Chapter IV

Improving Usability of an Online Learning System by Means of Multimedia, Collaboration and Adaptation Resources

Elizabeth Furtado
Universidade de Fortaleza, Brazil

João José Vasco Furtado
Universidade de Fortaleza, Brazil

Fernando Lincoln Mattos
Universidade de Fortaleza, Brazil

Jean Vanderdonckt
Université Catholique de Louvain, Belgium

ABSTRACT

This paper describes an adaptive and collaborative environment for helping problem solving. The main user of the environment is a teacher, here called teacher-student, who accesses the environment aiming at solving difficulties he/she encounters in the classroom. In order to improve the usability of the system during the problem-solving process, the environment provides the teacher-student with adaptive assistance by identifying what information should be

provided and how it should be shown on the screen according to characteristics of the teacher-student, domain and context of use. Moreover, the teacher-student has a collaborative support that allows him/her to interact with other teacher-students.

INTRODUCTION

The usability of an interactive system refers to how easy it is to use and learn the system. In on-line learning system contexts, the pedagogic usability is also related to how easy and effective it is for a student to learn something using the system. An attempt to ensure usability is to take into account characteristics of the user (such as preferences, language, culture and system experience) and of the context of use (such as easy accessibility and good luminosity of the environment) during the development of a system. This allows the adaptation of the interfaces to the user's needs, varying, for instance, the kind of assistance that is to be offered to the user and the way it is to be shown in order to cope with individual differences. Adaptability improves handling and learning of the interface (Benyon, Crerar, & Wilkinson, 2001). Another way to ensure pedagogic usability is to make it possible for the user to reflect about his/her difficulties on his/her own and with others. Several educational theories claim that learning depends on the individual's knowledge being built by social interactions (Bourne, McMaster, Rieger, & Campbel, 1997; Vygotsky, 1984). We have identified some problems to a successful deployment of on-line learning:

- Lack of learning quality—Many on-line learning systems don't bring users to reflect about their problems since they simply present predefined solutions.
- Lack of adaptive tools and guidelines—Learning tools are very useful, but most are not adaptive (Schön, 1987) or else the user model is predefined (Gomes & Viccari, 1999). In addition, user interfaces (UIs) of such tools are generally specified without taking into account guidelines (Eleuterio & Eberspacher, 1999).
- Lack of training in new technologies—Any teacher (our teacher-student), as part of his/her professional development, needs continuous training. Teachers' training is often carried out by using old technologies that cannot deal with adaptive and collaborative processes. It is necessary to fulfill these needs by adopting an integrated pedagogical-technological content (Perrenoud, 2001).

All of these issues have a critical impact on the usability of on-line learning. Thus, we developed a collaborative and adaptive distance learning environment called Tele-CADI that helps a teacher-student solve his/her difficulties during classes by offering adaptive assistance. Tele-CADI aims:

- To increase the quality of learning—Tele-CADI is supposed to do this by adopting a collaborative problem-based solving strategy. The basis of this strategy is the use of case-based reasoning methods (Aamodt & Plaza, 1994).

A case is a didactic situation that represents the difficulties found by a teacher during his/her classes. Thus, a case study is used to help the teacher-student both to identify and formalize a problem he/she faces and to express a possible solution using reflective techniques. This includes both technical and practical knowledge that the teacher acquires through experience in the classroom.

- To increase the UI usability—UI plays a vital role in improving the communication between the user and the system. The UI is not a complement for the software itself, but an integral part of its contents. Because of this, increasing user interface usability is crucial to the results in the solving of problems by teachers. Tele-CADI can do this by adapting case studies, considering human factors and guidelines. Depending on the adaptation process, a case study can be shown on the screen in different ways.

The remainder of this chapter is structured as follows: in the next section, we explain the main pedagogic principles studied that help us to understand the development of the practical-reflective teacher. Then, we provide the basic concepts used in Tele-CADI with a focus on the usability issue. The Tele-CADI architecture is described in the subsequent section. Then, the process of modeling and representing case studies is described, followed by a depiction of the adaptive process of user interaction and the collaborative process. The technical aspects of Tele-CADI are shown next. Finally, we discuss future developments and summarize the main points of this chapter.

BACKGROUND

Nowadays, many on-line learning systems are based on the problem-solving method (Pozo, 1998). This is due to the fact that many theories show that learning must be a collaborative constructive process (Schank, 1994) to be followed through problem solving in order to develop the users' capacity for reflection (Dewey, 1959). This inspired us to build a system that provides assistance to the teacher in a collaborative situation of solution of problems. In order to do that, we have studied both the cognitive models of problem solving and the reflective process in the development of the teacher.

