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Developing Higher-Order Skills with the MEDIT Web-based Learning Environment

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ABSTRACT

Interaction among actors involved in a Web-based learning environment is widely thought of as a valuable process, in that it stimulates collaborative work and augments the effectiveness of learning itself. This may be extensively achieved by the integration of groupware tools and techniques, originally coming from the *Computer-Supported Cooperative Work* discipline. This paper reports on *MEDIT*, a Web-based environment that addresses various pedagogical issues and has been developed in line with the above. Offering complementary support, and not substituting traditional practices, our approach distinguishes three *virtual workspaces* and provides appropriate services for each of them. The paper focuses on the presentation of the innovative tools MEDIT is composed of. These concern the *multiple view representation* of a course, the creation and maintenance of *student customised courses*, several *exercise methods*, *argumentative discourse* between teachers and students, and *group decision making*. MEDIT has already been used in five undergraduate courses demonstrating promising evaluation results.

Keywords

Distance learning, World-wide web-based courses, Argumentative discourse, Group decision making

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1. Introduction

The use of World-wide Web as a platform for learning systems receives much attention in the last few years, mainly due to its communication framework and associated facilities for representing, storing, exchanging, searching and accessing multimedia information. The design and implementation of an efficient and effective *Web-based Learning System* (WLS), however, is not a straightforward task. It relies on a comprehensive problem modelling and an appropriate use of the underlying information and communication technologies [Erickson 96]. Despite the attractive perspectives, WLS developers have to face technical difficulties concerning the production of multimedia information (which is to be shared among a variety of users and applications), efficient information retrieval, reuse of existing pedagogical material, and management of communication between the users (not to mention other problems such as quality assessment, intellectual property rights, etc.).

Most of the above issues are addressed in various research projects, both in academia and industry. Major problems raised when developing an educational hypertext system are the conceptual linking of documents, design of user-friendly interfaces, and customisation of access to pedagogical material [Brown 87]. The current trend is obviously towards the development of open hypermedia systems that encompass Web technologies [Anderson 97]. Production of computer-based teaching material to be both accessed and viewed in an interactive way is certainly an important issue during the development of a WLS [Ressler 97]. Efficient organisation of document bases for multi-user activities is another [Rein et al. 97]. In line with the above, *ARIADNE* is a European project that aims at defining, implementing and testing methodologies for the proper use of telematics-based solutions for academic education and certain types of corporate training [Forte et al. 96]. A system for managing electronic documents, namely the *Knowledge Pool System*, has been specified, which is based on a pedagogical indexation scheme. Other aspects addressed are the course assembly and delivery. *MATILDA* is another information framework that considers the above issues by separating the information domain from the application one, aiming thereby to promote information reuse and provide a "cleaner" identification of information structure [Lowe and Ginige 96].

Other systems have developed integrated frameworks that include remote edition and hyperdocument management facilities, communication tools, and specific educational services (for a comprehensive review evaluating seven such systems, see [Bethoney 97]). For instance, *World Wide Web Course Tools* (WebCT) [Goldberg et al. 96], [Goldberg and Salari 97] and *CourseInfo* (see http://www.cit.cornell.edu/atc/cst/) propose interactive quizzes; *Lotus Learning Space* (see http://www.lotus.com/home.nsf/tabs/learnspace) and *TopClass* (see http://www.wbtsystems.com/) offer the possibility to create a virtual classroom; *CyberProf* (see http://www.howhy.com/home/) and WebCT provide tools to track and evaluate students and classes.

However, the use of a computer-supported learning environment also raises social issues related to whether it will be accepted and understood by the actors involved, since it significantly changes traditional teaching practices. Moreover, its associated learning and educational effectiveness has frequently been criticised; the emphasis on deploying fixed bodies of information and the failure to develop critical thinking and problem solving skills have been reported as serious weaknesses in such systems [Alavi 94]. On the other hand, interaction among all actors involved is widely thought of as a valuable process, in that it stimulates collaborative work and augments the effectiveness of learning itself. This may be extensively achieved by an appropriate integration of groupware tools and techniques, originally coming from the *Computer-Supported Cooperative Work* (CSCW) discipline [Baecker 93], [Greenberg 91].

