comparative evaluation belongs to our future plans. The paper ends with the main points of our work and future plans (Section 3).

2. ALTERNATIVE APPROACHES IN LEARNING ACTIVITIES & AIDS

In this section we present two different approaches in designing learning activities and aids in the context of AEHSs which reflect alternative pedagogical design approaches. The first is an *instructional design* approach, in which learners are provided with structured content (consists of a variety of knowledge modules which differ in their format and interactivity level) and individualised support in order to acquire the knowledge, skills and attitudes, whilst the second one is a *constructivist* approach, in which learners are stimulated to explore the content (consists of multiple cases) in order to solve a problem - in the context of an authentic activity -, rather than solving the problem as an application of learning. In both approaches, learners are provided with a set of learning goals in order to select the one to study. Learner control is a critical issue in both approaches: the aim of the support provided is to suggest and advice learners on their study, navigation, etc. providing them the option to decide on their steps.

2.1 The instructional design approach: the case of INSPIRE

INSPIRE (Papanikolaou et al., 2003) is a web-based AEHS designed to support web-based instruction. In INSPIRE, learners have always the option to select and study the learning goal they prefer independently of their previous selections; all the material necessary for their study is provided when a learning goal is selected. In particular, INSPIRE plans the content of instruction for the particular learning goal and learner, i.e. selects the contents of a sequence of lessons that gradually supports the learner to achieve his/her goal. INSPIRE aims to facilitate learners during their study, providing personalized instruction (a) proposes a navigation route through the lesson contents based on learner’s knowledge level and progress, and (b) adapts the presentation of the educational material to the learners' learning style (Honey and Mumford, 1992).

Learners interact with the content performing learning activities, with the aim to progressively deal with the different concepts comprising the goal and attain the learning objectives posed. Learners are not restricted to follow system suggestions, as they are always able to navigate through the hyperspace or to intervene in the adaptive behavior of the system (see Table I - *Learner control opportunities*).

Learning activities & aids. In INSPIRE, the notion of *learning goals* is used in order to build a hypermedia structure that provides an overview of how all the relevant information fits together. INSPIRE provides learners with structured *content* which is comprised of units, such as concepts and educational material modules that can be reused for learners of different profiles. In particular, each goal is associated with a conceptual structure that includes all the necessary concepts and their relationships – outcomes, prerequisites, related concepts. Each outcome concept is accompanied by educational material pages which include a variety of knowledge modules of different interactivity level – theoretical presentations, examples, hints on the theory, exercises, experimentation activities, self-assessment questions/tasks -, aiming to support learners in achieving three levels of performance (Merrill, 1983): Remember, Use and Find.