Among the models of problem solving (Hoc, 1996; Rasmussen, 1983), John Dewey (1959) defined that, when solving a problem, the student executes the following phases: identification of the problem to be solved, problem evaluation, decision making, execution of the actions taking part in the solution and evaluation of the solution. In a problem-solving situation, varied assistance can be offered during each phase. Such assistance can be of three types: i) procedural, which refers to the strategies that a student can use; ii) content-related, which refers to the information and knowledge involved; and iii) attitudinal, which refers to strategies of the student's motivation to solve the problem.

Concerning the development of the teacher, our studies of the reflective thought and of the practical ways to express this thought (Dewey, 1959; Schön, 1987) helped us to understand the development of the practical-reflective teacher. The *practical-reflective teacher* notion refers to the professional who has competence associated to "a knowledge placed in action, which is holistic, creative, personal and constructed; a knowledge that depends, among other things, on the professional's capacity to appreciate the value of his/her decisions and the consequences of them" (Alarcão, 1996).

According to Schön, in order for a teacher to solve a problem in a practical way, he/she must first understand it very well. From the analysis and reflection of case-study characteristics, it is possible to understand a problem as well as to visualize its consequences. During the examination of a problem, the teacher-student can access a set of case studies that describe similar problem situations. These will induce him/her to ask himself/herself questions like What caused this problem? How can I prevent this problem from occurring again? and How can I break down this problem into simpler problems? When we ask ourselves questions, we integrate new information into our memory, tie old information together in new ways and correct our faulty generalizations (Schank & Cleary, 1995).

Case studies represent real and detailed situations that are interpreted and discussed by an expert. In the case studies, knowledge about a specific event is represented, as well as the theoretical knowledge of the expert who is responsible for the narrative of the situation.

Each case study represents a situation and is composed by the following features:

- Case-study name, which identifies the case study being described;
- Case-study goals, which specify the implicit intentions of the expert when he/she presents the case study;
- Case-study description, which represents a story characterizing a situation composed of problem and solution;
- Case-study orientation, where the assistance to understand the situation and to solve the problem is described; and

Figure 1: Concepts of Tele-CADI (modified from Hix & Harston, 1993)

<table>
<tr><td rowspan="2">Quality of the User

(e.g., Training the user in new technologies, allowing the user to collaborate and communicate with other users)</td><td>Usability through Interaction Devices
Video and microphone</td><td>Usability of the User Interface
Guidelines
Human Factors
Adaptive User Interaction</td><td>Quality of the Learning Application
Cases
Ontology
Scenarios</td></tr>
<tr><td colspan="3">Usability of the Computer-Based System</td></tr>
<tr><td colspan="4">Usability of the Overall On-line Learning System Tele-CADI</td></tr>
</table>

- Results, which are critical reports describing the consequences of the application of the orientation.

The Tele-CADI system proposed here aims at the development of the practical-reflective teacher, taking into account the following concepts related to the usability of this system.

BASIC CONCEPTS RELATED TO USABILITY IN TELE-CADI

Many concepts studied in different areas (interaction human-computer, cognitive sciences, ergonomic, artificial intelligence and pedagogy) have been considered in order to assure Tele-CADI's usability. We have used these concepts to develop each Tele-CADI component (see Figure 1). Tele-CADI's usability is assured when its components have been built with quality and when the teacher-student's knowledge of interaction with the system has been developed. Quality of a component means the following: i) Quality in application, which corresponds to a good specification of noninteractive information of the system. In Tele-CADI, the noninteractive information of pedagogic domain is related to the development of the practical-reflective teacher, the assistance provided, the case-study representation, etc. ii) Usability in the user interface, which refers to a good specification of the interactive information of the system (its windows, its buttons, etc.). iii) Quality of the interaction device, which makes possible the interaction with different media (sound, text, image) through devices as cameras, microphones and so on. The quality of the user refers to his/her ability to use new interaction devices and technologies, experience with computer-based systems and acquaintance of the domain in question.

The concepts related to usability in Tele-CADI are the following:

- Utilization of ontology to domain model, particularly, to represent case studies. The ontology notion comes from the artificial intelligence area where it is identified as the set of formal terms with one knowledge representation, since the representation completely determines what "exists" for the system (Gruber, 1993). The advantage of using this representation is that the ontology can be defined once and used as many times as necessary. When it is necessary to consider more information in models, such as in the user model, this ontology can be updated accordingly. In on-line adaptive learning systems, such a flexible user modeling approach is important because there is no predefined information on the users to ensure that interactive applications yield high quality of interaction to a stereotype of all users. In addition, the ontology is useful to create generic representations for case studies representing the problems that the teacher-students have faced. Moreover, as we will show in this chapter, such a representation plays a very important role when the case-study-retrieving phase is executed.