MEDIT (Multimedia Environment for Distributed Interactive Teaching) is a recently completed research project that provides an innovative Web-based environment for a variety of pedagogical issues (see http://medit.epfl.ch:4444). It was an internal project of the MEDIA (Models and Environments for Document-related Interaction and Authoring) research group, Department of Computer Science, EPFL (Swiss Federal Institute of Technology), which took place from Jan.'97 to Dec.'98. The system implemented intends to offer complementary support to traditional practices, and not to replace them, while is highly focused on the stimulation of collaboration between the actors involved. We consider computer-mediated collaboration as a superior pedagogical process and we aim at giving all actors, and especially students, a more *active* role. Using MEDIT, teachers and students may cooperate on a variety of course-related activities (i.e., lessons, exercises, informal discussions, etc.), and are able to work with multimedia documents using a set of *Hypermedia Authoring Tools* implemented for the needs of the project.

MEDIT offers most of the services provided in the above mentioned systems and research projects [Abou Khaled et al. 98b]. However, the originality of our approach lays on the use of highly structured documents that renders an efficient management of all document classes. For instance, starting from the same set of course documents, actors may extract *multiple view course representations* (by chapter, session, or semantics), even create and maintain their own *customised courses*. The system also provides several interactive *exercise methods*, both for self and supervised training. Furthermore, keeping in mind that learning environments require appropriate mechanisms to motivate discussions and collaborative work [Okamoto and Inaba 96], MEDIT provides an advanced tool for Web-based argumentative discourse and decision making between teachers and students [Karacapilidis and Papadias 98b].

The rest of the paper focuses on the presentation of the innovative features of the system. It is organised as follows: Section 2 reports on the modelling of the issues addressed during the development of the project; we describe the actors and roles involved, the services provided, and the *virtual workspaces* we have distinguished. Sections 3 to 5 discuss tools and techniques related to the *Courses*, *Cooperative* and *Exercises* workspaces, respectively. In the sequel, Section 6 provides the system's evaluation data, while Section 7 presents a comparative analysis of MEDIT against eight well-used WLSs and outlines future work plans.

2. Modeling issues

As highlighted above, MEDIT was conceived as a learning environment that would be able to offer higher-order skills to the users involved. The introductory goals were to go beyond traditional WLS practices, stimulate collaboration and provide the means for an "active" learning process. During the early phases of the project, we had many discussions with a variety of experts and users involved in the pedagogical domain. The major objective was to clearly prescribe the roles of the *actors* involved and the *services* required. Having thoroughly studied the existing WLSs, the first part of the questions asked concerned whether the already provided WLS features cover the users' needs. The second part was focused on the introductory goals mentioned above. More specifically, it included questions of the type: *"Do you think that a web-based collaboration tool would be helpful for a class project?"* (addressed to both students and teachers), *"What is your opinion about the ability to flexibly organise a course?"* (addressed to teachers), *"According to your learning practices, do you think that the ability to restructure a course the way you wish would be a plus to a WLS?"* (addressed to students), etc. The outcome of those discussions led us to distinguish a set of course-related activities, the idea being that each of them is often associated with different *actors* and/or *services* and, therefore, different tools are needed. This partition was based on the concept of *virtual workspaces*.

2.1. Actors and services

In a teaching environment, the basic actors are certainly *teachers* and *students*. They can either produce or consume information. In the first case, they are responsible for generating and organising the documents (choosing the appropriate layout and formats), while, in the second one, they seek information for various purposes (research, review, consulting, etc.). Use of Web-based technologies involves numerous technical and administrative problems which have to be addressed by another actor, the *system manager*. Furthermore, when working with a web-based group discussion and decision making tool, like the one our system provides, the various argumentation elements inserted by the basic actors need first to be "checked" by a *discussion moderator* whose role is to assure that they are to be inserted at the right position in the corresponding discussion graph (see Section 4), to check cognitive and comprehensibility issues of such elements, etc.

