9. A Didactics Aware Approach to Knowledge Transfer in Web-based Education

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In this chapter we argue that the current Web-based educational systems, as well as the recent standardization efforts in this field are strongly technology-centric. Because of this, such endeavors usually neglect the didactic component of Web-based education thus becoming completely didactic-neutral.

However, recent research in the field shows that in order to achieve improvements in efficient knowledge transfer, learning outcome, or users' satisfaction didactics plays a crucial role. For example, such promising didactic approaches as collaboration, project-oriented learning, or experiential-learning need to be addressed by Web-based education systems and standards.

In this chapter we present an innovative system called WBT-Master that was built by our institute at Graz University of Technology. In WBT-Master technology is applied only as a vehicle that supports didactic aspects of Web-based education.

The main idea of WBT-Master is in the use of both conventional and innovative tools compatible with the current Web and Web-based educational standards to support didactics in a Web-based environment and in that way facilitate, more efficiently, transfer of knowledge from people who posses that knowledge to people who need to acquire it.

9.1 Introduction

It is our experience that most of the system development and standardization efforts in Web-based Education (WBE) field concentrate on the technological aspects of the field. Usually, these efforts neglect to a great extent the didactic side of WBE.

For example, the major commercial WBE systems, such as WebCT [30] or Blackboard [4] are mainly concerned with providing the tools to enable easy development, access, and work with Web-based educational material. From the didactic point of view such systems are based on learners taking a part in what can be simply called Web-based reading of educational material.

Similarly, the standardization efforts such as Sharable Content Object Reference Model (SCORM) [2] developed by the international standardization bodies deal mainly with interoperability issues in WBE at the content level. Thus, such standards focus on creation, distribution, exchange and reuse of educational material in different WBE systems. However, SCORM compliant educational material usually does not carry any additional didactic-related information. Rather it only defines a simple navigational structure which prescribes how to navigate through the content. Such a navigational structure supports yet again only the most simple Web-based consumption of the educational content - Web-based reading.

However, we believe that WBE should support a wide range of different didactic approaches to enable efficient knowledge transfer in a Web-based environment. Here Web-based reading might be seen as just one (and for that matter the simplest one) of such didactic approaches. In such an approach to WBE the Web-based technology is applied only as a vehicle that supports didactic aspects of WBE, and ceases being the central part of it. Thus, the key here is in the use of both conventional and innovative tools compatible with the current Web and WBE standards to incorporate didactics into WBE and in that way facilitate, more efficiently, transfer of knowledge from people who posses that knowledge to people who need to acquire it.

We believe that the simplest way of introducing didactic aspects to WBE is by implementing tool support for a number of teaching and learning scenarios into WBE systems. For example, such typical scenarios as project-based learning, goal-oriented learning, or experiential-learning should be supported by tools and systems to cover a wide range of day-to-day training situations in both academic and corporate environment.

This chapter describes our efforts to implement this support into the WBT-Master, an innovative WBE system that was developed at our institute. The system supports a number of typical, as well as innovative teaching and learning scenarios applicable in WBE.

The remainder of this chapter is organized as follows. The next section describes in more details the current trends in WBE system development, research, and standards clearly identifying the above mentioned technology-centric problem of WBE. The third section provides an introduction to WBT-Master and lists teaching and learning scenarios supported by the system. The consequent sections describe in more details the listed scenarios at both levels - the didactic and the technological level. Finally, we present the results of an evaluation of the WBT-Master system and its concepts. The evaluation was conducted with hundreds of users in both academic and corporate environment and concentrated on estimating the improvements in learning outcome by using the traditional classroom approaches, the current WBE approaches, and the innovative approaches presented in the chapter. Moreover, issues such as learning experience, user satisfaction, usability, and others were addressed by the evaluation.

9.2 Current Trends in WBE

Recent surveys on the number of installations and distribution of WBE systems at universities in Europe [23], Australia [5] and the USA [6] show that the two most popular and used systems are WebCT and Blackboard. Approximately, the installations of these two systems constitute more than 60% of all WBE system installations.

Both of these systems can be categorized as so-called course management systems, i.e., they utilize the well-known "online course model". Usually, all the tools in such systems are optimized to support easy creation, publishing, update, and access to Web-based courses. Such Web-based courses are composed of a number of Web pages interrelated by means of computer-navigable links. Thus, the authoring tools allow authors to upload Web pages created on their local sites, or to create new Web pages directly with the system via integrated Web page editors. At the next step, the pages are related to each other and the publishing procedure makes the finished course accessible for learners. Additionally, the published courses are associated with a discussion forum which provides the communicational context for the learning sessions [21].

From the didactic point of view the facilities offered by these systems leave much to be desired. Usually, these systems support only traditional forms of teaching (e.g., a teacher prepares educational material that learners need to read) and encourage poor instructional design models. Consequently, the learning outcome and the users' satisfaction (of both teachers and learners) is quite low [20]. For example, a study conducted at the College of Nursing, University of Oklahoma, compared the learning outcome in a traditional vs. Web-based baccalaureate nursing research course. The study showed the following disappointing results. Overall, there was no significant difference in examination scores between the two groups as far as the three multiple-choice examinations and the course grades are concerned. Students who reported that they were self-directed and had the ability to maintain their own pace and avoid procrastination were most suited to Web-based courses [16]. Clearly, these results need to be improved tremendously.

The main reason for this situation lies in the fact that such systems are strongly technology-centric. Basically, the current WBE systems try to solve technology-based problems of WBE, such as authoring of educational material, reuse of Web-based courses, user management, efficient learners' progress tracking, and so on. Thus, the role of didactics is strongly neglected in such systems. For example, Mioduser refers to this situation as "one step ahead for the technology, two steps back for the pedagogy". However, the key must be in research and development of novel Web-based educational models and in the support of the current pedagogical approaches (e.g., use of inquiry-based activities, application of constructivist learning principles, and use of alternative evaluation methods) [19].

Similarly, other research work suggests development of pedagogy-aware Web-courses emphasizing that the strategies that enhance learning in the traditional classroom should be replicated in Web-based learning sessions. For example, these strategies include but are not limited to accommodating diverse learning styles, incorporating a good study guide with a content section, providing a communicative network and establishing a review process [10]. Clearly, the current WBE systems are far away from supporting such methodologies.

On the other hand, organizations such as IEEE Learning Technology Standards Committee, IMS Global Learning Consortium, and Advanced Distributed Learning Initiative (ADL) are working on standardization efforts in WBE. These efforts include the following standards:

- Learning Object Metadata (LOM) standard [15] for describing educational material with standardized metadata. This metadata should support learners and teachers in retrieving relevant educational material in an easy and efficient way. Further, it should provide the technical background for interoperability of educational material from different WBE systems. Thus, reuse and exchange of educational material between two different WBE systems is encouraged by this standard.
- SCORM suite of standards, such as SCORM packaging or SCORM Simple Sequencing [1]. These standards address issues of packaging Web-courses so that interoperability, reuse, and exchange of Web-based courses between different WBE systems is guaranteed. For example, SCORM packaging provides a standardized way of organizing the educational content into items, small packages, or even complex structures, and prescribes how such content can be navigated. SCORM Simple Sequencing goes one step further by specifying so-called learning paths, which can branch according to the current learning situation.
- IMS standards [11], such as IMS Metadata, IMS Content Packaging or IMS Simple Sequencing, which address similar issues as LOM or SCORM standards. Actually, many of the IMS standards, such as IMS Simple Sequencing are included in other standards such as SCORM Simple Sequencing.