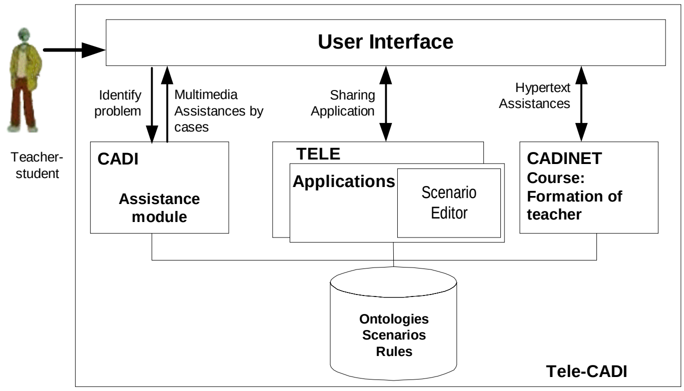
- Utilization of guidelines and human factors to assure the adaptive interaction since Tele-CADI determines which case study should be shown and how it should be shown on the screen. Human factors, such as the teachers' beliefs, and guidelines related to graphic aspects and characteristics of the user and his/her context of use are considered. Guidelines are suggestions about the ergonomic aspects of the interfaces, such as showing only the necessary information or letting the user control the system dialog (Bastien & Scapin, 1993; Bodart & Vanderdonckt, 1993). Taking into account guidelines in the interface design of a system allows the designer to determine the best way in which information is to be provided to the user during his/her interaction with the system.
- Utilization of multimedia resources to improve interaction. The approach adopted to provide a multimedia environment for an on-line learning tool was the use of different interaction devices to improve interaction (microphone and video camera). Our proposal to specify a multimedia supporting system derives from the great worldwide call for non-textual information. Non-textual information characterizes the systems that use different channels and codes in their interaction with the user.
- Utilization of collaboration and communication mechanisms to assure the quality of the user. Tele-CADI has a module, called TELE (Neto, Raimir, Bezerra, & Sarquis, 2000), which implements the collaborative aspect by allowing a teacher-student to share an application. In addition, Tele-CADI is integrated to another on-line learning system, called CadiNET (Furtado, Silva, Alves, & Távora, 2001), in order to allow the teacher-student to be trained in new technologies, mainly concerning the Web application. The CadiNET system enables a teacher-student to obtain texts, to perform on-line activities and to interact with others by means of a forum and chats.

DESCRIPTION OF TELE-CADI

Figure 2 depicts the architecture of Tele-CADI including five main components (Furtado, Mattos, Furtado, & Holanda, 2001):

- The assistance module, which coordinates the recovering of assistance (case studies, texts or links) that is to be presented to the teacher-student.
- The TELE module, which allows the collaboration and communication over the Web by chat and the sharing of any application, such as the scenario editor, with which the teacher-student can appreciate already existing scenarios and build new ones with others.
- The user interface (UI), which is used by the teacher-student to interact with the environment.
- CadiNET, which offers administrative support to the courses and hypertext assistance to show texts and links.

Figure 2: Tele-CADI architecture



- Knowledge base, which gives support to the greatest part of the problem-solving process through models (such as the user model and the case-study model) and rules which express the teacher's beliefs.

The cooperation between the main components is the following: The teacher-student requests the analysis of a case study that expresses his/her problem. During this analysis, the UI component provides the teacher-student with some assistance. The teacher-student is provided with case studies retrieved from the knowledge base by the assistance module. The case studies are shown in different ways. If the teacher-student wants to communicate with other teacher-students who have gone through similar problem case-studies and create a scenario together as a possible solution for the identified problem, the UI component calls the TELE module. If the teacher-student wants to read some text, suggested by the assistance module, the UI component calls the CadiNET module. The teacher-student solution is validated by a pedagogic specialist before being effectively stored and made available to others.

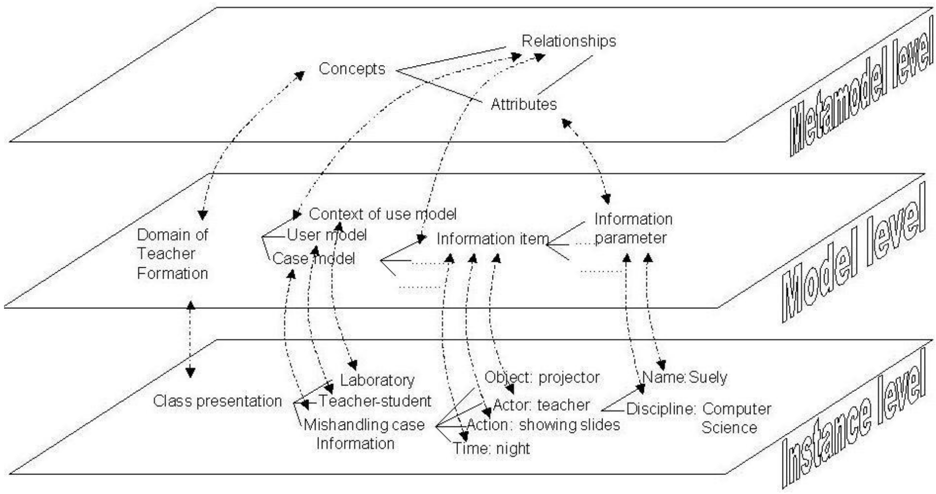
In the next section, we will describe the ontology and the tools used by the expert teacher to define and represent the different models stored in the knowledge base. These models are mainly built through two editors: the ontology editor and the scenario editor.