The services provided in MEDIT have been classified as follows:

- *authoring services:* They concern a variety of document classes and the basic actors. Our environment provides appropriate authoring tools for teachers to edit and organise their courses (based on contents, semantics, etc.), exercises (questions, quizzes, simulations, etc.), and collections of information (bibliography, announcements, links, etc.), and for students to resolve exercises, perform examinations, create customised courses, etc.
- *information access and retrieval services:* They are related to multiple view representation, navigation and search mechanisms applying for all document classes (courses, exercises, articles, etc.). They also concern the exchange of documents and usual problems arising from different document formats and contents type.
- *communication and collaboration services:* These include features provided in the tools related to group discussion and decision making, news, mailing lists, and Frequently Asked Questions (FAQs).
- *Management services:* They concern the organisation and storage of documents, documents' coherence, access rights, communication protocols, etc. They have often been addressed together with the services of the above categories (for instance, in most cases authoring also involves coherence management and access rights definitions).

Keeping in mind that the effectiveness of a learning system can be seriously reduced by a badly conceived *human-computer interaction*, much care was given to the design of the Web interfaces and the usability of the system. The former took into account the specific features of the platform, such as the totally customised information access, while the latter concerned the system's suitability for a task, determining whether the user requirements are met (for more, see [Abou Khaled et al. 98a]).

2.2. Virtual workspaces

After a series of interviews with the main actors and experts in the teaching domain, and in order to fulfil their needs, we developed an architecture based on a decomposition of *virtual workspaces*. A workspace can be viewed as an instantiation of the teaching environment (with its own document classes and tools), according to one's specific teaching context. Therefore, each workspace is related to specific teaching services and offers the appropriate tools for them. Workspaces are further decomposed, as shown in Table 1.

During the development of a WLS, most approaches view a course as an indivisible entity. That is, they do not allow the teacher to have a choice of services or a personal configuration of the course. On the contrary, our environment allows him/her to select the spaces he/she desires for the course and, in the sequel, the corresponding virtual course environment is automatically generated. This incorporates *on-the-fly* creation and compilation of the associated software classes.

COURSES	COOPERATIVE WORK	EXERCISES
Multiple View Representation *(by Chapter, Session, or Semantics)*	Newsgroups and Mailing Lists	Electronic Homework *(Self or Supervised Training)*
Student Customised Course	Argumentation and Group Decision Making	Logically Structured Exercises
Other Information *(Bibliography, Assignments, Agenda, Announcements, Utilities)*	Frequently Asked Questions	Quizzes *(Self or Supervised Training)*

Table 1. The MEDIT virtual workspaces

3. The Courses Workspace

The *Courses Workspace* includes tools for *multiple view* course representation, *course customisation* and maintenance of related material, such as bibliography, assignments, agenda, announcements and utilities (hardware and software needed for each course). We present in this section its most interesting features, paying particular attention to those that promote interaction among actors. Students here are not only consumers of information but, on the contrary, they are able to enrich the course by attaching annotations and generating a customised version of the course.

