Designing Project-based Adaptive Educational Systems

K. A. PAPANIKOLAOU[1], M. GRIGORIADOU[1], A. ALEXI[1], M. SAMARAKOU[2]

[1]Department of Informatics and Telecommunications
University of Athens
Panepistimiopolis, GR-15784 Athens
GREECE
{spap, gregor, grad0432}di.uoa.gr

[2]Department of Energy Technology
Technological Educational Institution of Athens
Ag. Spyridonos, GR12210 Egaleo
GREECE
marsam@teiath.gr

Abstract: - In this paper we investigate the design of adaptive educational systems based on constructivist theories. Particularly we propose a design approach which combines the project-based and case-based learning theories. Based on this approach, learners are provided with a set of *learning goals* and a *project* to complete, 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 deal with the project and accomplish the goal they selected. The web-based adaptive educational system ProSys developed based on the above approach is also described.

Key-Words: - Adaptive Educational Systems, Project-based learning, Case-based learning, Adaptivity, Adaptation, Learning cycle, Constructivist learning environments

1 Introduction

Adaptive educational systems (AESs) [1] possess the ability to make intelligent decisions about the interactions that take place during learning, aiming to support learners without being directive. Typically, AESs reflect several learner characteristics to the 'learner model', and apply this model to adapt various visible aspects of the system to individual learners [2]. An important issue in designing AESs is the sharing of control between the system and the learner, as many researchers acknowledge that learners benefit from learner control opportunities [3] [4]. However, the development of web-based AES in which learners are individually supported in accomplishing their personal learning goals (adaptive dimension of an AES) and at the same time they are allowed to control when, what and how to learn (adaptable dimension of an AES), requires a deep understanding of the learning and instructional processes. To this end, it is important to consider adaptation within the framework of modern learning theories and models, and thoroughly enhance learner control opportunities over the instructional process [5].

Although several instructional approaches have been used in AESs that reflect specific learning/instructional theories, the use of constructivist theories as a base for the development of AESs is very limited [6]. Constructivist theories acknowledge the importance of learner control over the learning process and assume that knowledge is individually constructed and socially constructed by learners based on their interpretations of experiences of the world. Constructivist learning environments engage learners in meaning making (knowledge construction) having as a focus a problem, a question, or a project, and surround it with various types of support [7]. 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. Moreover, following Spiro and Jehng [8], the multiple representations, such as those offered by realistic cases in case-based instruction, best support learning in complex, ill-structured knowledge domains. A challenge research goal for the development of adaptive educational systems is the use of constructivist theories for the design of a flexible instructional approach that incorporates authentic activities and uses adaptation technologies to individually support learners to accomplish their learning goals in a realistic context.

In this paper we investigate the design of adaptive educational systems based on a combination of project-based and case-based learning theories. Particularly we propose a design approach where learners are provided with a set of *learning goals* and a *project* to complete, 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 deal with the project and accomplish the goal they selected. We also present how this approach may inform the development of a web-based AES.

2 Instructional approaches in AESs

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 the different modules of the particular systems, such as the learner model, the domain knowledge, the instructional model, the adaptive engine. In several cases, these approaches are based on teaching expertise or built on a theoretical background that reflects specific learning/instructional theories. In the Dynamic Course Generation (DCG) system [9] 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) [10], to suit better to learner's individual goals, progress and preferences. GTE provides an instructional model that reflects the instructional knowledge and expertise that underlies human teaching. In INSPIRE [11] the instructional approach adopted builds on a combination of instructional theories about planning the content and delivery of instruction, with the learning style theory, providing the basis for delivering individualized content. INSPIRE adopts a prescriptive instructional strategy, according to which learners are progressively provided with structured content in a sequence that matches learners' knowledge level, and individualised study guidelines based on learner's knowledge level and learning style. In KBS Hyperbook [6], 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. Thus, learner-system interaction is based on activities, which have been developed according to the project-based learning theory.