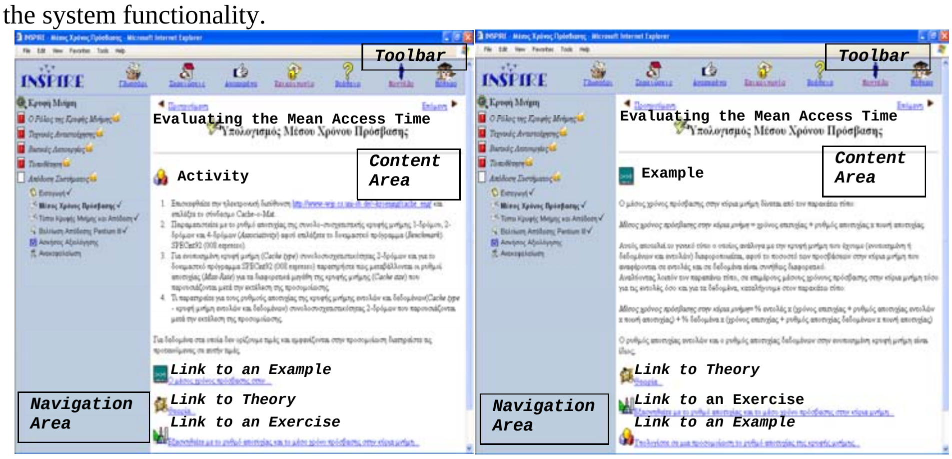
The *sequencing of learning activities* proposed to learners aims to organize their study on two levels: the concept level - suggesting appropriate concepts -, and the educational material level - suggesting appropriate educational material pages and knowledge modules for each concept. On the concept level, learners are suggested to study the concepts of a learning goal following the elaboration sequence (Reigeluth, 1999). Learners gradually study the concepts of the learning goal according to their progress, starting with the broadest, most inclusive and general concepts and proceeding to narrower, less inclusive, and more detailed ones, until the necessary level of detail has been reached. On the educational material level, the proposed sequencing depends on the knowledge level and learning style of the learner. In particular, learners interact with the educational material of each outcome concept in order to gradually (a) speculate on newly introduced ideas by answering to introductory or self-assessment questions, following instances of the concept and real-life analogies accompanied by appropriate questions, studying the theory (“Remember” level of performance), (b) become able to apply the concept to specific case(s) by undertaking experimentation activities, following application examples, studying hints on the theory that concentrate on specific outcomes, solving exercises (“Use” level of performance), and finally (c) find a new generality, principle, procedure by accomplishing specific tasks in the form of small projects (“Find” level of performance). The sequencing of learning activities that learners perform in order to attain the different levels of performance differs depending on their learning style - the (Honey and Mumford, 1992) categorisation has been adopted which suggests four types of learners: Activist, Pragmatist, Reflector, Theorist. In particular, for each level of performance learners are recommended to start from activities that match their style exploiting their own capabilities, and continue with less ‘style matching’ activities in order to develop new ones (for more details see (Papanikolaou et al., 2002)). For example, at the “Use” level of performance, Activists, who are considered to prefer activities where there are new experiences, problems, opportunities of active experimentation from which to learn, they undertake an active role and through experimentation construct their own internal representations for the underlying concept. In particular, they start with an experimentation activity, i.e. run an experiment following a specified scenario that uses a computer simulation. If they need help, they can follow the application example and study the hints from the theory provided (see Figure 1 – the Activist’s view). Also, they may solve the exercise provided offering additional opportunities for practicing. Accordingly, Reflectors, who are considered to prefer activities where they are allowed to watch, think, ponder over activities, they study all the necessary information before acting. In particular, they start by following the application example, continue studying hints from the theory, and then try to solve an exercise (see Figure 1 – the Reflector's view). Afterwards, they perform an experimentation activity using a computer simulation following a specified scenario and getting an active role experimenting with already acquired knowledge or just testing their knowledge.

Moreover, *assessment and self-assessment* opportunities are provided through solved exercises, activities on computer simulations, and assessment tests that accompany each outcome concept and include different types of questions that correspond to the three levels of performance (Remember, Use, Find).

As far as the *learning aids* provided is concerned, these can be summarised as following:

- generation of 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),
- provision of individualised navigation advice by annotating the lesson contents (use of visual cues) reflecting learners' competence on the different concepts included,
- provision of individualised presentation of the educational material following learners' learning style.

Learners are also provided with *opportunities to take control* over the system. In any case, learners are allowed to follow the system's advice or not, or even to deactivate adaptation and work on their own. They are also provided with the option to reflect on and update the contents of their learner model. By changing their individual characteristics in the learner model, i.e. knowledge level on the concepts of the goal and learning style, they are able to intervene in the different stages of the lesson generation process reflecting their own perspective. In this process INSPIRE supports the learners by providing appropriate information about its functionalities, the way it has estimated their characteristics, and the consequences of changing their model on the system functionality.



Activist's view **Reflector's view**

Figure 1. The main screen of INSPIRE (http://hermes.di.uoa.gr/inspire) provides learners with a complete view of the structure of the domain knowledge (Navigation Area) and direct access to learning resources (Content Area) and systems' functionalities (Toolbar). At the Content Area, the educational material page "Evaluating the Mean Access Time" appears as it is viewed by an Activist and a Reflector. This page corresponds to the Use level of performance for the main concept "Cache Performance (CP)" of the learning goal "Describe the role of cache memory and its basic operations".