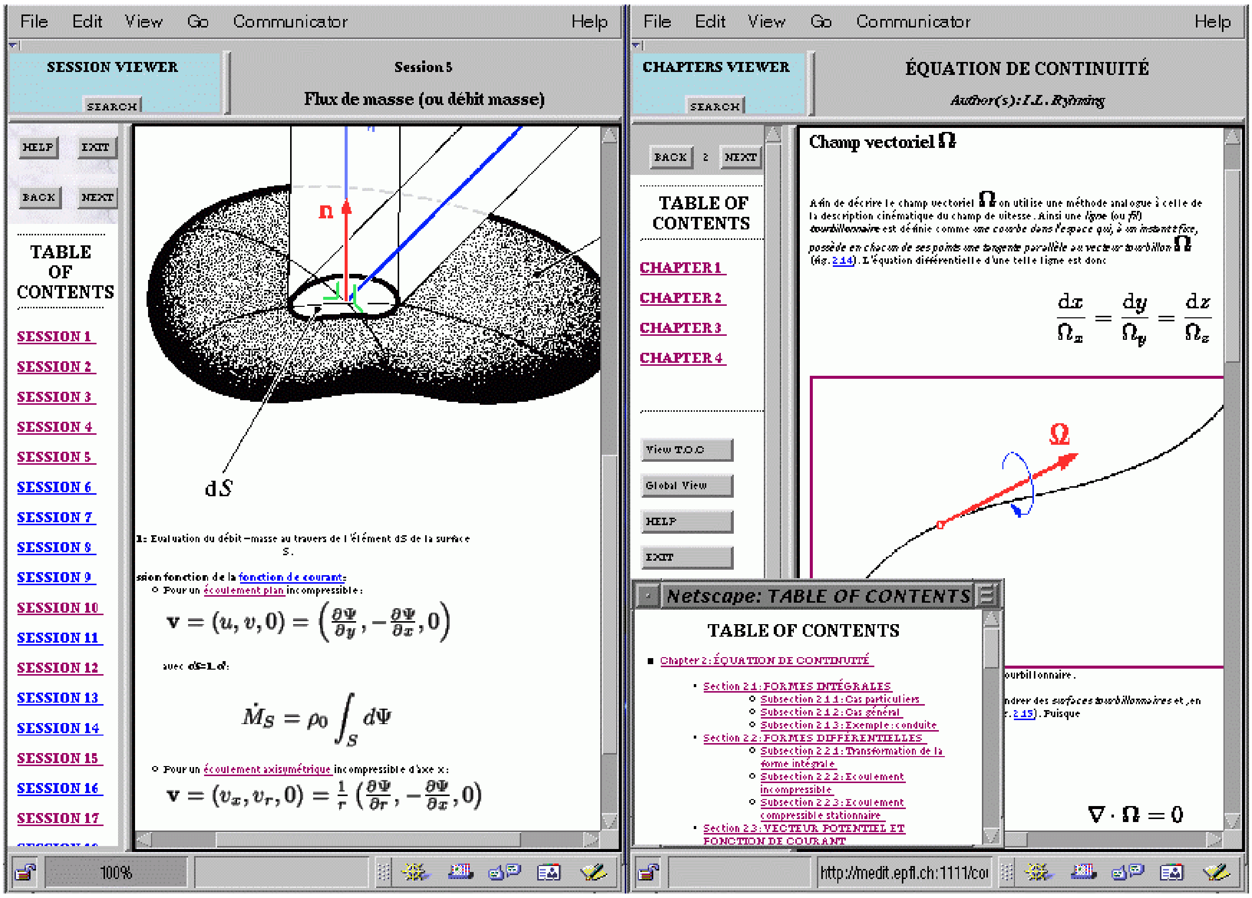

Figure 1. Working with MEDIT: sample course pages

3.1. Multiple view representation

The course book and notes are the basic support for any course. The contents of the book are organised by *chapter*, while the course notes by *session* (samples of such course pages, built through MEDIT, are shown in Figure 1). Beyond traditional approaches, that provide a course view by book chapter or session date, MEDIT offers another view based on course *semantics*, the idea being to reuse the same course contents in order to present it according to alternative viewpoints. Semantic view allows an actor (teacher or student) to select what and how he/she wants to present or emphasise, according to his/her specific interpretation. For instance, one may want to represent a course in a way that is useful for him/her to resolve exercises following a particular approach. Such an ability has been proven to give an active role and improve the critical attitude of students.