Although such standardization efforts have many advantages, such as sharing and reuse of educational material, standardized way of packaging of educational material, flexibility in content presentation, interoperability across systems, they also have some disadvantages. The basic disadvantage is the total lack of addressing didactics and pedagogy in WBE. For example, SCORM claims to be "pedagogically neutral", which means that it is impossible to create SCORM packages that relate to some didactic approach, say project-oriented, or problem-solving learning approach [12]. In other words SCORM packages can not capture didactic relations between their components.

However, as recent research studies show incorporating didactics into WBE leads usually to far better results in learning outcome, learners' and teachers' satisfaction, learners' community building, and so on. For example, Hirumi shows in his study [9] that careful planning and design of interactions in WBE, where learners are supervised by means of immediate feedback, discussions and clear didactic and learning goals leads to improvement in learning outcome. Similarly, the study with deployment of project-oriented collaborative didactic approach conducted by King [14] shows tremendous improvements in building a community of learners, which helped to solve problems related to the project at hand. In the future, one of the keys to the learning process in WBE will be communication between learners themselves, learners and teachers, and the formation of learning communities held together by a common learning goal, which is modeled by a sound didactic approach.

9.3 WBT-Master: A Didactics Aware Approach to WBE

In WBT-Master didactic approaches are referred to as teaching or learning scenarios. These scenarios might be seen as a particular way of how different types (roles) of users work with the system, the system's tools and educational material available in the system to achieve a particular learning goal. Thus, each scenario can be described by:

- a particular way (i.e., a story) of how to achieve the learning goal,
- the user roles that are involved in the story,
- the system tools needed to support the story,
- educational material that is needed to achieve the learning goal.

For instance, the above mentioned Web-based reading scenario can be defined as the following teaching scenario:

- An author has a group of learners that need to improve their knowledge on a certain subject. Thus, the author prepares a number of Web pages containing relevant educational content and connects these pages with links in a navigable structure (i.e., course). After the course has been created the author publishes it in the system. Now, the learners access the published material and read through it to improve their knowledge about the subject. During their work with the published material the learners communicate with the author via the attached discussion forum. Additionally, the author tracks the progress of the learners by means of different statistic tools.
- The user roles involved in the scenario are authors and learners.
- The system tools needed to support the scenario are the authoring tool for preparing Web-based educational material (i.e., courses), and a standard Web browser to access and work with educational material.
- Educational material comes in the form of a number of Web pages, which contain relevant educational content. The pages are connected by links into a navigable structure.

With the teaching and learning scenarios, which are implemented in WBT-Master we tried to take into account recent advancements in the traditional classroom didactics, as well as in the technology enhanced didactics. These scenarios incorporate such promising didactic approaches as project-based learning, problem-solving, constructivist approaches, collaboration, and so on.

In this chapter we present the following teaching and learning scenarios from WBT-Master:

- Web-based reading - this basic WBE scenario was extended in WBT-Master by sophisticated communicational and collaborative features such as annotations.
- Web-based tutoring - a teaching scenario where a tutor works with a group of learners in both synchronous and asynchronous mode, leading them to achieve a particular learning goal.
- Knowledge profiling - a scenario supporting the acquisition, structuring, and reuse of extracted expert knowledge.
- Knowledge mining - a learning scenario where learners are supported in exploring extracted expert knowledge by means of personalized knowledge retrieval facilities.
- Project-oriented learning - a learning scenario where a group of learners works together on a project, e.g., a software engineering project.

In the remainder of the chapter each scenario is described according to the above introduced template, i.e., the user roles, the system tools, educational material and the story of the scenario are given. After the scenario was defined we firstly discuss didactic aspects of that approach. Then, the technical issues such as software requirements, technical problems and obstacles, as well as possible solutions are discussed. Finally, we present an example and a screenshot of a typical learning session with that particular scenario.

9.4 Web-Based Reading

The Web-based reading scenario was already defined in the previous section. The support for this simple teaching scenario in WBT-Master closely reflects the similar support in other WBE systems, such as WebCT or Blackboard. However, there are also a few significant differences.

Didactically, the Web-based reading scenario in WBT-Master was extended by the promising collaborative facilities, such as annotations and synchronous and asynchronous communication [17]. Thus, the learners and the author can add and change the content by annotating it for themselves or others. Other users can even annotate the notes previously made, in this way activating a powerful communication channel. Each annotation has a certain type, such as "Comment", "Question", "Answer", etc., which provides a communicational context that can be very important in the learning process [24].

Moreover, annotations can also take the form of links, i.e., material can be linked together by the learners for their own benefit and for the benefit of the whole group. Thus, learners themselves contribute to the content on-the-fly (see Fig. 1).

Further, the Web-based reading scenario in WBT-Master supports other ways of synchronous and asynchronous communication between the learners and the author. These communicational facilities include chat rooms and the attached discussion forum. Note, that all the annotations that were made previously within the context of the educational content are also accessible via the discussion forum.

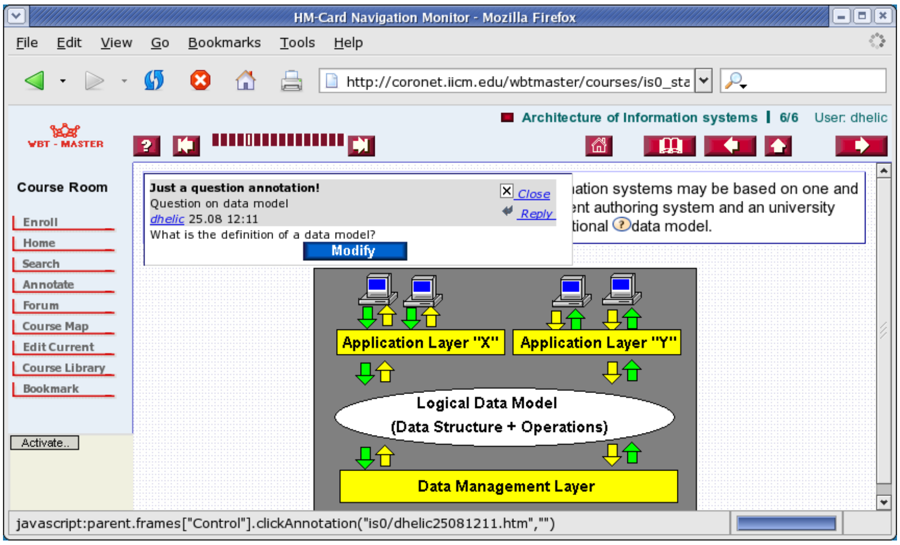

Fig. 1. Annotations in WBT-Master

Technically, educational material in the Web-based reading scenario is SCORM compliant. This ensures modularity, reuse, and interoperability of the educational content units. For example, suppose that we developed an educational unit about "Relational Data Model". Now, this unit might be reused in a number of different contexts. For instance, it can be reused in the context of another educational unit dealing with "Databases" in the practical sense, but it can also be reused in the educational unit dealing with the theoretical aspects of "Data Models".