2.2 The Constructivist approach: the case of ProSys

ProSys (Papanikolaou et al., 2005) is a web-based adaptive learning environment which uses projects as a building element in organizing learners' study: learners select a learning goal and then they start working on a project following the different stages of a learning cycle, which is represented as a puzzle in the Navigation area (see Figure 2). The pedagogical approach adopted combines project-based (Thomas, 2000) with case-based learning theories (Bennett et al., 2002). The goal is to support authentic activities aligning the context in which knowledge is constructed and the real-life setting in which that knowledge will be called upon.

Learning activities & aids. According to the constructivist approach, learners undertake authentic problems to solve which are presented in the form of *projects*. ProSys provides learners with a *case library* of relevant situations and problems as a resource in order to support them deal with different perspectives of the project. The case library offers a means to contextualise learning in a way that connects content and action.

Moreover, as the biggest problem that learners face in project-based courses is what strategies to employ, how to start and proceed with their project, ProSys proposes learners to follow a particular *sequence of learning activities* in the form of a learning cycle with several stages - inspired by STAR LEGACY Cycle (Schwartz et al., 1999). The aim of these stages is to stimulate learners progressively deal with the different concepts and issues involved in the project as follows:

– At first, learners observe several clues that aim to help them develop a more concrete vision of the context and challenges that they will face through their project ("Introduction" stage). Then, learners answer to several questions and submit their ideas about the general context described. For example, learners observe five different images - the first one illustrates runners during a race, the second and third ones illustrate pills and medicine, and the last two are the main screens of two different search engines – and express their opinion about the connection among them, submit their opinion/ideas and then check what their peers have suggested and criticize them (provide one of the characterizations "Agree", "Disagree", "Indifferent"). Note that in this case, learners will undertake the project "the consequences insulting from doping on athletes" for the learning goal "How to search the Internet",
– Then learners read, hear, or watch, in an authentic context, data about the project, such as the context, the place, the necessary resources, and they answer specific questions about the context and content of the project ("Project Description" stage). For example, at this stage learners read or hear a story accompanied by a real dialogue that includes all the aforementioned information. Then, learners answer to several questions about the subject of the project, available means and constraints posed, and submit their ideas. Afterwards they are able to see and comment on their peers' opinions.
– At the next stage ("Generate Ideas"), learners argument on how they would face the problem posed. For example, learners propose alternative solutions and strategies for searching information on the Internet, comment on the advantages and disadvantages of each one, and submit their ideas. Afterwards they are able to see and comment on their peers' ideas.
– Next, learners explore and study multiple resources in order to deal with the different concepts involved in the project or overcome an impasse in achieving their goals ("Multiple Perspectives & Research" stage). The resources provided include several modules such as cases (in the form of examples or exercises), theory and exercises. Learners can also self-assess their knowledge by completing the exercise-cases (see below how the cases are constructed), self-evaluating their understanding on specific content modules, submitting automatically corrected exercises. The system supports learners in their study by providing individualised navigation advice based on their knowledge level and progress.
– At the final stage ("Solution and Evaluation"), learners reflect on their ideas proposed at the "Generate Ideas" stage and experiment in an authentic context in order to propose a solution to their project and provide appropriate arguments in support and against of their proposal.

The building element of the *content* provided at the "Multiple Perspectives & Research", is multiple *cases* that reflect different perspectives of the project. Cases are interpretations of experiences. Cases, as stories do, have several subcomponents (Kolodner and Guzdial, 2000): (a) the setting, the actors and their goals: the description of the problem that the case encounters, (b) the solution, (c) a sequence of events, i.e. the different steps that an expert followed to solve the problem, (d) explanations linking results to goals and the means of achieving them, (e) results of the proposed solution (see Figure 2). In ProSys, learners are provided with two types of cases: example-cases that include all the components described above, and exercise-cases that play the role of formative assessment tasks. In the latter, the part of the solution (subcomponent b) or the different steps followed (subcomponent c) is missing, and the learner is proposed to complete it.