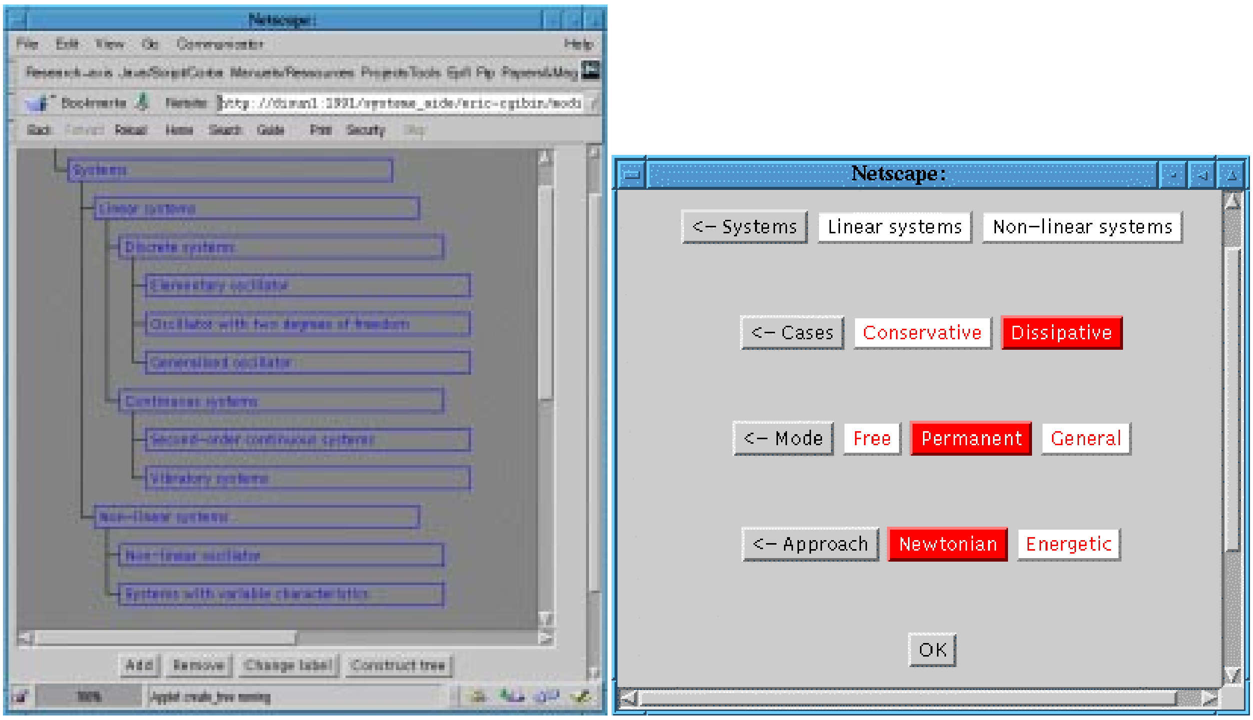

Figure 2. Semantic representation and access of a course

To create the semantic view, our approach proceeds as follows: The teacher has first to conceive his/her view of the course. As argued by most teachers who have already used the system, this is a "hard task". MEDIT allows them to represent their views in multiple dimensions and abstract levels, the aim being to satisfy individual needs and viewpoints. Each dimension can be represented via a tree-like schema where nodes correspond to those levels. MEDIT offers an easy-to-use tool to support this task (Figure 2, left window). Every leaf of the tree may correspond to a course *concept*, *method* or *definition*. The addition, removal and renaming of such leaves are performed with the use of the Add, Remove and Change label buttons, respectively. Having finished with such tasks, the teacher has just to click on a button (Construct tree) and the system will generate a set of HTML files corresponding to the tree specified (note that in each such file there is information about its corresponding path in the tree). The teacher can also launch an editing tool and use existing views (by chapter or session) and external information to edit the files that correspond to the semantic view. To access this course view, actors may use the interface shown in the right window of Figure 2. In the example given here, the course was built across four dimensions, which are represented by the four series of nodes in the figure, while red buttons correspond to the already selected nodes. The nodes appearing in this interface are related to the tree constructed by the teacher and are updated automatically whenever the teacher modifies the tree. Clicking on the OK button, the required node is retrieved.