Building elements of the instructional approaches that the above systems adopt, are (a) the learning goals that learners select to accomplish, (b) the educational content provided to support the learner accomplish his/her goal, and (c) guidance provided through the structure and form of the content. Typically the educational content consists of multiple types of modules that present specific concepts of the domain, such as theoretical presentations, examples, exercises, assessment tests. However, as Jonassen [7] suggests a critical characteristic of meaningful learning is mindful activity and in such activities the lack of experience is especially critical. Thus, it is important when designing constructivist learning environments that engage learners in activities, to provide access to a set of related experiences that assist the learners in understanding the issues implicit in the problem/activity they undertake.

3 Design Rational

The educational approach we propose builds on and expands further the above-mentioned ideas by combining project-based learning [12] with case-based learning theories [13]. The goal is to design a learning environment 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. Project-based learning focuses on relatively long-term, integrated units of instruction where learners focus on complex projects consisting of multiple cases. Moreover, following Jonassen [7], the inclusion of realistic cases in a constructivist learning environment provides learners with access to experiences that they have not previously encountered. A case-based approach, which combines engagement with meaningful real-world tasks and expert coaching, can provide deeper insights into processes and practices [3].

Four discriminative characteristics of the proposed approach are (a) the use of *projects* as authentic activities that learners undertake: learners select a learning goal from a set of meaningful ones, and then they start working on a project to accomplish their goal, (b) the adoption of a specific *learning cycle* that proposes learners to follow a sequence of activities in order to deal with the project and progressively deepen their understanding, (c) the provision of educational content consisting of multiple *cases* that deal with different perspectives of the project and offer a means to contextualise learning in a way that connects content and action, and the provision of individualised navigation support through the content based on the learner's knowledge level and progress, (d) the externalization of the learner model that the system maintains during the interaction, and the opportunities offered to learners to articulate the reasons of their actions, explain the strategies they use, and comment on other learners' arguments and strategies, aiming to enhance reflection.

Since the key to meaningful learning is ownership of the learning goal, the different projects proposed to learners are interesting, relevant and engaging for the particular target group of learners. A useful prescription for designing projects is to examine the field of study for what practitioners do and use specific cases, situations or problems that they have solved [7]. Moreover the projects are ill defined or ill structured, so that some aspects of the problem are emergent and definable by the learners. This way learners are more motivated to solve or resolve the problem as such projects require learners to make judgments about the problem and to defend their judgments by expressing personal opinions or beliefs [14].

With the aim to propose a flexible educational design that provides guidance but at the same time allows learners to tailor instruction to their own strengths and preferences, we adopt the idea of suggesting learners to follow a particular learning cycle. This cycle proposes a sequence of activities with the aim to make learners progressively deal with the different concepts involved in the project. This learning cycle has been inspired by STAR LEGACY Cycle [15], and in our case includes the following stages:

1. At the "Introduction" stage we aim to help learners understand the learning context and goals. In our approach instead of posing a set of objectives, we provide several clues that aim to help learners develop a more concrete vision of the context and challenges that they will face through the cycle. Through several questions learners are stimulated to submit their ideas about the general context described. After learners have submitted their answers they are able to see the contributions of other learners and criticize them.
2. At the "Project description" stage we present learners with the project they will undertake, the context, the place, the necessary resources. Learners are stimulated to answer specific questions about the context and content of the project. After learners have submitted their answers they are able to see the contributions of other learners and criticize them.
3. At the "Generate Ideas" stage learners are stimulated to submit their ideas on how they plan to deal with the specific project (strategies and tools) by answering on specific questions. After learners have submitted their answers they are able to see the contributions of other learners and criticize them.
4. At the "Multiple Perspectives & Research", multiple educational resources are provided, which surround the main concepts of the subject matter. These resources include case studies (in the form of examples or exercises), theory presentations and exercises. Individualised navigation advice through the content is proposed based on learner's progress. The adaptive navigation support technology [16] is adopted to guide learners' study through the different resources. In particular, the different resources are graphically annotated to reflect the type of resources and the level of performance to which they correspond. Moreover, the appropriate resources that the learner is ready to study based on his/her knowledge level are also graphically annotated.
5. At the "Solution and Evaluation" stage, learners self-evaluate their knowledge. They are asked to select the solution that they consider as most appropriate for the particular project from a list of alternatives. Moreover each solution is accompanied by different arguments (marked as "in support of" and "against" the solution). Learners should also select the appropriate ones for the solution they propose. This way the system is able to evaluate their answers and provide appropriate guidance.