Multiple *assessment* and *self-assessment opportunities* are provided. In particular, learners, through the activity of completing exercise-cases are stimulated to explain their ideas to others. Moreover, automatically-corrected assessment exercises and self-evaluation questions embedded in particular content modules are also provided. In the latter case, learners undertake the responsibility to self-evaluate their level of understanding of these modules and notify the system accordingly. In the constructivist approach, as *learning aids* are provided (see Table I):

– a specific *sequencing of learning activities* through the learning cycle is proposed, which advices the learners to progressively deal with the project and deepen their understanding. Moreover, *individualised navigation support* is provided through the content at the "Multiple Perspectives & Research" stage based on the learner's knowledge level and progress. The content modules appear in the Navigation Area, below the learning cycle (see Figure 2). The adaptive navigation support technology (Brusilovsky, 1996) is adopted to guide learners' study through the content. The different icons that accompany each module reflect its type, the cognitive function it supports (Mayer, 2002), and if it is proposed to the learner or not (the proposed modules are accompanied by colored icons and the rest ones by black & white). Moreover, a navigation history mechanism is adopted, according to which the modules that the learner has already mastered are marked with a checkmark. The navigation advice provided through the graphical annotation of the icons that accompany the content modules is based on a case-based algorithm that takes into account the priority and the difficulty level of each module.

– A *case library* is provided as a resource. The explanations (subcomponent d) that tie pieces of a case together, allow individuals to derive lessons that can be learned from a case. On recall of a case, the lessons an individual has derived from it are available for application to the new situation (Kolodner and Guzdial, 2000). Moreover, the exercise-cases offer learners opportunities to reflect on their experience and self-evaluate their knowledge.
– Several *learner control opportunities* are provided. Learners are allowed to follow the stages of the learning cycle in the sequence they prefer as well as to check and reflect on their learner model. Moreover, *supports for reflection* on the learning process are provided: (*i*) learners, at the different stages of the learning cycle, are stimulated to submit and argue about their actions/selections, explain the strategies they use, see and comment on their peers' opinions. Publishing their ideas makes them available to others to incorporate into their solutions. The need to clearly explain to others their proposal, requires reflecting on a situation, sorting out its complexities, making connections between its parts and organizing them into coherent chunks, offering opportunities to articulate knowledge and reflect on their experiences. Reading the ideas of others gives them ideas. Commenting on others' ideas requires consideration of how the ideas of others work. Comments from others encourage deeper thought about the implications of their own ideas, (*ii*) learners are able to see their learner model and reflect on their performance and contributions at the different stages of the cycle.

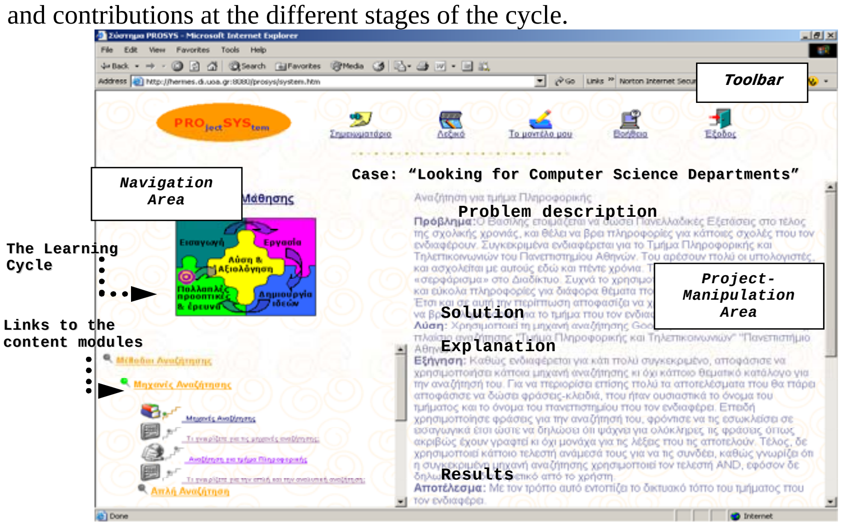


Figure 2. The main screen of ProSys (http://hermes.di.uoa.gr:8080/prosys) (at the "Multiple Perspectives & Research" stage) which consists of (a) Toolbar (b) Navigation area (c) Project Manipulation area that presents instructions, activities, content at each stage. At the Navigation Area appears the Learning Cycle in the form of a puzzle and links to the content modules, whilst at the Content Area the case-example "Looking for Computer Science Departments" appears.