9.5 Web-Based Tutoring

The Web-based tutoring scenario might be defined as the following learning scenario:

- A tutor has a group of learners that need to achieve a particular learning goal, e.g., the learners need to acquire some knowledge in a particular subject matter or they need to learn how to solve a particular kind of problems. The tutor defines a learning path, which the learners need to follow in order to achieve the learning goal. Such a learning path is a sequence of learning actions that need to be accomplished in a step-by-step manner by the learners. Each learning action comes with some educational material which should be consumed by the learners at that particular step. Alternatively, a learning action might be associated with a test that the learners need to pass, a request for publishing a document, a request to solve a particular problem, or simply a request to communicate with the tutor. Thus, the learners access the learning path and work through the learning actions consuming learning resources, working on tests, publishing documents, and so on. During this time the tutor can provide feedback to the learners by evaluating tests, answering their questions, etc.. Finally, the tutor may alter the learning path (e.g., insert a new learning action) as long as the learning situation requires it. Additionally, the learners and the tutor can communicate via the attached discussion forum.
- The user roles involved in the scenario are tutor and learners.
- The system tools include the authoring tool for developing learning paths as sequences of learning actions. Additionally, the tool for managing a library of educational material needed for a particular learning session is at the tutor's disposal. On the other hand, the learners need only a standard Web browser to access and work with educational material, to make tests, or to publish their documents.
- Educational material can be of any kind, i.e., courses, documents, discussion forums available in the system or external Web resources such as external Web pages.

The Web-based tutoring scenario reflects the well-known goal-oriented didactic approach [29]. Thus, the tutor leads the learners to achieve a particular learning goal. For example, a particular learning goal for software engineering students might be to learn how to write the user requirements document for a software system.

In the Web-based tutoring scenario the learning goal is achieved by following a predefined sequence of learning actions, i.e, the learning path. Since there are different types of learning actions, such as reading, writing, solving a problem, answering questions and others, the learning process can be based on sophisticated instructional models (see Fig. 2). For example, the above mentioned software engineering students, after having read more theoretical documents, might become involved in writing a sample user requirements document to gain practical experience. Note here the difference between the Web-based tutoring and the Web-based reading scenario. In the Web-based reading scenario the learners are supposed to reach their learning goal by simply following the navigational sequence and reading the educational content. Consequently, the Web-based reading scenario cannot prescribe a writing assignment for the software engineering students as the Web-based tutoring scenario can.

Another important aspect of the Web-based tutoring scenario is the immediate feedback by the tutor to the current learning situation. At each particular step of the learning session the tutor can provide feedback to the learners by communicating with them, evaluating their contributions, or alternating the learning path if new learning actions need to be inserted. For example, the tutor recognizes that the learners did not understand some concept entirely (e.g., by looking at the test result) and that they need some additional information. Thus, the tutor decides to insert a new learning action into the learning path attaching to it a document that provides the needed information. Note that the feedback can be provided for the whole group of learners, as well as for a single learner. In this way, the learning actions are customized to the current learning needs, learning situation, knowledge level, and learning preferences not only of the whole group but also of a particular learner. Thus, each learner's learning experience can be highly personalized by the tutor.

From the technical point of view, the tutor is involved in managing the library of educational material and in creating and manipulating the learning path. Note that the tutor is supposed to reuse all educational material available in the system by including it into the library. This material is then being referenced from within the learning path. To ensure interoperability between different scenarios and to enable reuse we decided again to apply the SCORM standard for defining the educational content (i.e., packaging of the content) and the learning path. The SCORM standard includes the simple sequencing model, which provides means for defining learning paths and rules for choosing between different alternatives. Although the simple sequencing model cannot capture all aspects of the Web-based tutoring scenario (e.g., altering of the learning path based on communication between the tutor and the learners) it can be seen as a solid basis for further development. Note also that our solution works as an authoring tool for such simple sequence models because the sequences are defined by the tutor on-the-fly taking into account the current learning situation. This can be seen as the additional value of the tool because authoring of such sequences before any learning session starts is usually a very hard task.

9.6 Knowledge Profiling

The knowledge profiling scenario is defined as the following learning scenario:

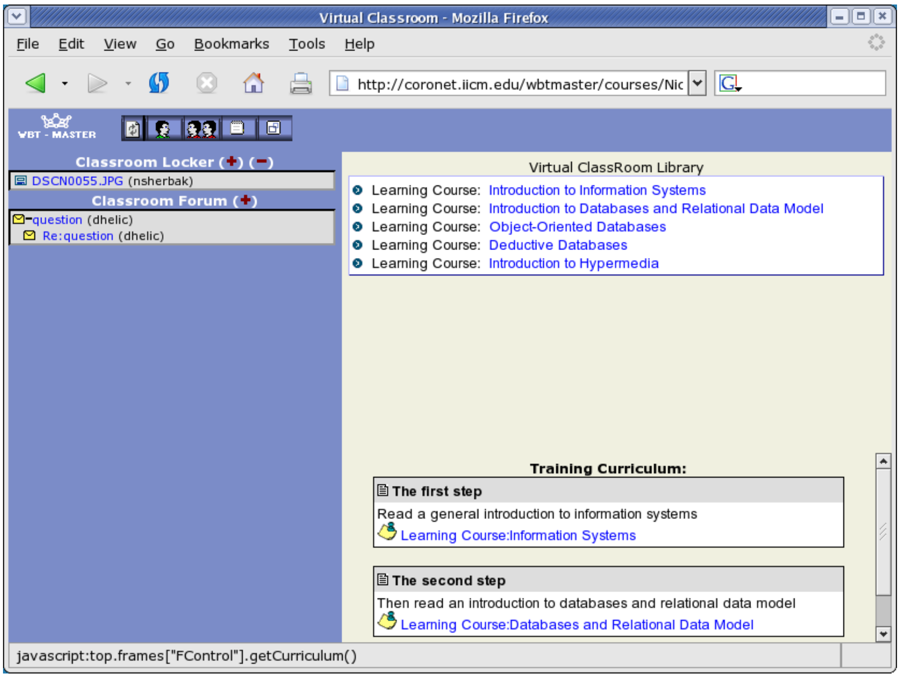

Fig. 2. Working with Learning Actions

- A teacher (e.g., an author or a tutor) has a group of learners that need to improve their knowledge on a certain subject. The organization with which the teacher and the learners are affiliated manages a large repository of extracted expert knowledge in the form of documents, external Web pages, lessons learned, discussion forums, etc. To ensure that the learners learn from the expert knowledge the author develops a domain ontology of the subject and classifies the expert knowledge according to the ontology. Finally, the learners access and work with the classified knowledge.
- The user roles involved in the scenario are teachers (either authors or tutors, or both), learners, and indirectly experts.
- The system tools which are needed include the authoring tool for developing a domain ontology, the authoring tool for classifying extracted expert knowledge according to the developed domain ontology, and a standard Web browser for learners to access and work with the classified expert knowledge.
- Educational material in this scenario is extracted expert knowledge coming in the form of internal documents, external Web pages, discussion forums, etc.