The building element of the content provided is multiple cases that reflect different perspectives of the project. Moreover, theory presentations and exercises for the main concepts of the subject matter, are also provided. In our approach each case constitutes of five parts [17]: (a) the description of the problem that the case encounters, (b) the solution that an expert proposed, (c) the different steps that an expert followed to solve the problem, (d) an explanation about the way the particular case unfolded as expected or not, (e) the results of the proposed solution. The educational content includes example-cases that include all the different parts and exercise-cases that play the role of formative assessment tasks. In particular, the part of the solution (part b) or the different steps followed (part c) is missing from the exercise-cases, and the learner is proposed to complete them.

The educational content is characterized by different attributes, such as type of content (example-cases, exercise-cases, theory presentations, exercises), the concept of the subject matter on which the particular content focuses, priority (based on "prerequisite" relations of the underlying concepts), level of difficulty, cognitive functions that the content supports (*Remember*, *Understand*, *Apply, Analyze* [18]). These attributes are used by the system to select the appropriate content for learners with different profiles.

Moreover, the proposed design enhances reflection on the learning process through two different options: (a) learners are stimulated to argument on their selections, see and comment on other learners' opinions, (b) learners are able to see their learner model and reflect on their contribution at the different stages of the cycle.

4 The ProSys learning environment

Based on the above design we developed a web-based learning environment named ProSys (http://hermes.di.uoa.gr:8080/prosys). Projects are used as a building element in organizing learners' study: learners select a learning goal and then the system proposes them to start working on a project in order to master the main concepts of this goal. Learners are proposed to follow the different stages of the learning cycle, which is represented as a puzzle in the Navigation area (see fig.1). In fig. 1 the learner chose the learning goal "How to search the Internet" and the system proposes him/her to start working with a project about "the