2.3 Evaluation studies

Several empirical studies have been conducted to evaluate INSPIRE (Papanikolaou et al., 2002;2003) and learners' activity through the interaction with the system, which proved a variety of learning preferences and studying attitudes among the learners. Moreover, in a pilot study conducted in a classroom-based environment, we investigated how understandable and manageable the learning cycle adopted in ProSys is by students (Papanikolaou et al., 2005). We currently conduct an expert review of ProSys, in which expert-instructors who are familiar with the design of computer-based educational systems, evaluate the design approach of ProSys and determine conformance with a list of design principles for project-based curricula

(Barron et al., 1998). Experts' comments and suggestions will be incorporated in ProSys. Our near future plans include the empirical evaluation of ProSys with real users as well as the investigation of the usefulness of the alternative designs of INSPIRE and ProSys for different learners and contexts. This way we aim to compare and evaluate the two design approaches in order to result to design principles of learning activities & aids in adaptive learning environments for a variety of learners' profiles and contexts.

Table I. Comparing the Instructional design and Constructivist approach in terms of learning activities & aids

	Building elements	Instructional Design approach	Constructivist approach
Learning Activities & Aids	Learning goals	Learners select the learning goal they prefer or need to study.	
	Sequencing	Learners follow the conceptual structure of a learning goal. For each outcome concept of the goal, learners according to their knowledge level and progress, gradually achieve the Remember, Use and Find levels of performance through a variety of activities (solve exercises, study theory, etc.) performed in a sequence matching their learning style.	Learners undertake a project. Following the learning cycle, learners perform a sequence of learning activities in order to gradually deal with the issues and concepts involved. As part of their activity, learners explore and study the content provided, according to their knowledge level and progress.
	Assessment opportunities	Assessment opportunities through assessment tests aligned with the content and objectives posed (criterion-based assessment), solved exercises, experimentation activities.	Assessment opportunities through the completion of exercise-cases, self-evaluation questions, and automatically-corrected exercises.
	Type of content	Multiple types of content are provided, hierarchically organised: for each learning goal a *conceptual structure* is built with all the outcome concepts comprising the goal and their relations. For each concept multiple types of *educational material* are provided to support achievement of specific performance levels such as theory, exercises, examples.	For each learning goal a *project* and a *conceptual structure* surrounded by a case library, theory presentations and exercises, are provided. *Case library* as a resource: collection of cases that reflect different perspectives of the project. Two types of cases are provided: example-cases and exercise-cases.
	Learner control opportunities	Learning goal selection. Learners interact with the content which is provided in a hypermedia form enabling them to follow their own paths. Learner model open to learners in order to reflect and update its contents, including learner's: (a) knowledge level on the outcome concepts s/he has studied, (b) learning style. Learners may follow system's suggestions or not, intervene and guide the instructional process modifying their model (knowledge level and learning style), deactivate adaptation taking full control over the system.	Learning goal selection. Learners undertake an active role as the project drives learning, requiring learners to make judgments, to defend them, and criticize their peers' opinions. Learners are free to follow the learning cycle in any sequence. Content is provided in a hypermedia form. Self-evaluation opportunities. Learner model open to learners to reflect on: (a) their opinions and arguments, (b) their comments on their peers' opinions, (c) the educational material & the concepts they have already studied.

3. CONCLUSIONS AND FUTURE PLANS

In this paper we described learning activities and aids adopted in different pedagogical design approaches of AEHS. These approaches reflect different amounts of structure and support provided to learners in order to accomplish their goals. On the instructional design approach, learners are provided with: (i) hypermedia courseware structured according to prescriptions derived from theories of the instructional design and learning style area about selecting, sequencing, and synthesizing educational content, (ii) individualised support for learning aiming to assist learners in selecting, organizing, studying and integrating material based on their knowledge level, progress and learning style, and (iii) assessment opportunities aligned with the content. On the constructivist approach, learners are engaged in meaning making having as a focus a problem, a question, or a project, which is surrounded with various types of support such as a specific sequencing of learning activities, a case library, opportunities for reflection on the learning process.