MODELING AND REPRESENTING CASE STUDIES

The ontology is explicitly structured into three separate levels: metamodel, model, and instance. Each level can be considered as a different abstraction level as represented in Figure 3.

The domain basic concepts are defined in the model level from the instantiation of more general concepts defined in the metamodel level. In the instance level, the

Figure 3: The different levels of the ontology (adapted from Furtado, Futado, et al., 2001)



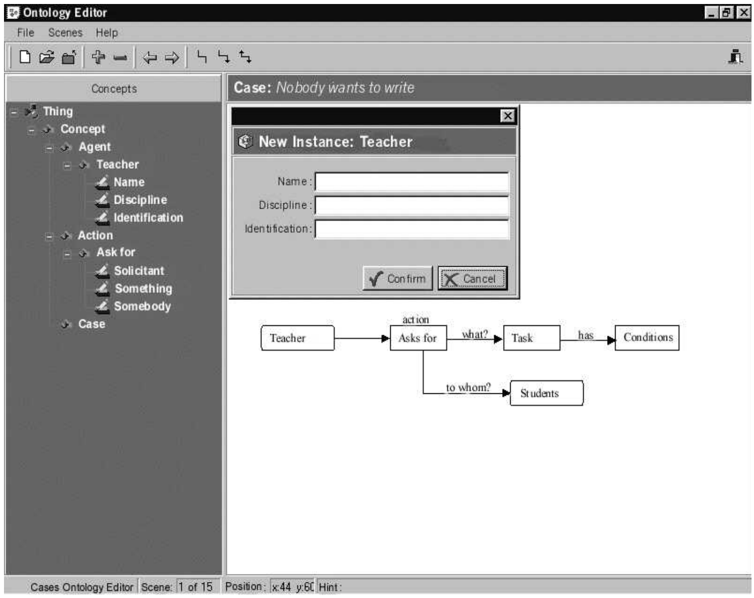
concepts related to a specific situation are defined. The example in Figure 3 shows a way to model a situation involving a teacher presentation during a class. The teacher, named Suely, mishandles a projector during a computer science night class. In the model level, concepts about the teacher-student domain are modeled while in the meta-model, we can make the modeling of the basic and general concepts related to any domain as relations, attributes, entities, and so on.

For the simplicity of this paper, we focus on describing the ontology of the case-study model, but the ontology editor is also used to describe the ontology of the user model in order to describe the user's characteristics.

To create the case-study model, the expert teacher models (or defines) the structure of the case study, then instantiates it. During the modelling process of a case study, he defines the information item and its information parameters. We have already predefined some attributes of the case-study model, e.g., a case study representing a problem (called problem case-study) is composed of scenes. One scene represents one specific situation occurring within this generic problematic situation. Modelling a scene, the expert can define the following information items: actor (student, teacher), actions (saying, showing, complaining), objects (table, projector, slides) and environment (place, time, lighting condition). He also defines the information parameters of the *teacher* actor participating in a scene, such as name, discipline and identification. During the instantiation process, the expert teacher instantiates each information item instantiating its parameters.

To facilitate the instantiation and modelling process of an ontology we have built an ontology graphic editor. Figure 4 depicts how the ontology graphic editor can be used to instantiate a scene of the case study "nobody wants to write." In this scene, the teacher asks the students to perform a task under certain conditions. On the left

Figure 4: The instantiation of a scene of the case-study "nobody wants to write"



side of Figure 4, information items are instantiated, with the parameters of the scene being specified on the right side. In addition, multimedia files, generated by the graphic scenario editor, can be associated with a scene. The graphic nature of the editor improves the legibility and the communicability of information, while information that cannot be represented graphically is maintained in text properties. In the pop-up window, the parameters of the *teacher* actor can be instantiated, for instance, the name of the teacher who asks the students to perform the task, his/her discipline and identification.

THE ADAPTIVE ASSISTANCE PROCESS

The assistance process is carried out by the assistance module and addresses the tasks of retrieving and showing a case study.