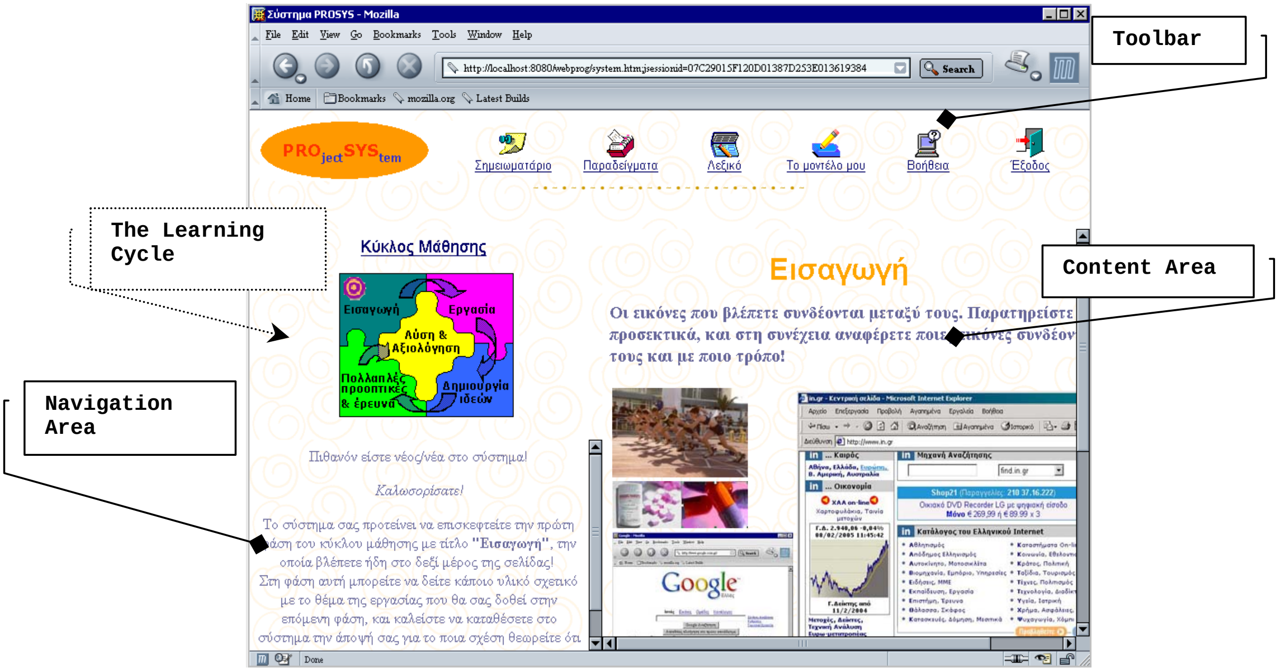

Fig. 1: The main screen of ProSys consists of (a) Toolbar (b) Navigation area on the left including the Learning Cycle (c) Content area on the right that presents instructions, activities, content at each stage

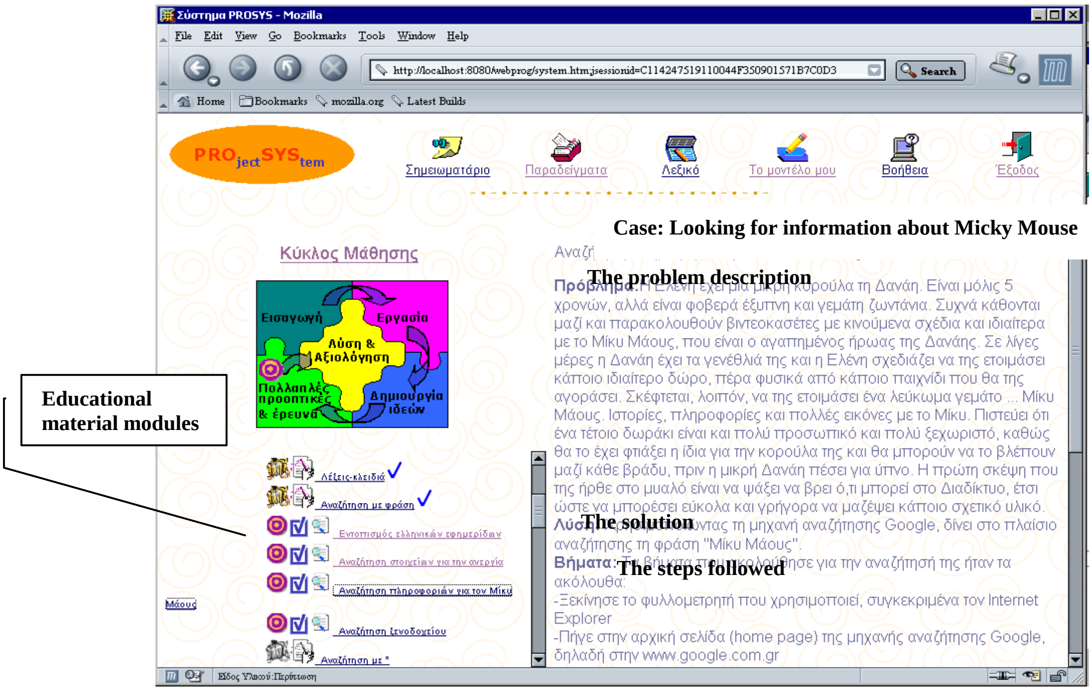

Fig. 2: The main screen of ProSys at the "Multiple Perspectives & Research" stage. At the Content Area appears the case-example "Looking for information about Micky Mouse" including the "Problem", "Solution", "Steps" parts