From the didactic point of view, this scenario addresses a few issues of the so-called experiential-learning. The experiential-learning is related to learning with experiences [7, 8]. The main concern of the experiential learning is how to transfer these experiences efficiently. Such experiences are mostly provided by experts, where the expert experience results from many years of practice. The problems in the experiential learning come from the fact that the knowledge of experts is somehow routine and difficult to make explicit or understandable to novices. Some of the reasons for this situation are the lack of the background knowledge of the domain (the declarative knowledge) and the lack of anchoring between experiences and the declarative knowledge [18]. The knowledge profiling scenario tries to bridge this gap in the experiential-learning by providing a high-level declarative description of the domain (i.e., the domain ontology), and by linking the expert experiences to the ontology, i.e., by classifying the experiences to the categories and the relations of the domain ontology.

For example, suppose we have the extracted expert knowledge in the domain of databases and information systems. This knowledge is comprised of, let say, a single general document about information systems and a single "lessons learned" document on the practical development of database systems. The domain ontology might include two categories: the "Information Systems" and the "Databases" category. Since database systems are a special kind of information systems the domain ontology might relate the "Information Systems" category to the "Databases" category by means of the "includes" relation. Additionally, the ontology might include the inverse relation of the "includes" relation, i.e., the "isKindOf" relation. Finally, we might classify the general document about information systems to the category "Information Systems" and the "lessons learned" document to the "Databases" category. Note, that the two documents are now automatically anchored within the background knowledge, i.e., they are explicitly related by means of the "includes" and its inverse "isKindOf" relation (see Fig. 3).

Technically, the implementation of the knowledge profiling scenario needs to meet the following requirements. Firstly, the system must support the development of domain ontologies or seamless integration of domain ontologies developed with external ontology editors. To ensure interoperability between the system and external tools domain ontologies should be developed by means of standardized knowledge representation techniques, such as recently developed RDF Schema [32] and OWL [31] languages.

Secondly, the system needs to support the teacher during the classification of the extracted expert knowledge by means of automatic and semi-automatic methods. For example, the system might suggest to the teacher that a particular document should be included into a specific domain category. There are a few different ways to support automatic or semi-automatic document classification, such as metadata management or full-text processing. In WBT-Master we apply metadata for this purpose, since implementing document classification is usually very hard in a WBE environment. Usually, such an environment deals with heterogeneous documents (e.g., Web pages, discussion forums, internal documents in different formats, etc.), which makes supporting of full-text processing very difficult.

Also, metadata management and especially metadata gathering in such an environment can be very expensive since the users of the system need to provide metadata manually. In WBT-Master we apply a semi-automatic approach for metadata gathering. Thus, the system manages sophisticated user profiles, which contain information of users' field of expertise, users' general interests, users' current involvement in the learning and teaching processes, and so on. Then, the system tries to apply this information to automatic generation of metadata. For example, suppose we have an expert in "Databases". The expert declares the "Database" expertise in his/her user profile. Now, whenever this expert contributes a document to the system, the system automatically adds a metadata description to the document stating explicitly that this document deals with "Databases". Then, this information can be used during the classification process.

Finally, the system needs to support learners in their work with the domain ontology and the classified expert knowledge, i.e., the categories of the domain should be searchable and navigable. For example, the learners might want to search for all documents belonging to the "Databases" category, or they can navigate through the domain ontology and in that way reach the "Databases" category and its documents (e.g., by following the link "includes" emanating from the "Information Systems" category).

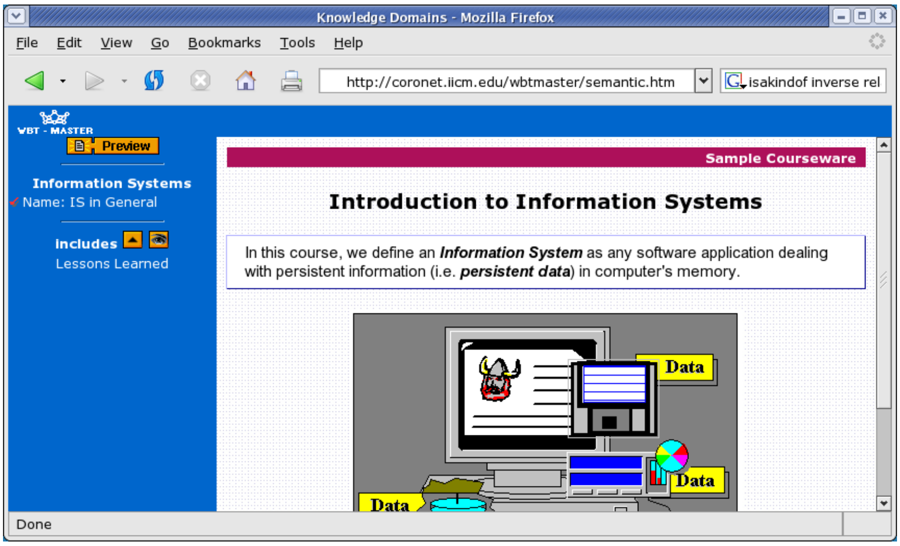

Fig. 3. Accessing Documents Anchored to Background Knowledge

9.7 Knowledge Mining

The knowledge mining scenario might be seen as a refinement of the knowledge profiling scenario. Thus, this scenario is built up on the same infrastructure, i.e., the domain ontologies and the classification of the extracted expert knowledge by means of these ontologies. The main difference is in the way how learners access that knowledge. In the knowledge profiling scenario learners had to navigate or search through the ontology categories to find the relevant information. Taking into account that a typical domain ontology can include hundreds, even thousands, of categories and relations this might be seen as a rather tedious task. Moreover, in a typical training situation in a corporate environment learners need to find relevant information easily and quickly, and usually do not have time to navigate through thousands of categories. In such a common on-demand training situation, the knowledge mining scenario tries to provide support for learners in their initial access to relevant information.

Didactically, the knowledge mining scenario addresses yet another issue related to the experiential-learning. This issue deals with the way how learners access relevant information, i.e., how they find such information in an efficient manner.