Case-study retrieving. The case-study retrieving is done in an adaptive way by taking into account the ontology and the beliefs of the teacher-student. During the analysis of a problem case-study, the assistance module tries to retrieve similar past case studies stored in the case-study base. The search for similar case studies considers concepts represented on the ontology in order to improve the heuristic function used by the algorithm. This function computes the similarity between case studies by measuring the similarity between the case study's characteristics and those of the case studies in the database. During this computation, it navigates into the ontology in order to identify generic concepts that are common to the characteristics being compared. Thus, the similarity computation is based on the characteristic hierarchical position. For instance, if a teacher-student has a problem related to the mishandling of the blackboard and pencils during the class presentation, the assistance module can retrieve case studies related to the mishandling of a projector.

This is possible because the projector and the blackboard are represented in the ontology as being didactic equipments, then the algorithm attributes a degree of similarity to them. In addition to the use of the concepts defined in the ontology, the assistance module takes into account a set of rules representing the beliefs of the teacher-student. The assistance module instantiates the conditions of these rules with the characteristics of the problem case-study in order to deduce new characteristics of the problem case-study or to increase the relevance of the ones already detected that are associated to implicit beliefs the teacher-student may have. For example, when a teacher-student faces a problem of relationship with students during a night class, the assistance module can recover from the base of rules the following belief: "Teachers believe that students of night classes are uninterested in doing homework during the day." In that way the assistance module can retrieve past similar case studies where this belief is presented.

*Case-study showing***.** To define how a case study must be shown, the adaptation process takes into account the characteristics of the teacher-student and of his/her context of use. After these characteristics are identified, the assistance module chooses the best view to show a case study. For instance, a view that is a combination of sound and image of a case study cannot be appropriate if the context of use of the user (a laboratory, for instance) is very noisy. The views are predefined according to guidelines. These guidelines allow us to determine the best way to divide a screen, to show many media at the same time, to give the user the option of hearing a story about a case study in a quick or slow way, or to repeat a story.

Figure 5 shows a view combining a graphic scenario and a textual story that corresponds to a scene of the case study "nobody wants to write." In this scene, the students complain because they do not want to perform the required task. Figure 5 depicts some buttons that express the assistance available for the teacher-student. These types of assistance are as follows:

- To see reflective questions (*reflective questions* button), which refers to some questions the teacher-student puts to himself/herself, in order to help him/her recognize the problem and reflect about it.
- To obtain specifications of concepts describing the problem case-study (*see more* button).
- To obtain didactic material (*didactic material* button), which suggests some text to be seen in CadiNET, for instance.
- To see the case-study orientation and results of the case study which he/she thinks has some similarity with his/her problem (*found my case* button). The case-study orientation and results refer to a procedural strategy that can help the teacher-student decide what to do, taking into account what other people did

Figure 5: One scene of the case study "nobody wants to write"

(their solutions). It should be stressed that case-study solutions were not presented at first, since it is desirable to instigate students' reasoning and creativity in finding their own solutions.

- To obtain the list of teacher-students who are using the system and that can collaborate (*Cadi on-line users* button).

The collaborative assistance process will be described in the next section.

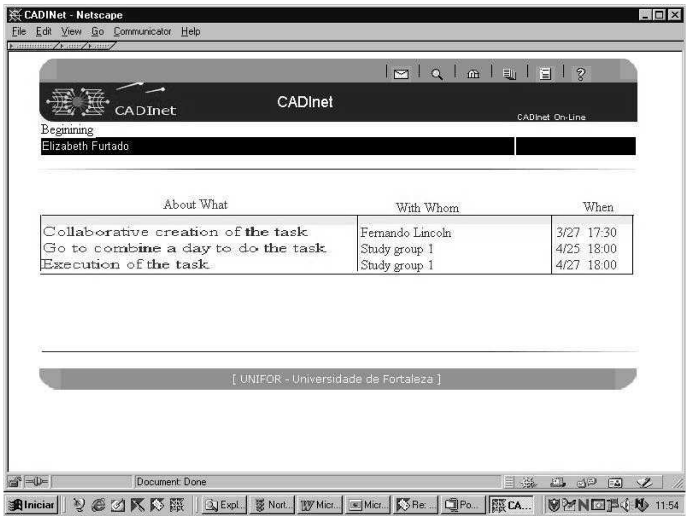
THE COLLABORATIVE ASSISTANCE PROCESS

In this process, emphasis is given to collaborative features among teacher-students through the integration of CADI with CadiNET and TELE. The CadiNET environment helps the teacher-student discover when and with whom he/she can collaborate.

