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Combining Adaptive Hypermedia with Project and Case-Based Learning

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In this article we investigate the design of educational hypermedia based on constructivist learning theories. According to the principles of project and case-based learning we present the design rational of an Adaptive Educational Hypermedia system prototype named MyProject; learners working with MyProject undertake a project and the system offers a variety of learning aids to support them accomplish the project. MyProject proposes learners a set of learning activities (at different stages of a learning cycle) that contribute to the overall understanding of the problems posed or their ability to complete the project, and stimulate learners to reflect on and monitor their own learning. Moreover, MyProject allows the learners to undertake varying levels of initiative and control, offers hypermedia content in the form of realistic cases and adaptive navigation advice through the content. An expert review has been performed to evaluate the design rational, determine conformance with a list of design principles for project-based curricula, and provide appropriate feedback for further improvement. The way this review was organized as well as the report of this study including positive aspects of the design, and recommendations for possible modifications

or extensions, are presented. Finally, a pilot study that aimed at investigating how understandable and manageable the learning cycle is by students, is also described. Preliminary results provide encouraging indications about the potential of the proposed approach in enhancing learner control, and promoting active and reflective learning.

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). 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 stimulating web-based learning environments. Towards this direction there has been current research into the areas of network learning/instruction (Bank, Goodyear, Hodgson, & McConnell, 2003; Federico, 2000; Chan, Hue, Chou, & Tzeng, 2001; Goodyear, 2005), multimedia learning (Mayer, 2003; Reimann, 2003), computer supported collaborative learning (Jermann, Soller, & Muehlenbrock, 2001; Dimitracopoulou & Petrou, 2003; Avouris, Dimitracopoulou, & Komis, 2003) and adaptive instruction/learning. Especially, in the area of adaptive instruction (Federico, 1999; Brusilovsky, 1996; Magoulas, Papanikolaou, & Grigoriadou, 2003), the design of Adaptive Educational Hypermedia Systems (AEHSs) (Brusilovsky & Peylo, 2003) is based on the primary principle that learners will be able to achieve their learning goals more efficiently, when pedagogical procedures accommodate their individual differences. AEHSs typically model learner characteristics in a learner model which is used in conjunction with a model of the target domain to enable the system to adapt the interaction to the learning needs of the individual student. Such adaptation usually involves individualization of navigation recommendations, content presentation, content sequencing, and feedback given. Although several pedagogical approaches have been used as the theoretical basis for the design of AEHSs, there are limited examples of AEHSs which are based on constructivist theories (Henze, Naceur, Nejdl, & Wolpers, 1999).

Constructivist theories acknowledge the importance of learner control over the learning process and assume that knowledge is individually constructed and socially co-constructed by learners based on their interpretations of experiences of the world (Jonassen, 1999). The main characteristic of *constructivist learning environments* is that a specific problem drives

learning, rather than acting as an example of the concepts of the subject matter. Jonassen (1997) argues that ill-structured, real world problems must become the basis for improving learning, and that effective pedagogy should include the provision of appropriate support. Especially in complex and ill-structured knowledge domains, the multiple representations, such as those offered by realistic cases in *case-based instruction*, are considered a valuable support for learners (Spiro & Jehng, 1990). A challenging research goal for the area of AEHSs is the use of constructivist theories for the design of a flexible learning environment that incorporates authentic activities and uses adaptation technologies to individually support learners in accomplishing their learning goals in a realistic context.

In this article we investigate the design of AEHSs based on contemporary theories and in particular a combination of project-based and case-based learning. The aim is to create a constructivist learning environment in which students are encouraged to undertake control over their learning and supported to construct their own knowledge and interact with peers through the accomplishment of a project. Particularly we present an AEHS prototype named MyProject. MyProject supports learners in accomplishing *projects* aiming to help them progressively understand the implicit issues of the project and organize their work. To this end, MyProject proposes learners a set of appropriate learning activities (at different stages of a learning cycle), and assists them in following their own path through the cycle providing adaptive guidance. Moreover, the system supports learners in studying the hypermedia educational content (mainly composed of real cases) through adaptive navigation support, whilst opening the learner model to learners aims to enhance reflection on the learning process. Social interaction is promoted allowing learners to share ideas and proposals when working with activities or studying the content. The article is organized as follows. A review of pedagogical approaches used in the design of AEHSs is presented. An overview of MyProject from the user perspective is provided. We describe the design rational of MyProject and its distinct characteristics such as the learning cycle, the content (projects, cases), the adaptive behavior, and the open learner model, as well as the learner control and social interaction opportunities offered. We report the results of an expert review performed to evaluate the design rational of MyProject, including positive aspects of the design, and recommendations for possible modifications or extensions, as well as the preliminary results of a pilot study with students. The article ends with concluding remarks and future plans.

DESIGN APPROACHES IN ADAPTIVE EDUCATIONAL HYPERMEDIA

A variety of design approaches have been used in AEHSs, inspired by different instructional design or learning theories that provide the theoretical background for the design of the modules of the particular systems, such as the learner model, the domain knowledge, the adaptive engine, but also of the interactions that may take place between the learner and the system (Papanikolaou & Grigoriadou, 2005). The design approach adopted by the main stream of AEHSs (DCG, ELMART, AST, KnowledgeSea, INSPIRE) focuses on the definition of specific outcome objectives, design of materials and procedures that are targeted on these objectives, and assessment procedures that determine if learners have attained the desired objectives, whilst the constructivist approach focuses on in-context learning organized around authentic tasks (KBS Hyperbook).