From the technical point of view, the knowledge mining scenario extends the knowledge profiling scenario in the following way. In the knowledge profiling scenario we were mainly concerned with creation of the domain ontologies and the classification of the expert knowledge to the categories from the ontologies. One of the methods applied to automatic or semi-automatic execution of this process was a management of user profiles, and description of users' field of expertise with metadata. In the knowledge mining scenario we extend the notion of user profiles by describing what are the fields of interest of each particular learner. This information is then used to facilitate the initial access to relevant information.

For example, suppose a learner is interested in information systems. Now, whenever the learner accesses the categorized expert knowledge, say by navigation, the system provides links to all documents containing expert knowledge on the topic of information systems. Similarly, search mechanism profits from the same information by ranking documents dealing with information systems at the top of search results.

Finally, the system makes use of the another important property of domain ontologies, i.e., inference. Inference is a technique that supports deduction of new facts, e.g., automatic classification by investigating categories, relations and their properties in domain ontologies. Recollect the example that we introduced above, i.e., we have two categories: the "Information Systems" category and the "Databases" category. These two categories are related by means of the "isKindOf" relation, i.e., the "Databases" category "isKindOf" the "Information Systems" category. Usually, the "isKindOf" relation is defined as transitive, i.e., if "A" "isKindOf" "B", and "B" "isKindOf" "C", then "A" "isKindOf" "C", thus allowing the principle of subsumption to be applied.

Obviously, if a document is classified to the "Database" category then it can be (because of transitivity of the "isKindOf" relation) automatically classified to the "Information Systems" category. Now, whenever the learner who is interested in information systems access that category the system automatically provides the learner not only with links to the documents in information systems, but also with links to the documents in databases (see Fig. 4).

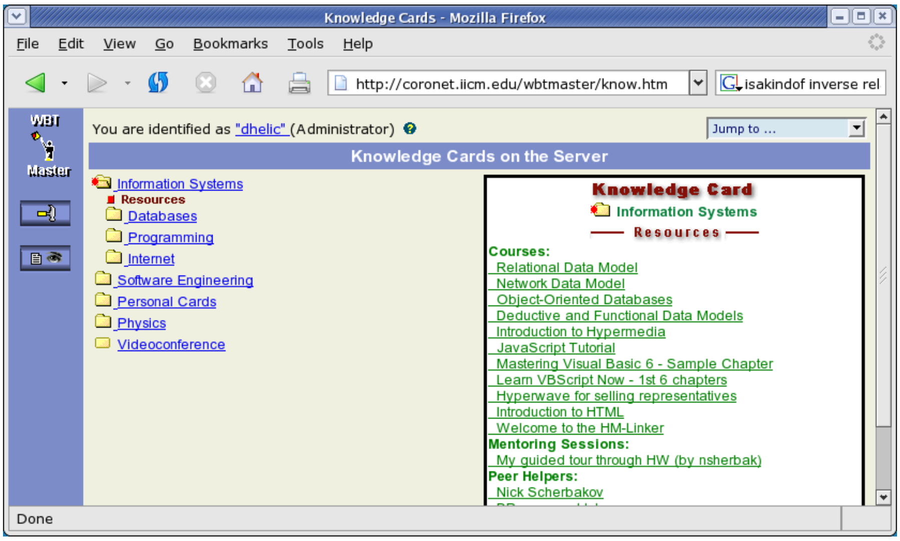

Fig. 4. Retrieving Documents Anchored to a Specific Category

9.8 Project-Oriented Learning

The project-oriented learning scenario can be defined as the following learning scenario:

- A teacher (an expert, an author or a tutor) has a group of learners that need to gain a practical experience in project-based collaborative work, e.g., working in a group on a software project. The teacher initiates a project-based learning session by creating a detailed project plan with the project steps and the time plan. At the next step, the teacher provides a sample project, which shows all the steps of a successfully executed project. Finally, the teacher provides a number of project alternatives for the learners. The learners constitute a number of teams, where each team selects one of the possible project alternatives as their practical example. The system provides communication tools, such as a discussion forum, a chat room, as well as collaborative facilities, such as version control system, annotations, tools to write project documents in collaboration, and so on. The teacher monitors the progress of the learners and provides feedback when necessary.

- The user roles involved in the scenario are teachers and learners.
- The required system tool is the integrated project management room, which provides facilities for creating and managing project plans, sample projects, project alternatives, as well as communicational and collaborative facilities.
- Educational material in this scenario consists of the project plan, the sample project, as well as external resources that may be linked to the project room via the discussion forum or annotation facilities.

Didactically, project-based learning is a model of learning that organizes learning around projects. Usually, projects are complex tasks, based on challenging questions or problems that involve learners in design, problem-solving, decision making, or investigative activities, furthermore they give learners opportunity to work relatively autonomously over extended periods of time; and culminate in realistic products or presentations [13]. Other defining features found of project-based learning paradigm include authentic content, authentic assessment, teacher facilitation but not direction, explicit educational goals, cooperative learning, reflection, and incorporation of adult skills .

Crucial for a successful and effective application of such a project-based learning paradigm is the careful developing and planning of effective projects. The basic properties of such effective projects might be summarized as follows [27]:

- Learners should be put at the center of the learning process.
- The project work is central to the curriculum.
- The project must motivate learners to explore important topics on their own.
- Project management should be accomplished by using appropriate tools, such as computer-based project management tools.
- The project outcome or the result that learners need to produce must include learning techniques such as problem solving, in-depth investigation of topics, research, reasoning, and so on.
- The project should include outcome alternatives that learners might choose from, or that they can work on one after another applying the experience they gained before.
- The project must be collaborative, that is learners might work together in small groups, or they can present and discuss their partial and complete results with other learners at any time.

Let us look now at an example of a project-based learning course. In a study reported by Barron [3], learners worked for five weeks on a combination of problem-solving and project-based learning activities focused on teaching learners how basic principles of geometry relate to architecture and design. The problem-solving component involved helping to design a playground in a simulated computer aided environment. The project-based component involved designing a playhouse that would be built for a local community center. Following experience with the simulated problem, learners were asked to create two- and three-dimensional representations of a playhouse of their own design and then to explain its features in a public presentation to an audience of experts.

Recently, numerous research papers on project-based learning have been published showing the benefits of this learning paradigm for learners and teachers as well. For example, these reports show tremendous gains in learner achievements, large gains in learners' problem solving capabilities, gains in learners' understanding of the subject matter, perceived changes in group problem solving, work habits, and other project-based learning process behaviors [26].

Technically, the project-based learning must be supported by means of an integrated project management tool (see Fig. 5). We implemented such a project-management tool in WBT-Master. This tool consists of the following components:

- A special document (curriculum) describing in few words the course and project motivation, problems that need to be solved, goals, etc.
- A special discussion folder providing a sample project with the definition of project plan, i.e., number of project steps and the time table for these steps. Each step is documented with a number of publications.
- A number of project discussion folders, which provide project alternatives for learners to chose from. These folders hold also all learner contributions.
- A number of collaboration and communication tools, such as online presence lists, chat rooms, discussion forums, etc.
- Evaluation tool for teachers evaluating learners' work.