TELE allows the teacher-student to have access to some functions which will, in turn, make it possible for him to establish synchronous interaction with colleagues (such as videoconferences and chats) or to share applications. This collaboration process is characterized by four sequences of operations, namely: the "access request," the "creation of a videoconference," the "entrance to work together," and the corresponding "exit from a videoconference." A practical example of the advantages of such integration is the possibility of performing a task in a collaborative fashion, with several colleagues interacting straight from home.

In the CadiNET environment, teacher-students of a given study group can book a conference to enable the performance of a task or the collaborative solution of a

Figure 6: The agenda in CadiNet



problem. The reservation is automatically included in the list of conferences, which can be seen in Figure 6.

On the day and at the time set for the conference, the students enter the environment and look for their colleagues to start the conference. This is quite a simple procedure: Press the *CadiNET on-line users* button and select the student, whose name appears on the pop-up window.

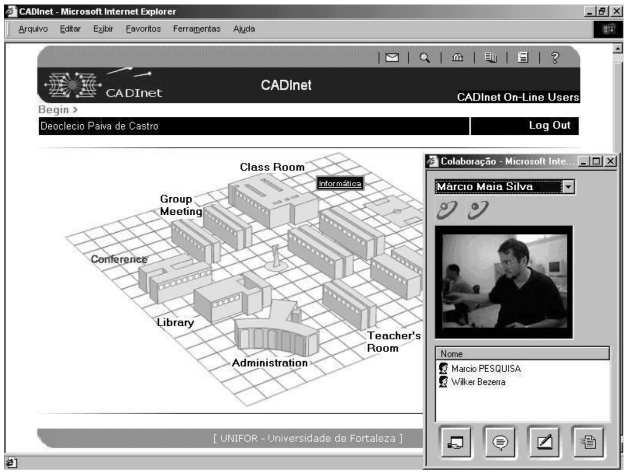
The system will provide the means to establish synchronous communication. When the student who was summoned answers the call he will appear on screen (Figure 7). Once they are in conference, the students will wait for the other members of the team to arrive so that the session can be actually held.

When all the members of a group are in conference, they start the work proper, using the features of the TELE environment, where they can talk among themselves (using the TELE chat), send one another new files that may be necessary (using an email), use blank areas to exchange ideas, and even open any application in order to share it.

The screen of the shared application will be shown on the computer of every student in conference, and any alteration performed by one of them will automatically reflect on the other teacher-students' screens.

In Figure 8 the scenario editor is shared. It is useful when some reflection on problems relative to the contents of the course is required, because teacher-students can, for instance, build one possible solution together. When the solution is ready, a teacher-student can send it to the expert through CadiNET.

Figure 7: At TELE, waiting for the "arrival" of the other members of the group



IMPLEMENTATION ASPECTS OF THE TELE-CADI

The environment presented here was implemented using different programming languages and technical solutions.

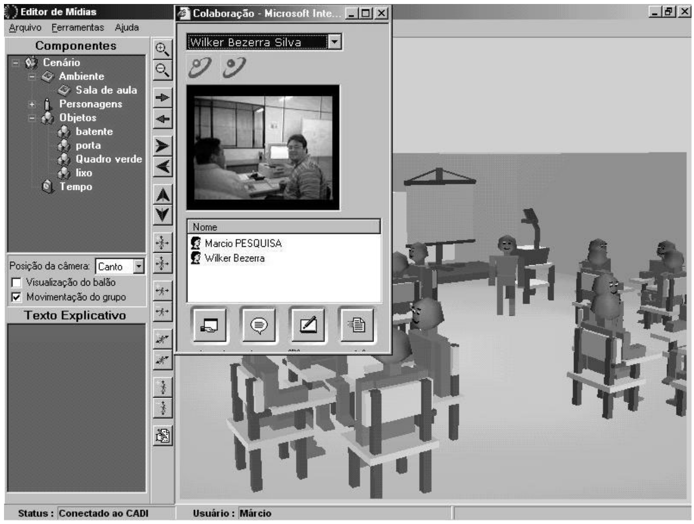
The ontology, scenario and rule editors were built in Borland Delphi 5.0. They access the knowledge base, whose internal representation is done by using SQL tables. The scenario editor makes it possible to construct the graphic scenarios through the GLScene component, which uses graphic objects built by the 3D Studio tool.

The case-study-based reasoning module was also implemented in Borland Delphi 5.0. The Web pages seen by the teacher-student use the Microsoft Component Object Model (COM) technology to run the reasoner. Even though the graphic case studies are shown in 3D, we intend to use the VRML programming language in order to allow the teacher-student to manipulate the 3D virtual graphic scenarios in the Web.

CadiNET is composed of approximately 100 pages programmed in Microsoft ASP and it also accesses the SQL tables that contain information on the user and the course as well as texts.