Most of the AEHSs provide learners with structured content consisting of theoretical presentations, practice-oriented exercises, examples, activities, assessment questions. Guidance provided is in the form of advice on the selection and/or sequencing and/or presentation of educational content using specific adaptation technologies (Brusilovsky, 1996). In the Dynamic Course Generation (DCG) system (Vassileva, 1997), courses are generated dynamically depending on the learning goal that learners select. These courses can be dynamically changed, following specified teaching rules and strategies of the Generic Task Model (GTE) (Van Marcke, 1998), to suit better to learners' individual goals, progress and preferences. GTE provides an instructional model that reflects the instructional knowledge and expertise that underlies human teaching. In INSPIRE (Papanikolaou, Grigoriadou, Kornilakis, & Magoulas, 2003), the notion of *learning goals* that learners select to attain is used in order to build a hypermedia structure that provides an overview of how the relevant content fits together. Individualised navigation advice is provided to learners by annotating the content (use of visual cues) according to their competence, whilst the sequencing of learning activities proposed is adapted to their learning style. In particular, learners are invited to interact with the educational content provided for a goal in order to gradually (a) speculate on newly introduced ideas by answering to introductory or self-assessment questions, following instances of the underlying concepts and real-life analogies, studying the theory, (b) become able to apply the underlying concept to specific case(s) by undertaking experimentation activities, working with computer simulations or microworlds, studying hints on the theory that concentrate on specific outcomes, solving small problems, (c) find a new generality, principle, procedure by accomplishing

specific tasks in the form of small projects. Moreover, in KBS Hyperbook (Henze at al., 1999), learners work with projects and the system provides individualized 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 some concepts, information pages on the WWW, e.g. Sun Java tutorial), former student projects (examples of projects performed by students of past courses), glossary, etc.

The AEHSs of both categories share specific features such as (a) the modularity of the educational content; multiple types of material are provided for the domain concepts such as theoretical presentations, examples, exercises, assessment tests, projects, (b) individualized support usually guiding learners in studying the content, (c) varying levels of learner control. Designing adaptation around learners' activities and experiences is a quite new and challenging target for AEHSs promoting learner involvement and reflection on the learning process, social interaction, as well as the development of metacognitive skills.

MYPROJECT: AN OVERVIEW

MyProject (http://hermes.di.uoa.gr:8080/prosys) is a web-based adaptive educational hypermedia system designed to support traditional classroom-based teaching as a supplementary resource. Projects are used as a building element in organizing learners' study; learners select a topic and then the system proposes them to start working on a project in order to achieve a set of learning goals.

In Figure 1, the main screen of MyProject is shown. It is divided into three different areas to better support system functionality: (a) the *Navigation area,* which presents the Learning Cycle as a puzzle (each of the pieces is a link to a stage of the cycle: Introduction, Project Description, Generate Ideas, Multiple Perspectives & Research, Solution and Evaluation), (b) the *Project Manipulation Area,* where the learning activities, educational content, and appropriate instructions appear for each stage and (c) the *Toolbar* containing several tools/icons (Notes: link to this page notepad, Glossary: link to a glossary of terms, Learner Model: link to a page where the learner can inspect his/her model, Help: information on system functionality) that provide direct access to several facilities.

Figure 1. The Introduction stage of the learning cycle for the project, "The consequences resulting from doping on athletes" for the topic, "Using search engines for searching information on the Internet."

Through the interaction with MyProject, learners are proposed to follow the different stages of the Learning Cycle in order to accomplish their project. Learners have access to all the stages of the learning cycle, which is visually represented as a puzzle in the Navigation area (see Figure 1 – Learning Cycle). They may run the different stages in the proposed order, from left to right, i.e. starting from the Introduction stage (see Figure 1 – Project Manipulation Area), or work with the one they prefer or need to. When the learner visits a stage by clicking on the corresponding piece of the puzzle, then appropriate information about the scope of the particular stage appears under the puzzle in the Navigation Area. Accordingly, when the learner clicks on a particular stage, appropriate instructions and specific activities are proposed in the Project Manipulation Area. Especially at the Multiple Perspectives and Research stage, the hypermedia structure of the content appears under the puzzle in the Navigation Area and when the learner clicks on a content link, the corresponding educational material page is presented in the Project Manipulation Area.

DESIGN RATIONAL OF MYPROJECT

Constructivist learning environments engage learners in meaning-making (knowledge construction) through focusing on a problem, a question, or a project, and surrounding it with various types of support (Jonassen, 1999). The design rational of MyProject is based on constructivist theories combining project-based (Thomas, 2000) with case-based learning (Bennett, Harper & Hedberg, 2002) in order to support learners work independently on a project and construct their own knowledge, enhance social interaction, and promote active and reflective learning. To this end, adaptation technologies are also exploited. The core idea is to support learners in accomplishing authentic projects aligning the context in which knowledge is constructed and the real-life setting in which that knowledge will be called upon. As learners usually feel lost in a project-based context, MyProject supports learners in facing the challenges posed, by organizing specific activities in a learning cycle and providing adaptive guidance based on their interaction behavior in order to assist them in moving through the cycle. The particular learning cycle consists of several stages that aim to help students progressively understand the implicit issues of the project, and become able to complete the project, reflect on and monitor their learning. Through the different stages of the cycle, multiple opportunities are offered to learners to make hypotheses, study and search for appropriate resources, evaluate and reflect on their ideas in an authentic context, articulate the reasons for their actions, explain the strategies they use, see and comment on their peers' ideas, arguments and strategies, aiming at promoting participation.

Project-based learning focuses on relatively long-term, integrated units of instruction where learners work on complex projects consisting of multiple cases. In this context, the lack of learners' experience is especially critical, usually impeding mindful activity able to lead to meaningful learning (Jonassen, 1999). To overcome this issue, MyProject provides educational content that mainly consists of realistic cases aiming to provide learners with access to experiences that they have not previously encountered and connect content with action. According to Kolodner and Guzdial (2000), on recall of a case, the lessons an individual has derived from it are available for application to the new situation. The cases included in MyProject consist of several subcomponents such as the problem that the case encounters, the solution given step by step, explanations, result, combining engagement with meaningful real-world tasks and expert coaching, aiming to provide deeper insights into processes and practices (Jonassen, Mayes, & McAleese, 1993). Moreover, the educational content provided is organized in a hypermedia

structure around the main concepts that learners need to know in order to deal with different perspectives of the project. MyProject supports learners in working individually with the content by advising them on appropriate resources according to their knowledge. To this end, adaptation technologies are used to graphically annotate the hypermedia structure accordingly.