9.9 Evaluation of WBT-Master Concepts

WBT-Master was developed within the scope of CORONET (Corporate Software Engineering Knowledge Networks for Improved Training of the Work Force) project funded by the European Union. The CORONET project was running from Mai 2000 until Mai 2002. The project consortium consisted of:

- Center for Advanced Empirical Software Research, the University of New South Wales, Sydney, Australia
- Atlante, Madrid, Spain
- DaimlerChrysler, Ulm, Germany
- Fraunhofer Institute for Experimental Software Engineering (IESE), Kaiserslautern, Germany

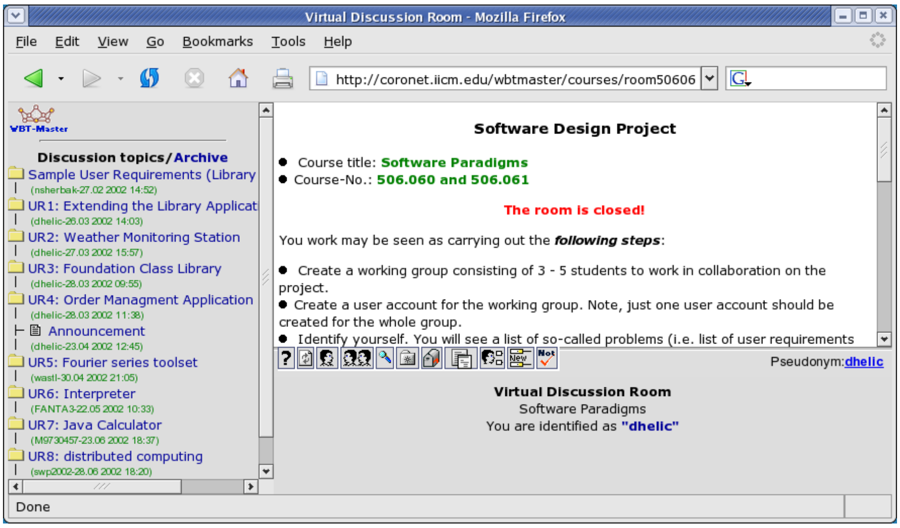

Fig. 5. Project Management Tool in WBT-Master

- Fraunhofer Institute for Computer Graphics (IGD), Darmstadt, Germany
- Highware, Paris, France
- Institute for Information Systems and Computer Media (IICM), Graz University of Technology, Austria
- Centro de Computacao Grafica, Coimbra, Portugal

WBT-Master was mainly developed by the IICM. The application partners in the project were DaimlerChrysler, both Fraunhofer institutes, and Highware. These institutions deployed WBT-Master and evaluated it in a wide range of possible applications. Additionally, we at the IICM used the system for hundreds of university students during lectures at our university.

9.9.1 CORONET Project Evaluation Approach

The CORONET project evaluation activities were performed through the following 3 phases [28]:

- Phase 1 (June - August 2001): In-depth assessment of the first WBT-Master prototype. The results from this evaluation were the main input for the enhancement of the CORONET methodology and infrastructure during the 2nd cycle of the CORONET project.
- Phase 2 (September 2001 - April 2002): Continuous evaluation studies performed with the WBT-Master prototype in parallel with incremental enhancements of the product.
- Phase 3 (February - April 2002): In-depth assessment of the improved WBT-Master prototype.

The three phases were performed in a systematic way during the project according to a detailed evaluation plan developed during cycle 1 of the CORONET project. The evaluation approach was finely tuned with the contribution of software and learning evaluation experts involved as members of the CORONET Pedagogic Advisory Board. Furthermore, the evaluation activities during phase 2 and 3 were monitored by additional requests derived from phase 1 results and from the comments of the 2nd and 3rd CEC in-depth project reviews in Paris (June 2001) and Madrid (March 2002).

General goals for WBT-Master evaluation were:

- Analysis of learning effectiveness: Evaluating the effectiveness of WBT-Master system in supporting knowledge sharing and collaborative learning.
- Usability analysis: Evaluating the perceived ease of use and the perceived usefulness of WBT-Master system.
- Cost-Benefit Analysis (CBA): Evaluating the cost-benefit ratio of using WBT-Master system.

In order to evaluate the WBT-Master, the partners that conducted the evaluation chose a "mixed evaluation" approach, i.e., each partner did not focus on all of the goals, but selected one or more focus areas to which individually tailored evaluation processes were applied.

To analyze learning effectiveness DaimlerChrysler, consistent with its role as a software development organization, focused on evaluating the effectiveness of WBT-Master in supporting continuing, self-directed, collaborative learning. The evaluation process was based upon the cognitive load theory and relied on a series of specifically designed evaluation sessions that were conducted in a specifically established evaluation laboratory setting, involving members of the research group as well as members of a business unit. Fraunhofer, consistent with its role as a research institute, focused on evaluating the effectiveness of WBT-Master in supporting collaboration and knowledge sharing. This was done by conducting two quasi-experiments that compared the efficiency and effectiveness of conducting similar tasks with and without using WBT-Master. Highware, consistent with its role as a training service provider, focused on evaluating the effectiveness of WBT-Master in supporting web-based learning by training and web-based experience sharing. Evaluation data was collected with the help of specifically designed questionnaires.

To perform usability analysis Perceived Ease of Use (PEU) and Perceived Usefulness (PU) of WBT-Master from the point of view of end users was estimated. In order to analyze the PEU and PU end users were requested to answer related sets of questions. For data collection, specifically designed questionnaires were distributed to end users of WBT-Master at the end of the trial period for a particular learning scenario. In order to test the reliability of their analysis results Fraunhofer IESE calculated and interpreted Cohen's Kappa coefficient. DaimlerChrysler used the questionnaire ISONORM 9241/10, which was evaluated with respect to validity and reliability. The

ISONORM questionnaire was derived from the software ergonomic standard DIN EN ISO 9241.

Finally, Fraunhofer IESE designed and guided the cost-benefit analysis. Cost-benefit data was collected by DaimlerChrysler and Highware with the help of specifically designed data collection forms. The cost-benefit analysis was based on a 3-phase learning reference model. The purpose of this model is to provide a common basis for comparing different learning and training approaches in one common framework. The reference model consists of the following main phases:

- Pre-Learning Phase: comprising all relevant activities before learning is performed.
- Learning Phase: comprising all relevant activities during learning.
- Post-Learning Phase: comprising all activities taking place after learning is finished.

For each of the phases, during the evaluation studies conducted by the application partners DaimlerChrysler and Highware, associated cost and benefit data was collected.

9.9.2 Evaluation Results in Corporate Environment

The first evaluation goal focused on the effectiveness of learning with WBT-Master from the perspective of software organizations, software engineering research organization, and software training service providers, i.e., DaimlerChrysler, Fraunhofer IESE, and Highware. In accordance with the findings related to the first goal, all partners appreciated the innovative concepts offered by WBT-Master.