In the TELE implementation, two premises were initially established. The first one concerns the adoption of patterns established by such organisms as ITU (International Telecommunications Union) and IETF (Internet Engineering Task Force); and the second one refers to the needs in adopting the Internet-based environment as basic infrastructure. We used some ActiveX controls of Microsoft NetMeeting. The interface was worked through the use of a group of parameters that

Figure 8: The scenario editor



control the objects that will be presented in the user interface. Among the different patterns that NetMeeting supports are the following: ITU H.323 for audio conference and video, ITU T.120 for multi-point conference of access for data, and IETF LDAP for directory services.

FUTURE WORK

The multidisciplinary dimension of this work is characterized by the studies done in divers areas of knowledge, from human-computer interaction and artificial intelligence to pedagogy.

Distance learning adheres to a vision where on-line learning applications are developed for the widest population of users in the most varied contexts of use by taking into account individual differences. One way to assure universal access to distance learning is to develop learning applications with adaptive user interfaces. These interfaces, able to *adapt* themselves to the user and contexts of use characteristics, are called user interfaces for all. Existing design methods do not necessarily support designing such user interfaces. New design methods have been proposed since then.

Even though we have not yet implemented a method for designing such user interfaces, we have described one method based on an ontology structured into the three levels defined here (Figure 3). The main goal of this method relies on its ability to exploit instantiations captured in individual models to produce multiple UIs, possibly for different computing platforms, development environments or programming languages. The major advantage of the method is that change operated at any level is instantly propagated to subsequent levels: When the ontology changes, all possible models change accordingly; when a model changes, all possible specifications change accordingly and so the set of all possible UIs that can be created.

A relatively new field being studied in artificial intelligence and business is the learning organization (LO). LOs are organizations that are constantly expanding their capacity to create and re-create their respective futures. Such organizations, also named “knowledge-creating” companies, will therefore be those that systematically create new knowledge, disseminate it throughout the entire organization, quickly incorporate it into new technologies and products, and provide a means to store it, thus insuring against loss.

We are integrating the Tele-CADI environment in a computational architecture called MC2 (Furtado & Colera, 2000) that brings together a set of tools that support the process of the learning organization by allowing the creation and maintenance of organizational memory. MC2 has a *participative space*, which makes computerized procedures available that seek to contribute to the development of better relationships between the people and sections of an organization. Tele-CADI has important features for achieving this goal because it provides tools to improve individual learning within an organization by collaboration during problem solving.

Not only can Tele-CADI be used with MC2 to improve the creation and maintenance of an organizational memory, but also to open the possibility of creating a corporate universe. In doing this, it is possible to reach the employee through the Internet in order to motivate him/her to improve his/her knowledge in interesting subjects proposed by the company.

As we have described previously in this article, the didactical approach we follow is strongly influenced by two new concepts: i) teaching must take into account the students’ goals and ii) problem-solving methodologies are the best alternative to achieve this.

Teaching is essentially a social task that involves a very strong component of dialogue. The interaction between teacher and students becomes a fundamental element in the learning process. Moreover, the collaboration among teachers is established as a central factor in the learning process. This collaboration leads an individual to reflect about the situations he/she encounters.

However, the teacher’s development is not limited to the contact with students and colleagues. It includes built-in social and historical experiences, which should also be taken into account during the processes of educational problem solving. Therefore, the teacher’s knowledge does not just result from his/her educational experience, but from the wider experience gathered during his/her life.

A collaborative and adaptive teacher’s development, therefore, should take into account these wider aspects of the individual. Therefore, besides case studies, Tele-CADI needs to improve its representational and inferential capacity to work with narratives that include social and historical components.

CONCLUSION

This chapter presented an environment which can be considered essential for transporting the teacher-student into a usable system for the following reasons: (i) the teacher-student can explore many kinds of multimedia facilities for the solution of problems according to guidelines and his/her own beliefs, preferences and autonomy; (ii) the teacher-student's reflection on these problems and the possible consequences of the solution he/she proposes can help him/her improve his/her classes and adopt an integrated pedagogical-technological content; and (iii) the collaborative support of assistance through case studies can help the teacher-student find a possible solution from the experiences that collaborators have had in their classes.

Our work is still at an early stage; however, the evidence encourages us to believe that the overall environment being developed has considerable possibilities. The knowledge base is based on concrete experiences, obtained from discussions with a group of 36 teachers. During these discussions, the groups debated and shared their didactic practice and the underpinning knowledge mobilized in this practice. These discussions helped us to discover 25 teachers' beliefs and 80 case studies. In the whole process, the method of problem solving guided us, but we were very privileged by the cooperation we received from the group. At this point, we are searching for solutions that fit the new educational paradigm we believe is evolving at the present time.