3.2. Student customised course

MEDIT reserves a private virtual workspace for each student registered in the course. The space remains his/her property during the semester. It serves like an electronic notebook where he/she can put his/her own notes and documents. The management of the space is totally autonomous for each student. Features involved here are the easy creation, editing and deletion of the space and its components, access protection capabilities, and attachment of annotations and external existing documents (according to different views, after searching the Web, etc.). Our tool for creation and maintenance of a student customised course does not only permit the attachment of annotations to an existing document (like what happens, for instance, in the *Web Course* environment - see http://www.madduck.com/), but also the integration of any course documents according to the students' favourite learning style. In the example illustrated in Figure 3, a student browses the course documents both by chapter and session (two top right windows). Having selected a link from one of these windows, the corresponding file appears in the top left window. This file is highly segmented according to a predefined set of HTML tags. The student can then select the segments he/she is interested in, and preview the file he/she has been working on so far in the window appearing in the bottom part of the figure.

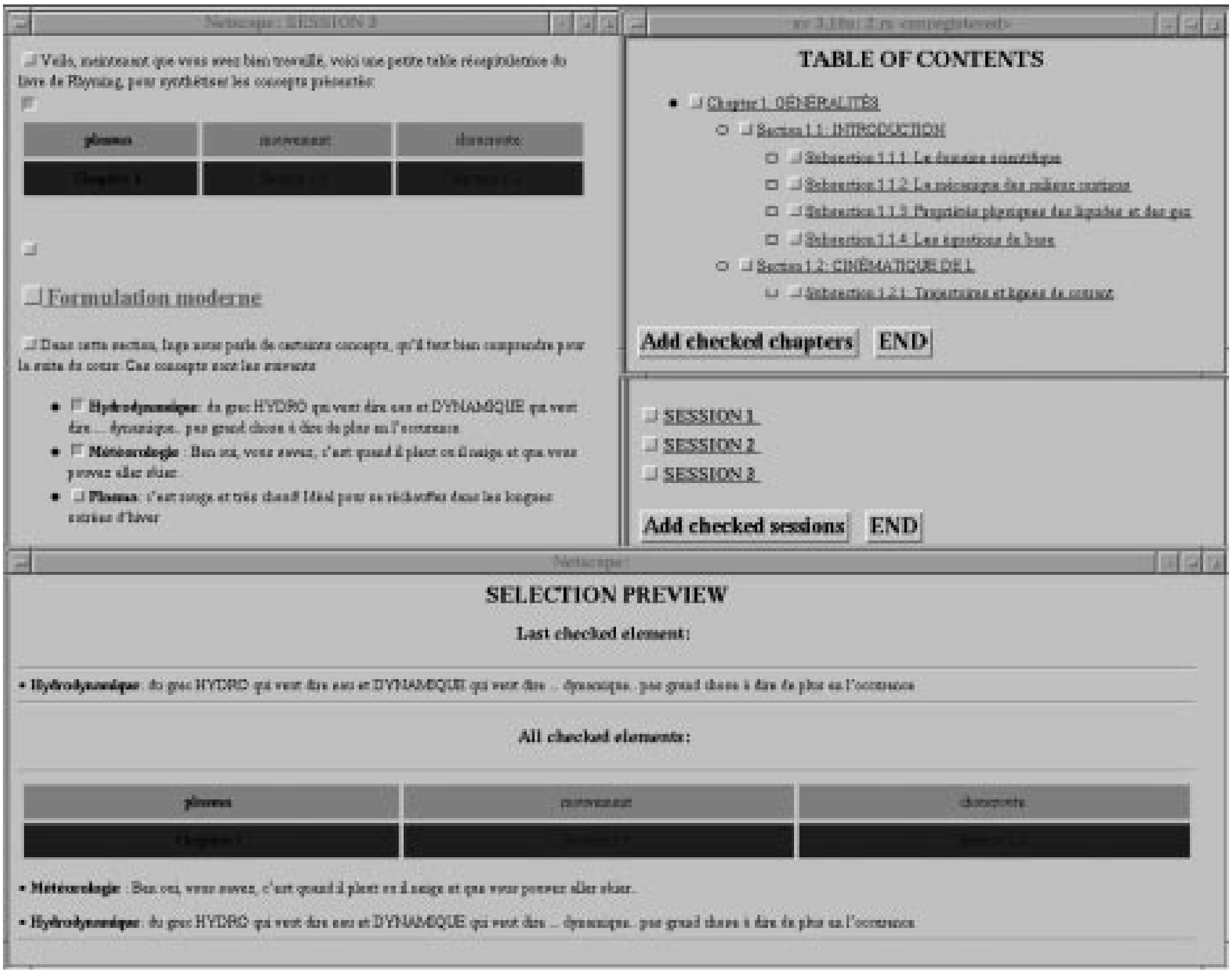

Figure 3. Creating a customised course

The ability to customise his own workspace makes the student responsible for the content of his/her course and may improve the quality of learning. Felder [Felder 96] has defined five categories of students according to their preferred way of learning (namely *active, reflective, visual, verbal* and *intuitive* learners). Our approach is well suited for any of them. For instance, a visual learner may prefer to create a course with many figures, tables and images. On the contrary, a verbal learner may mostly use annotations and notes when creating his/her own space.

4. The Cooperative Workspace

One of our main objectives in MEDIT is to augment the effectiveness of discussions among groups of students and teachers through the interactive sharing of information between them. Having removed communication impediments using the Web, we provided techniques for structuring the decision analysis and systematically directing the pattern, timing, or content of such discussions. Among the major issues arising during the development of such a tool are the effective organisation of (usually informal) discourses, and provision of rules and procedures for achieving consistency and automation of data processing.