Nevertheless, the results of the evaluation studies related to learning effectiveness were not fully consistent. The data reported by scientists, software engineers, and software trainers at Fraunhofer IESE, Highware, and Highware's partner and customer organizations generally indicated improved learning effectiveness when using WBT-Master. The analysis of learning effectiveness conducted by DaimlerChrysler was partly influenced by negative judgment of the usability of the WBT-Master platform. This was reflected by the data received from DaimlerChrysler system users who expressed the feeling that the cognitive load associated with tool usage prevented them from learning in the proper sense.

In addition to the evaluation studies conducted by DaimlerChrysler, Fraunhofer IESE and Highware within the scope of the CORONET project, a large number of students (more than 100) at the Graz University of Technology have been using WBT-Master extensively since mid-2001 without major problems, thus confirming that the system can be considered a helpful instrument for collaborative learning and knowledge sharing, see sect. 9.9.3.

As a by-product of the analysis of learning effectiveness, some observations and conclusions on cultural and organizational aspects could be drawn from the associated evaluation studies. The analysis of WBT-Master user profiles clearly showed that there was a positive predisposition to work with a web-based learning environment as most of the users had been familiar with ICT for more than two years. However, some cultural factors were detected as being critical. They should be taken into account when introducing and operating WBT-Master.

First, shifting to e-learning clearly requests changes in the behavior of nearly all the participants involved. The changes are mainly related to:

- Learning approach: shifting from the conventional presence learning mode to using the Internet is not obvious for learners who have not yet had experience with or have not been prepared for using the new learning and knowledge transfer processes offered by a web-based learning environment.
- Pedagogical approach: replacing interpersonal relations which typically occur in conventional classroom settings by interactions between the learner and the web-based learning environment requires new competence on the part of trainers, tutors, and authors of learning materials.

Using a learning environment like WBT-Master is not a one-shot experience: it is highly recommended to properly introduce both the methodology and the infrastructure to all types of users in order to facilitate the adequate use of the learning environment. It clearly appeared from all evaluation studies that system users need some time to handle the new environment before focusing on any specific learning activity.

Here are some highlights from the evaluation at DaimlerChrysler. In total, forty individuals were involved in DaimlerChrysler's evaluation studies. Twelve of them actively participated in thirty-four in-depth evaluation sessions. The qualitative analysis applied to the "think-aloud protocols" and recorded video tapes of the evaluation sessions indicated that the concepts offered by WBT-Master (e.g., to combine collaboration and document work) were generally appreciated by system users. The following functionalities were considered most beneficial for the specific setting of DaimlerChrysler's evaluation study:

- Inference enabled ontologies for self-paced worker's knowledge mining,
- Web-based tutoring for the experts to give advice, and
- Various collaboration tools, i.e., forums, to collaborative problem-solving with peer learners, and collaborative knowledge building.

The positive impression, however, was negatively influenced by the subjective perception that the current version of the learning prototype platform WBT-Master was too difficult to use. In particular, the various options for communication/collaboration were perceived as too numerous, too spread out, and too hard to differentiate. One possible explanation for these partly negative results is that DaimlerChrysler's software engineers have to cope with extremely high pressure to continuously upgrade their knowledge on-the-job, possibly without being able to spend any effort other than the project-related effort on learning. Hence, this highly specialized clientele is used to (and needs to) work with a software environment that perfectly matches their specific expectations and does not require any introduction and learning curve. Thus, the tolerance level regarding expectations and actual behavior of a new learning environment is rather low. This might explain why WBT-Master, having the maturity of a research prototype, had problems to meet the high expectations of DaimlerChrysler's trial users.

Some highlights of the Fraunhofer IESE's evaluation are as follows. In total, seven individuals actively participated in Fraunhofer IESE's evaluation studies. The results of the evaluation studies show that knowledge sharing activities in a research department setting can be performed more efficiently and more effectively with using the knowledge transfer functionality offered by WBT-Master.

Finally, some of the results of the evaluation at Highware are as follows. In total, thirty-two individuals actively participated in Highware's evaluation studies. The results of the evaluation studies were in its majority positive. The main findings can be summarized as follows:

- The concepts contained in the learning methodology of WBT-Master are presented in a clear and concise style so that learners, trainers, tutors, and authors can easily identify the right learning scenario for their particular learning/training needs. This was particularly true for the scenario Web-based tutoring, which was the main focus of Highware's evaluation studies.
- The Web-based tutoring functionality provided by WBT-Master offers a viable alternative to classical in-class training settings. The effectiveness of virtual classes was judged as being at least as effective as conventional in-class sessions.
- Regarding the effective support of web-based experience sharing, the second focus of Highware's evaluation studies, WBT-Master successfully helped to establish a network of geographically distributed learners. From the point of view of the management, the establishment of such a network, facilitating learning at the workplace by connecting people to a network of distributed learning resources (documents, courseware, peers and experts) was considered as one of the main strengths of the CORONET system.

Since the main focus of the CORONET project was to develop innovative solutions to support collaborative web-based learning, it was not surprising that evaluation results judged WBT-Master as being acceptable as a training management system, but several proposals for future enhancements were made.

It was interesting to observe that the results of the evaluation studies conducted within Highware and in collaboration with Highware's partner and customer organizations in real business cases were more positive than the results of DaimlerChrysler, the other industrial partner in the CORONET consortium. One possible explanation is the following: Since the use cases defined by Highware were more focused, relatively less effort for introducing WBT-

Master to their own staff and to their customers was needed. This helped to avoid misunderstandings of the concepts and paved the way for better tool acceptance. It also meant that both Highware staff members (who used the system internally) and end users of Highware's partners and customers were more tolerant towards a prototype system that obviously is not yet perfect (and thus imposes an initial learning curve) but delivers innovative functionality. Another explanation might be the differences between organizational cultures involved in DaimlerChrysler's and Highware's evaluation studies. Both DaimlerChrysler and Highware (and its partners and customers) are highly professional and successful in their respective businesses, but the individuals involved in DaimlerChrysler's evaluation sessions mainly work in complex team-oriented organizational settings with a strong product focus, whereas the individuals involved in Highware's evaluation sessions mainly work in small to medium sized network-like organizational settings with a strong service focus. Whether cultural differences induced by the different geo-political settings of the studies could also account for the different findings was not investigated.

Case studies to analyze perceived ease of use (PEU) and perceived usefulness (PU) of WBT-Master were conducted by DaimlerChrysler, Fraunhofer IESE, Fraunhofer IGD, and Highware. The data analysis of the various evaluation studies did not result in a consistent view. While subjective user acceptance of WBT-Master by individuals involved in DaimlerChrysler's evaluation studies turned out to be insufficient, evaluation data provided by WBT-Master users at Fraunhofer IESE, Fraunhofer IGD, and Highware (including their partner and customer organizations) showed positive PEU and PU ratings.