Moreover, MyProject enhances reflection to the learning process by opening the learner model to learners to inform them about their interaction behavior, submissions, performance, and allowing learners to share ideas and proposals. In particular, the four principles proposed by Barron, Schwartz, Vye, Moore, Petrosino, Zech and Bransford, (1998) for designing, implementing and evaluating *project-based* curricula, guided the design and evaluation of the proposed design rational (see also Section FORMATIVE EVALUATION): (a) defining learning-appropriate goals; (b) providing scaffolds that support learning; (c) ensuring frequent opportunities for formative self-assessment and revision; (d) developing social organizations that promote participation and result in a sense of agency.

The Learning Cycle: *Organizing Learners' Activities*

One of the biggest problems that learners face in project-based courses is what strategies to employ, how to start and proceed with their project. MyProject, in order to deal with this issue, proposes learners to follow a learning cycle which is inspired by STAR LEGACY Cycle (Schwartz, Lin, Brophy, & Bransford, 1999). Below, we use a real paradigm through the presentation of the cycle, to better illustrate the different stages and the activities involved at each stage. In this paradigm the project deals with 'doping on athletes' and corresponds to the 'Search engines on the Internet' topic. The core idea of this project designed for high school students, is that students search the Internet in order to collect information, images, and communicate with experts, in order to submit an essay about the consequences of doping on athletes. The different stages of the learning cycle and sample activities proposed at each stage for the particular project are presented below.

In the first stage (Introduction stage), several clues are provided that aim to help learners develop a more concrete vision of the context and challenges that they will face through the project. Through several questions learners are stimulated to submit their ideas about the general context of the project. 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 (see Figure 1 at the Project Manipulation Area) – and *submit* their opinions about the way these are related, and then they are allowed to *check* what their peers have suggested and *comment* on them (provide one of the characterizations Agree, Disagree, or Indifferent for each submission).

In the second stage (Project Description stage), information about the project such as time restrictions, the place, the necessary resources, is provided in an innovative way. At this stage an ill-structured project is proposed, whilst learners are stimulated to answer specific questions in order to clarify several issues and make their own proposal about the project they prefer to undertake. 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 story, available means and constraints posed, and *propose* an analogous project that they would prefer to work on. Afterwards, they are able to *see* and *comment* on their peers' proposals.

In the next stage (Generate Ideas stage) learners are stimulated through appropriate *driving questions*, to *think* how they would face different issues of the project which reflect the main learning goals posed, *make hypothesis* and submit their ideas. The role of the driving questions is critical in informing learners about the learning goals of this project (Barron et al., 1998). Moreover, learners are encouraged to assess what they already know and what aspects they need to learn more about. For example, for the goal "how to define appropriate keywords for efficient search on the Internet," the driving question could be, "Which keywords are more appropriate for searching information about your project? What makes a search on the Internet efficient?" After submitting their answers, learners are able to *see* and *comment* on their peers' proposals.

Next at the Multiple Perspectives & Research stage, learners are provided with hypermedia educational content, organized around the main domain concepts and composed by multiple educational modules such as cases (in the form of examples or exercises), theory presentations, and exercises (see in Figure 2: the hypermedia content structure). The hypermedia content structure is graphically annotated to reflect individualized navigation advice based on the student's knowledge level and progress through the interaction. At this stage learners are expected to *explore and study the content* provided in order to deal with the different concepts involved in the project or overcome an impasse in answering the driving questions. Learners are encouraged to self-assess their knowledge by completing the exercise-cases, such as providing the solution or the step solution part of the case that is missing,

submitting automatically corrected exercises, and self-evaluating their understanding on specific content modules.

During the final stage (Solution and Evaluation), learners are invited to reflect on their ideas proposed at the Generate Ideas stage. They *evaluate* their initial hypothesis in an authentic environment, they *use specific criteria* for judging their own products, *reflect on* their initial ideas and *argument on* their final proposals. For example, learners are asked to propose four new keywords about their project, use them to search the Internet and evaluate the results based on the total number of sites retrieved and the appropriateness of the first three sites. Then, learners evaluate their initial proposals submitted at the Generate Ideas stage, which they may change or retain, and justify their final proposals.

Designing Projects and Developing the Content: *Providing Appropriate Resources*

In MyProject, learners initially select a *topic* and then they start working on a *project*, which involves solving several authentic intermediate problems, in order to accomplish specific *learning goals*. Projects are designed for particular groups of learners, based on age, interests, background, since the key to meaningful learning is ownership of the learning goal. Moreover the projects are open-ended and ill defined, so that some aspects of the project are manageable and definable by the learners through the first two stages of the learning cycle (Introduction and Project Description). Learners are motivated to solve or resolve the problems posed as such projects require learners to make judgments and to defend their judgments by expressing personal opinions or beliefs (Jonassen, 1997).

For each project appropriate hypermedia educational content is provided at the Multiple Perspectives & Research of the learning cycle. The content is organized around the main concepts of the domain. For each concept, multiple types of modules such as example-cases, exercise-cases, theory presentations, exercises, are provided. These educational modules are characterized by several attributes, such as type (example-cases, exercise-cases, theory presentations, exercises), the domain concept(s) on which the module focuses, priority (based on prerequisite relations of the underlying concepts), level of difficulty, cognitive function supported (Remember, Understand, Apply, Analyze (Mayer, 2002)). MyProject uses these attributes for providing adaptive navigation support through the content to learners with different profiles.

The building element of the *content*, is multiple *cases* that reflect different perspectives of the project. Cases are interpretations of experiences. Cases, like stories, have several subcomponents (Kolodner & Guzdial, 2000): (a) the setting, the actors and their goals, that is, 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 has followed to solve the problem, (d) explanations linking results to goals and the means of achieving them aiming to tie pieces of a case together and allow individuals to derive lessons that can be learned from a case, and (e) results of the proposed solution (see the structure of a case in Figure 2, at the Project Manipulation Area). In MyProject two types of cases are used: *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 expected to complete it. In particular, learners in the process of completing exercise-cases are stimulated to explain to others, in a way that is comprehensible to them, the solution they propose or the different steps that lead to that solution. Moreover, the exercise-cases provide learners with opportunities to reflect on their experience and self-evaluate their knowledge.

More assessment opportunities are provided through automatically corrected assessment exercises as well as self-assessment exercises. In the latter case, the learner undertakes the responsibility to self-evaluate his/her level of understanding on particular modules and accordingly notify the system. This approach has also been adopted in KBS-Hyperbook, which uses four different levels of understanding.