4.1. The argumentation tool

Students usually have to confront decision making situations while, for instance, they participate in a group project, solve exercises together, etc. In order to reach a solution, they often have to consider a variety of alternatives. Conflicts among the individual students' suggestions are inevitable and support for achieving consensus and compromise is required. Each student may adopt and, consequently, suggest his/her own approach; opinions may differ about the relevance or value of a proposition when deciding an issue; students may also have arguments supporting or against alternative solutions. In addition, they have to confront the existence of insufficient and too much information simultaneously. In other words, for some parts of the problem, relevant information which would be useful for making a decision is missing, whereas for others, the time needed for the retrieval and comprehension of the existing volume of information is prohibitive.

MEDIT provides an advanced discourse and group decision making tool, which is able to address the above issues. The tool augments classical decision making approaches by supporting argumentative discourse among students and teachers. Its argumentation framework is a variant of the informal *IBIS* model of argumentation [Rittel and Webber 73], later used in the development of groupware tools such as *gIBIS* [Conklin and Begeman 87] to capture the rationale of a design process. The argumentation elements provided are *issues*, *alternatives*, *positions*, and *constraints* representing *preference relations*. In the sequel, we use a real example about the solution of an exercise given to a group of two students in the context of a Fluid Mechanic course. The actors involved in the discussion, namely the teacher and two students, bring up the necessary argumentation in order to express their perspectives. The left window of Figure 4 illustrates an instance of the corresponding *discussion forum*. As shown, our approach maps a multi-agent decision making process to a discussion graph with a hierarchical structure.