In the future we plan to further investigate alternative approaches in designing learning activities and aids based on the constructivist approach. Moreover, taking into account the diversity of the audience in web-based education and the issue that a pedagogical approach that benefits one category of learners may create obstacles for other categories, an interesting future research goal would be the unification of a variety of pedagogical approaches under a common framework allowing reusability across different web-based learning environments and enabling tutors/learners to select the one that better matches their preferences and needs.

ACKNOWLEDGEMENT

Part of this work is co-funded by 75% from E.E. and 25% from the Greek Government under the framework of the Education and Initial Vocational Training Program – Archimedes.

REFERENCES

Barron, B. J. S., Schwartz, D.L., Vye, N.J., Moore, A., Petrosino, A., Zech, L., Bransford, J.D., 1998. Doing with Understanding: Lessons from Research on Problem and Project-Based Learning. *Journal of the Learning Sciences*, Vol. 7, No 3-4, pp. 271-311.

Bennett, S., Harper, B. and Hedberg, J., Designing real-life cases to support authentic design activities, *Australian Journal of Educational Technology*, Vol.18, No.1, 2002, pp.1-12.

Brusilovsky, P. and Peylo, C., 2003. Adaptive and intelligent Web-based educational systems. In P. Brusilovsky and C. Peylo (eds.), *International Journal of Artificial Intelligence in Education, Special Issue on Adaptive and Intelligent Web-based Educational Systems*, Vol. 13, No. 2-4, pp.159-172.

Brusilovsky, P., 1996. Methods and Techniques of Adaptive Hypermedia. *User Modeling and User-Adapted Interaction* Vol. 6, No. (2/3), pp. 87-129.

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

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

Honey, P. & Mumford, A., 1992. *The Manual of Learning Styles*, P. Honey, Maidenhead.

Jonassen, D., 1999. Designing Constructivist Environments, In: C.M. Reigeluth (ed.): *Instructional-Design Theories and Models: A New Paradigm of Instructional Theory*, Vol. II. Lawrence Erlbaum Associates, Mahwah, NJ, London.

Kolodner and Guzdial, M., 2000. *Theory and Practice of Case-Based Learning Aids*. In D.H. Jonassen and S.M. Land (Eds.): *Theoretical Foundations of Learning Environments*. Lawrence Erlbaum Associates, Mhwah, NJ, London.

Land, S.M. and Hannafin, M.J., 2000. Student-centered Learning Environments. In D.H. Jonassen and S.M. Land (Eds.): *Theoretical Foundations of Learning Environments*. Lawrence Erlbaum Associates, Mhwah, NJ, London.

Mayer, R.E., 2002. A taxonomy for computer-based assessment of problem solving, *Computers in Human Behavior*, Vol.18, pp. 623-632.

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

Papanikolaou K., Grigoriadou M., Kornilakis H. and Magoulas G.D., 2003. Personalising the Interaction in a Web-based Educational Hypermedia System: the case of INSPIRE, *User-Modeling and User-Adapted Interaction*, Vol. 13, No.3, pp. 213-267.

Papanikolaou K., Grigoriadou M., Magoulas G.D. and Kornilakis H., 2002. Towards New Forms of Knowledge Communication: the Adaptive Dimension of a Web-based Learning Environment, *Computers and Education*, Vol. 39 No. 4, pp. 333-360.

Papanikolaou, K., Grigoriadou, M., Alexi. A., Samarakou, M., 2005. Designing Project-based Adaptive Educational Systems. *2005 WSEAS International Conference on Engineering Education*, Athens, Greece, July 2005. Available at: http://hermes.di.uoa.gr/lab/CVs/Papanikolaou.html

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*, Vol. II. Lawrence Erlbaum Associates, Mahwah, NJ, London.

Schwartz, D.L., Lin, X., Brophy, S., Bransford, J.D., 1999. Toward the Development o Flexible Adaptive Instructional Designs, In: C.M. Reigeluth (ed.): *Instructional-Design Theories and Models: A New Paradigm of Instructional Theory*, Vol. II. Lawrence Erlbaum Associates, Mahwah, NJ, London.

Thomas, J.W., 2000. A review of research on project-based learning. Available at http://www.bobpearlman.org/BestPractices/PBL_Research.pdf