Adaptation: *Providing Individualized Support*

MyProject individually supports learners' orientation and navigation through the learning cycle and the content, rather than provide direct guidance. The adaptive navigation support is implemented through the adaptive annotation technique (Brusilovsky, 1996) to graphically annotate the learning cycle and the hypermedia structure of the content provided at the Multiple Perspectives & Research stage based on the learner profile.

We aim at helping learners develop a map of their learning, understand where they stand on the cycle and decide where to go next, by augmenting the graphical representation of the learning cycle with the learner's current activity and a navigation advice. In particular, *adaptation* affects *the graphical representation of the learning cycle* by annotating the stage proposed to

the learner based on his/her interaction behavior such as their submissions to the previous stages (see Figure 1 – a mark appears on the first piece of the puzzle which represents the Introduction stage), as well as their current position on the cycle.

Moreover, adaptation affects *the hypermedia representation of the content in the Navigation Area*, at the Multiple Perspectives & Research stage. At this stage, MyProject provides hypermedia educational content (example-cases, exercise-cases, theory presentations, and exercises) structured around the main domain concepts. The adaptive annotation technique is used to propose to each learner an individualized navigation route through the hypermedia content structure (see Figure 2 – Hypermedia Content Structure) based on his/her knowledge level and progress. In particular, learners are informed about: (a) the type and cognitive function that each module supports through the two icons that accompany each content module (see Figure 2 – the first icon on the left of each module reflects its type whilst the second icon, i.e. a ladder with a bullet on specific steps, reflects the cognitive function); (b) their location in the domain (the active link is in bold); (c) the modules they have already mastered (marked with a checkmark); (d) the concepts/modules that they are able to study based on their knowledge level by graphically annotating the icons of the concepts/modules (two state icons are associated with the concepts/modules: colored icons denote that a concept/module is recommended for study, while black and white icons appear next to the rest of the concepts/modules).

The navigation advice that MyProject provides takes into account the concept priority, the difficulty level and the cognitive function of the modules as well as the learner's progress. MyProject allows learners to decide, on the basis of the information provided, what content may be best to proceed with.

In Figure 2, the case-example 'Looking for information about the C-Real music group' appears in the Project Manipulation Area. It consists of the Problem, Solution, Steps, Explanation, and Result components. In the Navigation Area of Figure 2, the hypermedia content structure appears: the concept 'Advanced Search' has been expanded (only one concept can be expanded in the Navigation Area each time) followed by a theory presentation (corresponding to the cognitive function - c.f. Remember) and two case-examples (corresponding to the c.f. Understand) (colored icons of concepts and content modules are marked with a bullet for clarity).

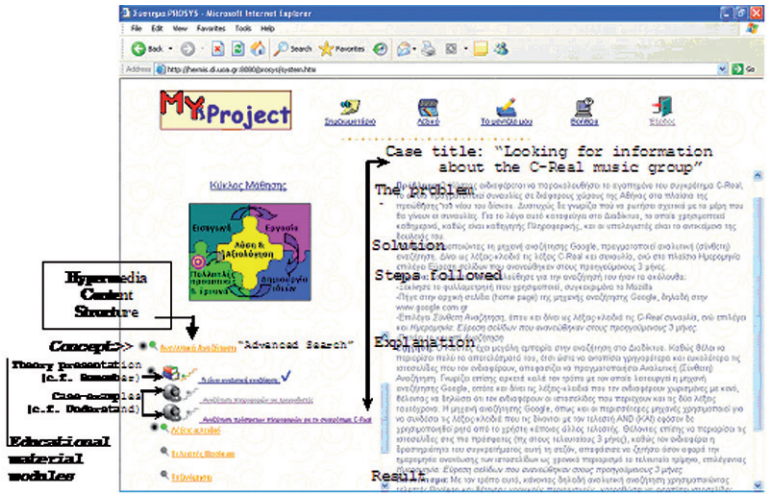


Figure 2. A screenshot of MyProject at the Multiple Perspectives & Research stage.

Learner model: *Promoting Reflective Learning*

During the learners' interaction with MyProject, a *learner model* is maintained for each particular learner which is continuously updated. The learner model is *open* to learners (through the '*My model*' tool of the toolbar) in order to stimulate them to reflect upon its contents. The externalization of the learner model provides a means of communication between the system and the learner and aims to promote reflection in learners about their knowledge and learning (Bull & Kay, 2005; Hartley, Paiva, & Self, 1995). In particular, the learner model maintains the following information (see in Figure 3 the Open Learner Model):

(a) the learner's opinions and arguments as they were submitted during 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 content modules that the learner mastered and information about the way this was estimated, for example, through automatically corrected assessment exercises or learner's notification,

(d) information about learner's knowledge on the concepts and content modules s/he has studied such as the difficulty level, the cognitive function, priority of the corresponding concepts/ modules.

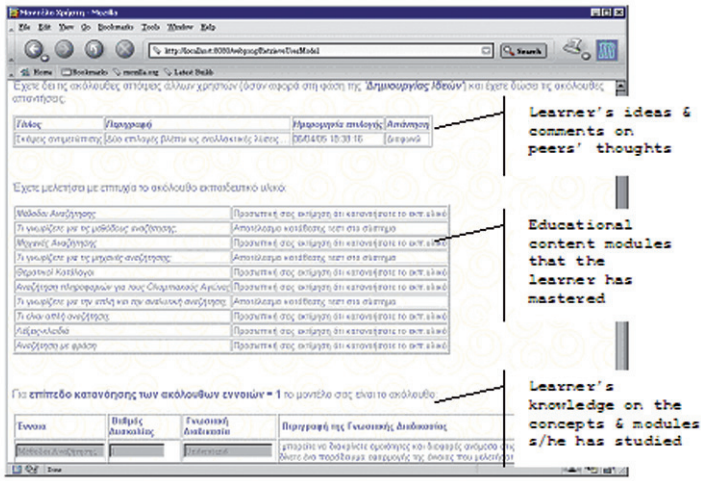


Figure 3. Open Learner Model: Externalization of the learner model.