ACKNOWLEDGMENT

We wish to thank Cnpq and Unifor, who have sponsored this project, and extend a special thanks to our team, who have supported us in this effort with so much competence that we have come to think of them as a real research group. Our deepest thanks go to: Leandro da Silva Taddeo, Daniel William T. Rodrigues, Wilker Bezerra Silva, Francisco José Alves, Felipe Távora and Márcio Maia Silva.

REFERENCES

Aamodt, A., & Plaza, E. (1994). Case-based reasoning: Foundation issues, methodological variations and system approach. *AI Communications*, *7*(11).

Alarcão, I. (1996). Formação reflexiva de professores—Estratégias de supervisão. Porto: Porto Editora.

Bastien, J. M. C., & Scapin, D. L. (1993). *Ergonomic criteria for the evaluation of user interfaces* (Rep. No.156). INRIA.

Benyon, D., Crerar, A., & Wilkinson, S. (2001). Individual differences and inclusive design. In C. Stephanidis (Ed.), *User interfaces for all—Concepts, methods, and tools* (pp. 21-46). Mahwah, NJ: Lawrence Erlbaum.

Bodart, F., & Vanderdonckt, J. (1993). Expressing guidelines into an ergonomical style-guide for highly interactive applications. In S. Ashlundn, K. Mullet, A. Henderson, E. L. Hollnagel, & T. White (Eds.), *Proceedings of InterCHI'93* (pp. 35-36).

Bourne, J. R., McMaster, E., Rieger, J., & Campbell, J. O. (1997). *Paradigms for on-line learning: A case study in the design and implementation of an asynchronous learning networks (ALN) course*. Retrieved from http://www.aln.org/alnweb/journal/issue2/assee.htm

Dewey, J. (1959). Como pensamos. São Paulo: Companhia Editora Nacional.

Eleuterio, M., & Eberspacher, H. (1999). A knowledge management approach to virtual learning environments. In *Conference International WISE* (pp. 55-61).

Furtado, E., Furtado, V., Bezerra, W., William, D., Taddeo, L., Limbourg, Q., & Vanderdonckt, J. (2001). An ontology-based method for universal design of user interfaces. *Proceedings of Workshop on Multiple User Interfaces over the Internet: Engineering and Applications Trends*. Retrieved from http://www.cs.concordia.ca/%7Efaculty/seffah/ihm2001/program.html

Furtado, E., Mattos, F. L., Furtado, J. J. V., & Holanda, R. (2001). Um sistema de aprendizagem colaborativa de didática utilizando cenários. *Brazilian Review of Learning Systems* (Vol. 8).

Furtado, E., Silva, W., Alves, J. J., & Távora, F. (2001, August). Um ambiente de ensino e colaboração a distância para formação e atualização de professores da unifor. Congresso Internacional sobre Educação a distância. Retrieved from http://www.abed.org.br/trabalhos

Furtado, J. J. V., & Colera, C. (2000). Integrating information systems and knowledge engineering to improve learning organization. *Americas Conference on Information Systems, AMCIS 2000*.

Gomes, F., & Viccari, R. (1999). Uso de Heurísticas no projeto de interfaces inteligentes. In *International Congress WISE* (pp. 103-109).

Gruber, T. R. (1993). Toward principles for the design of ontologies used for knowledge sharing (Tech. Rep. No. KSL-93-04). Stanford, CA: Stanford University, Knowledge Systems Laboratory.

Hix, D., & Hartson, R. (1993). *Developing User Interfaces*. New York: John Wiley & Sons.

Hoc, J. M. (1996). Supervision et contrôle de processus , La cognition en situation dynamique. Presses universitaires de Grenoble.

Neto, H., Raimir, H., Bezerra, W., & Sarquis, O. (2000). Especificando o tele-ambiente no contexto da educação a distância, Anais do SBIE'2000. Alagoas.

Perrenoud, P. (2001). Formando professores profissionais: quais estratégias? quais competências? Porto Alegre: Artmed.

Pozo, J. (1998). A solução de problemas. Porto Alegre: Artes Médicas.

Rasmussen, J. (1983). Skills, rules, knowledge: Signals, signs, symbols and other distinctions in human performance models. *IEEE Transactions on Systems, Man, and Cybernetics*, *SMC-13*(3), 257-266.

Schank, R. (1994). Dynamic memory: A theory of learning in computers and people. Cambridge, England: Cambridge University Press.
Schank, R., & Cleary, C. (1995). *Engines for education*. USA: Paperback.
Schön, D. (1987). *Educating the reflective practitioner*. New York: Jossey-Bass.
Vigotski, L. S. (1984). A formação social da mente. São Paulo: Martins Fontes.