consequences insulting from doping on athletes" in order to accomplish the goal and become able to search the Internet. Then the system proposes him/her to go on to the "Introduction". Note that the proposed stage is marked with a bullet, although learners are free to select any of the stages of the learning cycle through the puzzle that appears in the navigation area. In the "Introduction" five different images appear (see fig.1), 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. The learner is proposed to observe the different images and express his/her opinion, about the connection among the different images. S/he has the option to submit his/her opinion/ideas and then check what other learners have suggested and criticize them (provide one of the characterizations "Agree", "Disagree", "Indifferent").

Then the learner is proposed to pass to the next stage, "Project description stage". At this stage the project is presented to the learner as a narrative accompanied by a real dialogue between two brothers: one of them has to submit an essay about "the consequences insulting from doping on athletes" and he asks his brother, who has a computer and an Internet connection, to help him searching the Internet about relevant information. The learner reads or hears the whole story and then s/he is asked to answer several questions about the subject of the project, the means that the two brothers would use to search for information, etc. Again, the learner has the option to submit his/her opinion and then check what other learners have also suggested.

At the "Generate Ideas" stage, the learner is asked to think how s/he would face the problem, propose alternative solutions (places and tools for searching information) and comment on the advantages and disadvantages of each one.

At the "Multiple Perspectives & Research" stage the system provides educational material (example-cases, exercise-cases, theory presentations, exercises) relative to the project and proposes an individualized navigation route based on the knowledge level and progress of the learner. The educational material modules appear in the Navigation Area, below the learning cycle (see fig.2). The different icons that accompany each module of the educational material reflect its type, the cognitive function it supports (Remember, Understand, Apply, Analyze), and if it is proposed to the learner or not (the proposed ones are accompanied by a bullet). 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 that the system provides through the graphical annotation of the icons that accompany the educational material modules is based on a case-based algorithm [17] that takes into account the priority and the difficulty level of each module and compares it with the knowledge level of the learner.