An explanation for this inconsistent result could be the different approaches that were chosen to conduct the evaluation studies. DaimlerChrysler based their analysis on very complex use cases that require a relatively high usability of the tool environment in order to avoid that system users resign from trial experiments. Given that WBT-Master is a prototype platform - and not a fully developed product - time constraints coupled with high expectations of the system users and their low level of tolerance towards initial learning curves resulted in low usability ratings. Hence, the partial non-acceptance of the system by DaimlerChrysler users might be perceived as a confirmation of the project intention to develop a usable prototype, but not an "off-the-shelf" software product. Due to the different nature of their use cases and the associated learning scenarios it was less difficult for the other partners (Highware, Fraunhofer IESE and Fraunhofer IGD) to introduce the system as a working prototype to their respective end users. As a consequence, in their evaluation studies these partners better managed to focus on innovative functionality and to invest into providing additional learning and user support (which would not be needed for a software product). This led to the positive results of the usability studies of these partners, reconfirming the overall project success.

The results of the Cost-Benefit Analysis (CBA) were gained from data collected by DaimlerChrysler and Highware in seven evaluation studies conducted across two evaluation cycles. The majority of the results showed that using WBT-Master is - in addition to the non-monetary benefits generated by the innovative methodology and infrastructure - beneficial from the monetary perspective. The CBA showed that:

- For Highware, a training provider, using WBT-Master increases the Net Present Value (NPV) and thus can be considered as being monetarily beneficial.
- For DaimlerChrysler, which is not a training provider, using WBT-Master does not generate a positive NPV in a short term. However, using WBT-Master over a period of more than three years is expected to result in a positive monetary effect.

Generalizing the CBA results, it can be expected that:

- Training providers can be advised to buy and apply WBT-Master "as-is" because cost savings along with a profit increase caused by travel cost reduction, reuse of training materials, and additional (new) customer services (based on the CORONET features) that generate additional revenue can be expected.
- Customers of training providers will experience - besides the non-monetary benefits of CORONET - a cost reduction through reduced inter-location travel of the employees attending to the CORONET-based training.
- Non-training providers, i.e., software development organizations, can reach a positive NPV in the training and learning cost by using CORONET for a few years.

9.9.3 Evaluation Results in Academic Environment

We applied the project-oriented learning scenario to conduct the 2002 summer term course on Software Engineering at the Graz University of Technology with more than 200 students. The Software Engineering course at our university consists of:

- Lectures on basic software development paradigms and vocabularies applied to describe the development paradigms and development processes.
- Software development project where students develop a software application following one of the presented development methods.

Thus, the practical part of this course is already project-oriented. Consequently, we wanted to conduct this project by means of WBT-Master. Thus, we prepared a special project-oriented learning session for the Software Engineering project. The session included the following items:

- Curriculum for the project, where we described the learning goals, learning mode, presented time schedules, etc.

- A sample software development project clearly identifying the development method, development process, and all steps that students needed to accomplish to successfully finish their projects.
- Four software development proposals, from which students chose their own projects.

The integrated project management tool provided all necessary facilities needed to conduct a Web-based software development project, for both teachers and students. Thus, students made their accounts, groups, and assigned their accounts to the groups. They posted their results as multimedia replies to a particular project folder, following the steps from the sample project. Communicational tools were available for them at any particular time. Teachers were able to track students' progress, evaluate the students' results and provide them with valuable comments. Discussion forum was used extensively to discuss project related issues among students and among students and teachers.

After the course was finished we provided students and all involved teachers with a simple evaluation form to evaluate the results of applying this tool in practice. Here are some of the highlights that we got from this evaluation.

First of all, there were no additional efforts on the teachers' side to prepare and conduct the course. The sample project and the alternatives for students had to be prepared anyway, regardless of the environment where the course was conducted. However, there was a need for a special lecture to explain students how to work with the tool. No other session with students were needed, because all the communication was going on in the online mode. This greatly reduced the time effort on the teachers' side because otherwise teachers would need to have 4-5 project meetings with students in the offline mode.

The evaluation of students' answers was quite positive as well. Firstly, they were asked if accomplishing a Web-based project was more difficult than accomplishing an offline project, which is a project with face-to-face project meetings. Since these students already had a number of projects in other university courses, which were accomplished in the offline mode, their answers might be seen as relevant. Only 5% of students answered that a Web-based project was more difficult to accomplish than similar projects that they had during their classes.

Secondly, they were asked if they see advantages in using communication and collaboration tools to work together on the project with other students. 80% saw such advantages and stated that the communication using the tool was in the most cases even better than in the offline mode, where the communication is usually restricted to the project meetings.

On the question if accomplishing such a Web-based project helped them to acquire additional skills, 90% students answered that they had acquired additional skills, and that there had been no negative difference between the skills acquired as compared with the more traditional projects. 85% of those 90% answered that they acquired these skills because Virtual Project Management

Room provided an integrated environment needed to accomplish their task, e.g., they had communication with teachers and other students, possibility to discuss their results, to share their ideas with others, etc.

Finally, they were asked to assess the course and their overall assessment was 1.4, where 1 is the best possible mark on the scale from 1 to 5. The average assessment on the university is 2.5, and the average assessment on our institute is 2.

9.10 Conclusion and Future Work

The evaluation results clearly show that a didactics aware approach to implementing WBE systems and developing standards for WBE is a huge step in the right direction. However, some problems related to this approach need still to be resolved. For example, in order to support a new teaching scenario, e.g., a collaborative writing scenario, a new tool must be implemented. Obviously, each new scenario reflecting a particular didactic approach requires such a new tool. This, of course, can cost time and resources.

In our future work we plan to address this issue in the following way. Firstly, a modeling language for defining different didactic approaches should be developed. With such a language it should be possible to define all the components of a particular teaching scenario, such as educational material, user roles, the story of the scenario, student activities and others. For example, the story of a particular scenario might be defined as a number of learning actions that students need to accomplish. Student activities might include reading, writing, making tests, and others. Recently, some research efforts were undertaken trying to model didactics from different perspectives, such as constructivist perspective, activity-oriented perspective, etc. [22, 25]. We plan to investigate these research efforts and reuse as much results as possible coming from that research. Furthermore, the modeling language should be kept interoperable with the recent WBE standards. This will insure that standard compliant educational material can be easily incorporated within the system.

Secondly, a single generic tool capable of interpreting and executing teaching scenarios defined by means of the developed modeling language will be implemented into the WBT-Master. This tool will provide an integrated learning environment enclosing all educational material and other WBT-Master tools needed to support a particular scenario.

Thirdly, a number of typical teaching scenarios (such as scenarios presented in this chapter) should be modeled by the developed language and executed within the generic tool. We believe that different scenarios will share some common aspects. For example, communication in many different scenarios is usually based on a discussion forum and a chat room. Obviously, these two tools can be coupled together into a single communication component which may be reused as a module in different teaching scenarios. Thus, the modeling language must be component-oriented so that new teaching scenarios might be easily modeled by simply combining a number of already existing components.

Finally, we plan to implement a number of new teaching scenarios, such as collaborative writing, collaborative problem-solving, and others by combining and configuring existing and new components to meet the requirements of a particular teaching scenario.

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