Learner Control & Social Interaction: *Promoting Active Learning*

MyProject offers multiple *learner control opportunities*. Learners are allowed to follow the stages of the learning cycle in the sequence they prefer. Especially, *supports for reflection* on the learning process are provided through the externalization of the learner model to learners, as well as through the opportunity of sharing their ideas at the first stages of the learning cycle. In particular, MyProject allows learners to have access on their learner model and reflect on their performance and contributions at the different stages of the cycle. Moreover, learners are stimulated to submit and argue about their actions/selections, explain the strategies they use, see and comment on their peers' opinions. The need to clearly explain their proposal to others 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 fresh ideas. Commenting on their peers' ideas requires consideration of how the ideas of others work, whilst

receiving comments from peers encourage deeper thought about the implications of their own ideas.

FORMATIVE EVALUATION

Formative evaluation helps to improve several aspects of a system as part of an iterative process. This section describes an expert review and a pilot study with learners conducted as the first part of the formative evaluation of the MyProject prototype.

Expert Review

The expert review presented in this section has been designed to evaluate and improve of the design rational and the way this is reflected in MyProject.

Expert reviews can occur early or late in the design phase, when the design team is ready for feedback, resulting in a formal report of problems identified/recommendations for changes or in a discussion with designers (Shneiderman & Plaisant, 2005). They usually take from half a day to one week, although a training time may be required. An expert review report should be comprehensive rather than presenting a random collection of suggested improvements. To this end, a guideline document is usually helpful in structuring the final report. In such studies, reviewers are preferably knowledgeable experts who are familiar with the project and who have a long term relationship with the organization. Shneiderman and Plaisant (2005) argue that, "expert reviewers should be sensitive to the design team's ego involvement and professional skill, so suggestions should be made cautiously: it is difficult for someone just freshly inspecting an interface to understand fully the design rationale and development history" (p. 141).

METHOD

In this *expert review*, the design rational of MyProject was evaluated based on a list of design principles for project-based curricula. It involved a group of ten expert-instructors who acted as evaluators for the MyProject prototype. All the *experts* were both teachers at the secondary education and researchers working on the design of innovative computer-based learning

environments and tools supporting dialogue-based interaction, collaboration, concept mapping, game playing. Moreover, the experts and the designers of MyProject are also members of the Educational and Language Technology group of the Department of Informatics and Telecommunications, University of Athens, Greece, and are all familiar with the research works of the group in progress. The *goals* of this study were (a) to investigate whether the design of the MyProject prototype conforms with the main design principles for project-based curricula as these have been proposed by Barron et al. (1998) and (b) to provide appropriate feedback for further improvement. The *data analysis* was based on questionnaires and interviews. The *outcome* of this study was a report with positive aspects of the design, problems identified, and recommendations for possible modifications or extensions.

The expert-review *method* adopted is a heuristic evaluation in which reviewers need to determine conformance with a list of design heuristics (Shneiderman & Plaisant, 2005). In this method, it is quite important for the experts to be familiar with the design principles they should evaluate and able to interpret and apply them. To this end, a preparation phase, in the form of a meeting that lasted 4 hours, was organized. During the meeting, one of the system designers made a presentation of MyProject describing the system functionality and the design principles on which it is based. Afterwards, the designer and the experts discussed on the main design principles for project-based curricula and how these were followed in the design of MyProject. Then, a questionnaire that evaluates how the design principles reflect on MyProject, was administered. This questionnaire was developed by the system designers to guide reviewers in compiling a comprehensive report about the main features of MyProject. The reviewers had one week to work with MyProject in the time and place of their choice in order to master the design principles, review the system and answer the questionnaire. At the last phase of the expert review, the system designer interviewed the experts (most of them in groups of two) in order to pursue specific issues of concern and ascertain the universality of comments occasionally appearing in the questionnaires.

Measurement Development

A questionnaire was designed to investigate experts' opinions about how MyProject conforms or could be modified/extended to conform to the four design principles for project-based curricula proposed by Barron et al. (1998). The questionnaire was structured in four sections, each one corresponding to one of the four design principles. Each section includes a brief

presentation of the corresponding design principle and closed items evaluating how consistent are specific aspects of the system with this principle. Most of the items are followed by open-ended questions asking the experts to give reasons for their selections and propose possible extensions/modifications. Below, we describe the four different sections of the questionnaire and the evaluation goals of each one. In particular, for each section we present at first the corresponding design principle, and then the evaluation goals with reference to the items of the particular section as these appear on Table 1.

The first Section focuses on the first principle "*defining learning-appropriate goals that lead to deep understanding*: project-based learning experiences are frequently organized around a driving question (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991) which should be crafted to make connections between activities and the underlying conceptual knowledge that one might hope to foster, aiming at deepening the students' understanding. Providing learning-appropriate goals, helps create a need for students to understand the how and why of a project."

In particular, the items of Section A measured (see Table 1 – Section A) the effectiveness of the driving questions included in several stages of the learning cycle in presenting the learning goals of the project (Section A, Question 1) and linking learners' activities with the underlying conceptual knowledge of the domain (Section A, Question 2).

Table 1

A Sample of Representative Questions Posed to Experts

Section A: Defining learning-appropriate goals that lead to deep understanding
1. Do the driving questions included in the "Generate Ideas" and "Solution & Evaluation" stage support learners in understanding the learning goals of the project? 2. Do the driving questions included in the "Generate Ideas" and "Solution & Evaluation" stage support learners in making connections between their activities through the cycle and the underlying conceptual knowledge?
Section B: Providing Scaffolds
1. Does the learning cycle supports learners in defining and organising the appropriate activities that lead to the accomplishment of a project? 2. Do the first two stages succeed in supporting learners define the project? 3. Does the case library provided at the Multiple Perspectives & Research stage, is sufficient to support learners in accomplishing their project ?