During the learners' interaction with the system a

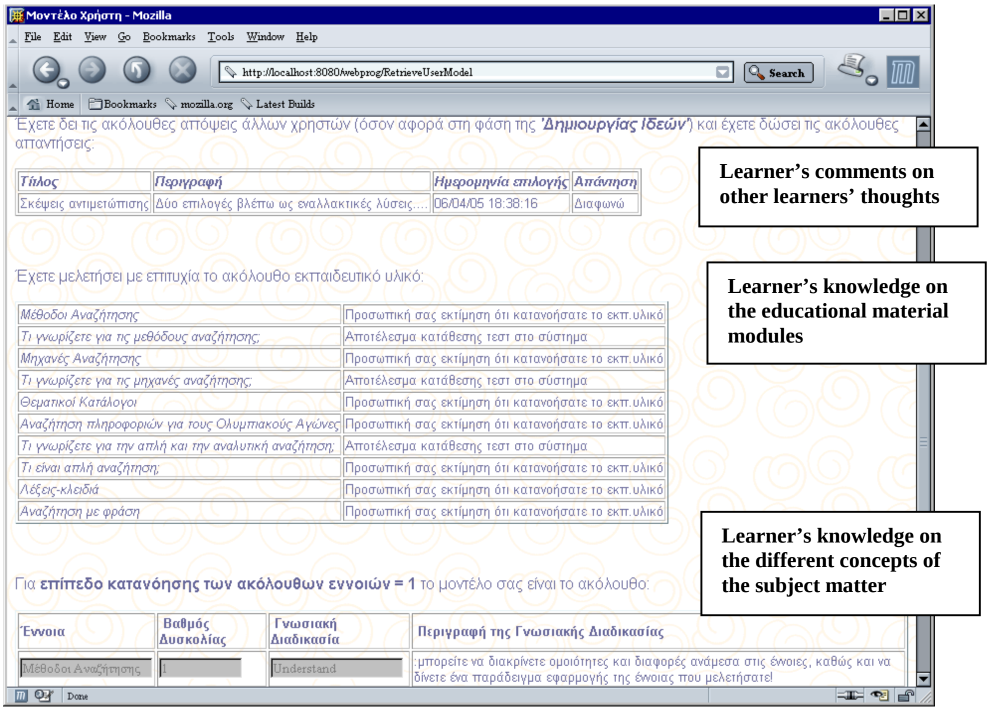

Fig. 3: Externalisation of the learner model

learner model is constructed for each particular learner which is continuously updated. The adaptive navigation support that ProSys offers is mainly guided by the learners' knowledge level and progress on the different educational material modules. In particular, learners' knowledge level is estimated by automatically corrected assessment exercises as well as from self-assessment exercises. In the latter case, the learner undertakes the responsibility to self-evaluate his/her level of understanding on particular modules and notify the system if s/he understood the content of the module or not. This approach has also been adopted in KBS-Hyperbook [6], which uses four different levels of understanding. This info is maintained in the learner model, which also reflects other characteristics of the learner. In more detail, the learner model maintains the following info (see fig. 3): (a) the learner's opinions and arguments as they were submitted at the first three stages of the learning cycle – history of the learner's "ideas", (b) the learner's comments on the opinions of other learners as these comments were submitted at the first three stages of the learning cycle – history of the learner's "comments", (c) the educational material that the learner successfully or unsuccessfully studied and info about the way this was estimated, i.e. through automatically corrected assessment exercises or learner's notification, (d) the concepts of the subject matter that the learner has successfully studied and the difficulty level, the cognitive function, priority of the corresponding educational material that s/he has already studied. The learner model is open to learners (see fig. 1: through the icon "My model" on the Toolbar) in order to stimulate them reflect upon its contents and enhance system's adaptable behavior. This externalization of the learner model provides a means of communication between the system and the learner [19] and aims to stimulate learners reflect on their learning process. Therefore, it is important that the learner model is maintained in a manner that allows it to be understandable, transferable and usable [19].

5 Experimental Study

The design rational proposed was experimentally studied under real conditions in a classroom-based environment. Our aims were (a) to collect realistic cases and enrich the case library of the system, and (b) to evaluate the material and the project descriptions (images, dialogue) provided, the different questions posed by the system, and to check how understandable and manageable the whole procedure was by young people. That's why this experimental study included the first three stages of the learning cycle – there was no sense to provide content in printed form as the adaptive dimension of the support provided at the "Multiple Perspectives & Research" stage could not be offered and evaluated. The whole cycle as well as the adaptive dimension of the approach will be evaluated in the experimental study of ProSys with university students.

In particular, the experiment was conducted in the 5th Lyceum of Byrona, Athens, Greece, during the 2004-2005 year. The test users were 7 high school students (at the third class of Lyceum). They were asked to complete a questionnaire which was divided in two sections: (a) at the first section they were asked to describe real experiences of searching the Internet, in the form of realistic cases: what they were looking for and which tools they used, (b) at the second section they were asked to follow the first three different stages of the learning cycle and answer the questions posed at each stage. Through their comments and answers we refined the questions posed by the system at the end of the three first stages in order to be more understandable. This final form was incorporated in ProSys. Moreover, we gathered the students' experiences and used them to develop authentic cases that interest young people.

6 Conclusions

The design of AES that allow learners to take varying levels of initiative is a challenging research goal. Research in this direction has a lot to benefit from the constructivist approaches to learning.

The educational approach described in this paper combines the project-based and case-based learning theories in order to build an authentic learning context in which learners undertake specific projects and the system supports them to deal with the different issues of their projects through a specific learning cycle providing supportive realistic cases and individualised navigation advices. The proposed approach guided the development of ProSys, a web-based adaptive educational system. Intended users of ProSys are University learners to whom access to an educational web-based system is provided as a supplementary resource. This design approach will further inform the design of INSPIRE with the aim to extend its educational approach to include multiple instructional strategies.

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