Table 1 Continued

4. On recall of a case-example, are the lessons an individual has derived from it, available for application to a new context? 5. The hypermedia structure of the content presented at the Multiple Perspectives & Research stage includes the outcome concepts of the domain, each one followed by multiple types of educational content. This structure visualises the hierarchical structure of the concepts based on their priorities ('prerequisite' relation). Does this representation supports learners in understanding the underlying conceptual knowledge of the domain and make connections between their activities through the cycle and this knowledge? 6. Does the hypermedia representation of the content structure (appropriate icons represent the type of the content modules and the cognitive process to which they correspond), supports learners in selecting the appropriate material for study? 7. Does the graphical annotation of the material based on the priority of the corresponding concepts and learners' knowledge (a) supports them in dealing with problems arising through the accomplishment of the project (b) supports them in studying the appropriate domain concepts (c) is indifferent (d) other …… 8. The learning cycle is graphically annotated to present the current position (stage) of the learner. Is this information useful to the learners? 9. Does the system succeed in cultivating learners' inquiry skills and how? 10. Does opening the learner model to the learner enhance reflection?
Section C: Ensuring Multiple Opportunities for Formative Self-Assessment and Revision
1. Does the process of completing a case-exercise stimulate learners to search for resources in order to deepen their understanding? 2. Does self assessment and revision are cultivated through the accomplishment of the project?
Section D: Developing Social Structures that Promote Participation and a Sense of Agency
1. Does active and reflective learning is supported by allowing learners (a) to submit their ideas in a database which is accessible by their peers; (b) to read and evaluate their peers' ideas; (c) to reconsider their ideas through the interaction. 2. Asking learners to submit their ideas in a database which is accessible by their peers stimulates them to clearly explain their proposal and better communicate their ideas? 3. Allowing learners to read and evaluate their peers' ideas (a) cultivates inquiry skills towards alternative solutions/proposals (b) stimulates learners to organize small groups (c) stimulates reflection on their own ideas (d) is indifferent (e) other……

The second Section focuses on the principle "*providing scaffolds* that help a novice to solve a problem, carry out a task, or achieve a goal which would be beyond his unassisted efforts, such as (a) those that function to communicate process, (b) those that provide coaching, and (c) those that elicit articulation. Scaffolds are designed to help students understand the relevance of particular concepts to activities in the world and to support inquiry skills (i.e., the abilities of students to research topics to advance their understanding and to collaborate and communicate with others in the furtherance of this goal), deep understanding (the ability to explain phenomena, rather than simply describe various procedural activities that are part of one's project), and the reflection on one's idea in relation to others' ideas."

In particular, the experts were asked to evaluate the role of (see Table 1 – Section B) (a) the *learning cycle* and the different stages, in communicating the process of dealing with a project (Section B, Questions 1,2), (b) the *content* (Section B, Questions 3,4,5) and the *adaptive navigation support* (Section B, Questions 6,7,8) offered in coaching learners through their study and eliciting articulation, (c) a variety of functions in cultivating *inquiry skills* (Section B, Question 9) (d) the *Open Learner Modeling* approach adopted in enhancing *reflection* on the learning process (Section B, Question 10).

The third Section focuses on the principle "*ensuring multiple opportunities for formative self-assessment and revision*: systematic attempts to bring students in on the process with an emphasis on self-assessment that helps students develop the ability to monitor their own understanding and to find resources to deepen it when necessary (Brown, Bransford, Ferrara, & Campione, 1983; Stiggins, 1995). Learners get opportunities to test their mettle, to see how they are doing and to revise their learning processes as necessary."

In particular, the experts were asked to evaluate the effectiveness of the assessment opportunities offered (see Table 1 – Section C) (a) to stimulate learners to search for resources in order to deepen their understanding (Section C, Question 1), (b) to support learners in monitoring their own learning (Section C, Question 2).

The last Section focuses on the forth principle "*developing social structures that promote participation and a sense of agency*: breaking down the isolation of the classroom can be a powerful way to support learning through social mechanisms as not only do we learn from the varieties of feedback given, but we also learn about more effective ways to communicate our ideas. Different ways to support active, reflective learning are small group interactions, opportunities to contribute, peer review, and having access to data about how others have thought about the same problem."

In particular, the experts were asked to evaluate if particular interactions (see Table 1 – Section D, Questions 1, 2, 3): (a) support active and reflective learning and (b) promote participation.

RESULTS

The expert reviewers identified positive aspects and possible problems, and made recommendations for improving/extending specific aspects of the design. This data was gathered through the questionnaires and discussed during the interviews. Actually, direct contact with experts led to specific, constructive suggestions, although solutions were left for the designers to produce. Below, for each of the design principles, we present, at first the positive aspects of MyProject that reviewers outlined, then the problems identified, and final the reviewers' proposals for alleviating those problems or improving/extending specific aspects of the design.

Experts' comments/recommendations aligned with the first design principle (Defining learning-appropriate goals that lead to deep understanding) based on Section A of the questionnaire.

All the experts agree that the "Generate Ideas" and "Solution and Evaluation" stages include specific *driving questions* that reflect the learning goals of the project. They note that this is very important as learners at both stages, through the specific questions, are stimulated to concentrate on critical aspects of their project which constitute the main learning goals. Especially, experts' comments on the usefulness of the driving questions of MyProject, suggest that they stimulate learners to reflect on their experience/prior knowledge and generate ideas, make assumptions, test their ideas and experiment on real conditions using the domain concepts. Moreover, all the experts agree that the driving questions of MyProject look appropriate for stimulating learners make connections between their activities and the domain concepts. Lastly, three of the experts suggested linking these questions with the content and/or additional resources in order to support learners (especially novices) produce alternative solutions.

Experts' comments/recommendations aligned with the second design principle (Providing Scaffolds) based on Section B of the questionnaire.

Learning cycle. All the experts agree that the different stages of the *learning cycle* of MyProject seem appropriate for supporting learners to deal with the project, as each stage concentrates on a specific task which is part of the solution. Two of the experts found the titles of the stages inappropriate and they proposed changing the stage titles into questions reflecting the

role of the stage in the process and/or the task learners should undertake through the stage. Moreover, another expert remarked that the dependencies among the different stages are not apparent to learners, for example, idea generation on the problems posed by the project (3rd stage) should better follow project definition (2nd stage), and he proposed to offer learners such information suggesting alternative paths through the cycle and informing them about the different options. He noted that this way, the navigation support functionality may be extended to provide advice to learners with varying levels of expertise or knowledge, about alternative routes through the cycle.

Eight of the experts found that the way the first two stages of the cycle (after which learners are expected to have defined the project) are organized is innovative allowing learners to contribute to the project definition, change or adapt it to their individual interests and needs. Two of the experts proposed to enrich the project definition with the roles that learners have to undertake and the deliverables they have to submit. Another interesting proposal came from one of the experts who suggested the investigation of the way the project definition at the first two stages of the cycle could be organized as a collaborative task among a group of learners.

Content. All the experts agree that the *case library* is an innovative feature of the design. Eight of them commented that a well structured case library such as the one offered by MyProject, is enough to support learners in dealing with a project. The other two experts suggested that multiple types of content could better support a variety of learners with different preferences and styles. All the experts agree that linking real cases directly with the concepts of the domain as in the hypermedia structure of the content in MyProject, supports learners in understanding the relevance of particular concepts to activities in the world. Alternative structures were also proposed by three experts such as structuring the cases based on (i) the main aspects of the project and the problems that learners have to deal with, or (ii) different contexts, such as a quick review of the domain. Other interesting ideas coming from two of these experts were to allow learners (i) contribute in structuring the case library aiming to stimulate them deepen their understanding by connecting domain concepts with real world problems, for example, they could suggest alternative linking structures between concepts and cases, or among the cases, and (ii) individually or collaboratively design case-examples or complete case-exercises. Furthermore, two of the experts suggested that appropriate activities need to augment each case-example in MyProject in order to increase interactivity and involve students in the process of dealing with the different aspects of the project. Lastly, one of the

experts proposed to further investigate the impact of studying cases in the context of web-based learning.

All the experts agree that the current *hypermedia structure of the content* offered by MyProject reflects the underlying conceptual knowledge of the domain (although this is the experts' representation) motivating learners to control their access to information and explore alternative navigational paths through the content. Most of the experts (8 out of 10) also agree that the link between learners' activities through the cycle and the content offered at the Multiple Perspectives & Research stage of MyProject could be enhanced by pairing learners' activities at the different stages of the cycle with the appropriate content.

In addition, all the experts suggest that MyProject, by graphically annotating the content based on the concepts' priority and learners' knowledge (ad*aptive navigation support),* may increase learners' awareness of their knowledge and further support learners' navigation and orientation through the content. Moreover, the graphical annotation of the learners' position on the learning cycle, provides a useful indication about their progress in accomplishing the project that might keep them in the process. One of the experts proposed an alternative approach in implementing the adaptive navigation support through the content: annotating the content based on learners' needs in dealing with different issues of the project.

Inquiry skills. The experts agree that MyProject cultivates learners' inquiry skills by encouraging them to experiment in an authentic environment, investigate resources, complete case-exercises, share their ideas/proposals. In this context, three of the experts propose that appropriate feedback should better augment case-exercises as well as the activities proposed to learners at different stages of the learning cycle, stimulating learners to visit specific resources on the Internet, or search for additional information through the content or external resources.

Open Learner Modeling. All the experts agree that opening the learner model to learners, informing learners about their knowledge state, progress, and submissions, is a powerful feature of MyProject enhancing learners' awareness of their knowledge and reflection on their learning. Two of the experts suggested replacing or augmenting the characterizations of the cognitive functions that the learners have already mastered, with their interpretations and additional comments reflecting learners' performance and progress. Moreover, one of the experts proposed to extend the learner model with more data about learners' interaction behavior and submissions, as such information could also support reflection on the learning process. Another interesting suggestion was to further investigate the visualization of the data maintained by the learner model.

Experts' comments/recommendations aligned with the third design principle (Ensuring Multiple Opportunities for Formative Self-Assessment and Revision) based on Section C of the questionnaire

All the experts found that the assessment activities offered by MyProject such as the completion of case-exercises, should motivate learners to search for appropriate information in the available content or investigate alternative resources cultivating inquiry skills. Furthermore, three of them suggested that appropriate feedback should augment each case guiding learners to use specific qualitative external resources, such as resources located on the Web.

It was a common belief among all the experts that the combination of opportunities offered by MyProject for self-assessment and reflection on peers' opinions/ideas covers the learning goals of the project, and looks appropriate for stimulating learners to reflect on and monitor their own learning. Three of the experts proposed that in cases where learners self-evaluate their understanding, the system should better provide appropriate study guidelines or additional resources. Following experts' comments, appropriate feedback could further support self-assessment. An interesting idea to this direction coming from one of the experts was to incorporate peer review activities in the content such as the review of the exercise-cases or the final solution proposed at the Solution and Evaluation stage by peers.

Moreover, the experts agree that the Solution and Evaluation stage of MyProject provides learners an opportunity to assess the goals of the project and their progress as they are stimulated to reconsider their initial proposals submitted at the Generation Ideas stage. Moreover, one of them suggested that at this stage the learners should be invited to submit their final proposal and allowed to read and comment on their peers' contributions in order to reflect on and self-evaluate their ideas.

Experts' comments/recommendations aligned with the fourth design principle (Developing Social Structures that Promote Participation and a Sense of Agency) based on Section D of the questionnaire

All the experts agree that submitting ideas on a shared database as in MyProject, reading and commenting on peers' ideas are useful activities towards the development of social structures as this way learners are stimulated to reflect on (a) the particular situation exploiting their own experiences and knowledge and clearly explain their proposal, b) their own ideas and/or further consider alternative solutions proposed by peers.

Most of the experts (8 out of 10) agree that learners should be free to see their peers' ideas whenever they wish to, i.e. not only after submitting their own ideas, even though they may be influenced by others in this way.

The other two experts suggested that learners should first submit their ideas and then be allowed to see their peers' ideas, as this way they will better concentrate on the problem they have to face. Finally, all the experts agree that learners should be allowed to change their submissions whenever they wish to, but the system should keep track of learners' actions/submissions through the interaction, in order to maintain a view of learners' cognitive activity as it unfolds.

Pilot Study

A pilot study was performed with students in order to experimentally study how understandable and manageable the learning cycle is by students. The test users were 19 students in the second class of a Greek high school, naive in searching the Internet. The experiment organized by one of the researchers/designers of MyProject, and performed in collaboration with the teacher of the particular class. Students initially completed a pretest on search engines on the Internet and then attended a brief lecture about search engines. Then they worked with MyProject following the stages of the learning cycle and studying cases about the definition of appropriate keywords, the use of phrases and Boolean operators in search engines. Based mainly on students answers as these were submitted in MyProject:

- at the Introduction stage, 45% of the students managed to acknowledge *doping on athletes* as the main subject of the project, whilst the rest proposed *athletics*, *Internet*, and *health issues*. Then at the Project Description stage, all the students managed to define a project either proposing a subject quite close to *doping on athletes* or a new subject related to sports.

- at the Generate Ideas stage all the students answered the driving question posed and worked on defining keywords for their project (which, later on, they would use in a search engine for searching the Internet). Actually 50% of the students selected general keywords related to the subject of their project, for example, student X who suggested a project on *Olympic games in ancient times* selected as keywords: *sports*, *ancient sports*, *win*, and *chaplets*.

- at the Mupltiple Perspectives & Research stage and after studying particular cases, 84% of the students answered correctly questions on the use of phrases and the boolean operator AND in search engines.

- at the Solution and Evaluation stage, 89% of the students improved the keywords proposed at the Generate Ideas stage replacing them with more accurate ones, using phrases and the boolean operator AND, for example, the student X replaced the keywords: *sport, ancient sports, win, chaplets* with the following ones: *ancient Olympic games, sports in ancient times, win* AND *awards* AND *ancient Olympic games.*

Students were actively involved in all stages of the cycle, answering to driving questions and proposing ideas at the Generate Ideas stage, studying cases and resolving relevant problems at the Multiple Perspectives & Research stage, making hypothesis at the Generate Ideas stage and experimenting in real conditions at the Solution and Evaluation stage, reflecting on their ideas and proposals. Students positively corresponded to several opportunities stimulating them to reflect on and reconsider their ideas through the interaction. Learners at the Solution and Evaluation stage evaluate and reconsider their initial ideas submitted at the Generate Ideas stage and most of them improve the keywords, proposing more accurate and focused ones. As far as the students' behavior is concerned, they were all actively involved during the lesson and they were keen on working with the computer, searching the Internet, and experimenting with the searching conditions trying to improve the quality and limit the quantity of results retrieved by the search engine. Thus, initial indications about the effectiveness of specific stages of the learning cycle in promoting active and reflective learning, are positive.

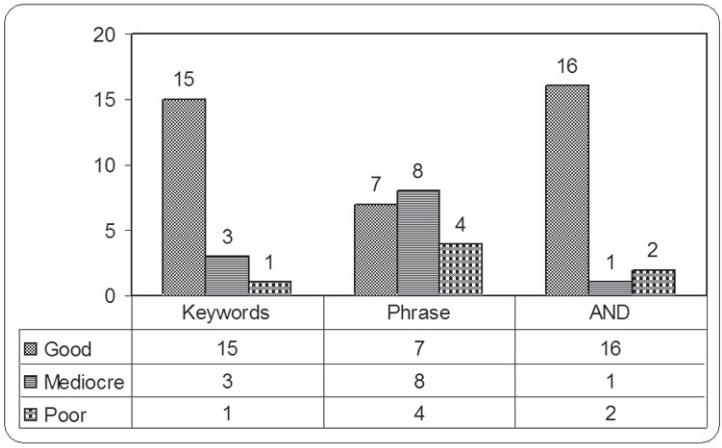
At the Solution and Evaluation stage, the 17 of the 19 students managed to successfully accomplish their project following all the stages of the learning cycle, while the remaining 2 students although they managed to complete the proposed activities, they failed in submitting a comprehensive solution at the Solution and Evaluation stage. Moreover, based on students' answers to the post test, as these appear in Table 2 (where Keywords: definition of appropriate keywords, Phrase: appropriate use of phrases, AND: appropriate use of "AND" boolean operator), students are able to define appropriate keywords according to the search topic as 15 of the 19 students (74%) – had a good performance, and 3 of the 19 students (21%), had a medium one. Also, 16 of the 19 students (84%) had good performance in using appropriately the Boolean operator "AND". However, students' performance in using phrases was not so good since 7 of the 19 students (37%) performed well and 8 of them (42%) performed mediocre. Analyzing their answers, we observed that students' errors were due to misunderstandings, for example the misuse of phrases and Boolean operators as in the case "artist name AND songs" where the operator is included in the phrase. A possible reason

for these errors might be the type of the cases that students studied which were uniquely instances of appropriate use of the underlying concepts, i.e. phrases and Boolean operators. Based on these results, it is worthwhile further investigating the synthesis and hypermedia structure of the case library.

Students' success at the Multiple Perspectives & Research and Solution and Evaluation stages, is a valuable indication of the potential of cases and the particular learning cycle in promoting learning.

Table 2

Students' Performance at the Post Test evaluating the Initial Learning Goals



	Keywords	Phrase	AND
Good	15	7	16
Mediocre	3	8	1
Poor	1	4	2

CONCLUSIONS AND FUTURE PLANS

The design of AEHS that allows 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 design approach incorporated in MyProject combines the project-based and case-based learning theories in order to build an authentic learning environment in which learners undertake a project and the system supports them in dealing with the different aspects of their project through a specific learning cycle providing content in the form of realistic cases and adaptive navigation advice. According to this constructivist approach, learners are engaged in meaning making (knowledge construction) having as their focus a project, which is accompanied by various types of support such as a specific sequencing of

learning activities to undertake, a case library, and opportunities for reflection on the learning process.

Elaborating on the experts' recommendations and learners' behavior through the interaction with MyProject at the initial stage of the formative evaluation, we intend to extend/improve specific aspects of the prototype. Especially, the design team ranked experts' recommendations in order of importance, interest to the team, and expected effort level and decided:

- to elaborate on the development and use of a case library as the main resource for learners and design specific learning activities related to the case library,
- enhance learners' interaction and collaboration through the different stages of the cycle
- provide additional scaffolds enhancing the adaptive behavior of the system
- extend the learner model with more data about learners' interaction behavior, and investigate the visualization of the data maintained by the learner model.

Finally, we intend to actively involve students in improving specific aspects of the system and thoroughly investigate students' interaction behavior and opinions on the issues arising.

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