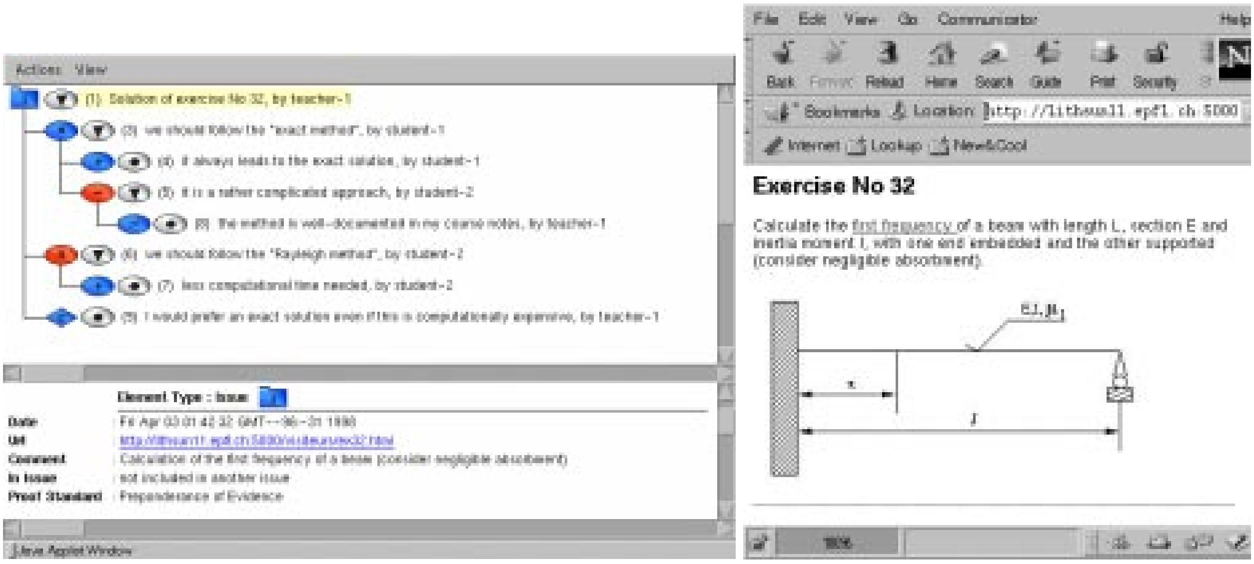

Figure 4. Discourse and group decision making in MEDIT

Issues correspond to decisions to be made, or problems to be solved (e.g., *issue-1:* "Solution of exercise No 32"). They are brought up by any type of actor and are open to dispute. Issues consist of a set of *alternatives* that correspond to potential choices (e.g., *alternative-3:* "we should follow the exact method", and *alternative-6:* "we should follow the Rayleigh method" both belong to *issue-1*, while they have been proposed by student-1 and student-2, respectively). Issues can be inside other issues in cases where some alternatives need to be grouped together. *Positions* are asserted in order to support the selection of a specific solution (alternative), or avert the actors' interest from it by expressing some objection. For instance, *position-4:* "it always leads to the exact solution" has been asserted by student-1 to support *alternative-3*, while *position-5:* "it is a rather complicated approach" to express student-2's objection to it. Positions may also refer to some other position in order to provide additional information about it (e.g., *position-8:* "the method is well-documented in my course notes" was brought up by teacher-1 to argue against *position-5*). A position always *refers to* a single other position or alternative, while an alternative always belongs to an issue.

In decision making environments, one has usually to weigh different criteria. Unfortunately, well defined utility and probability functions, regarding properties or attributes of alternatives (used in traditional decision making approaches), as well as complete ordering of these criteria are usually absent. In our approach, *constraints* provide a qualitative way to weigh reasons for and against the selection of a certain course of action. A constraint is a tuple of the form [position, preference_relation, position], where the preference relation can be *more (less) important than* or *of equal importance to*. Constraints may give various levels of importance to alternatives. Like the other argumentation elements, they are subject to discussion; therefore, they may be "linked" with positions supporting or challenging them. In Figure 4, *constraint-9*: "I would prefer an exact solution even if this is computationally expensive" expresses the preference relation "*position-4* is more important than *position-7*". Note here that the preference has been inserted by teacher-1; by participating - together with students - in such discussions, teachers also play a more active role (compared to other current approaches).

4.2. Group decision making

Alternatives, positions and constraints have an *activation label* indicating their current status, which can be *active* or *inactive*. This label is calculated according to the argumentation underneath and the *type of evidence* specified for them. In general, different elements of the argumentation, even in the same debate, do not necessarily need the same type of evidence. Active positions are considered "accepted" due to discussion underneath (e.g., strong supporting arguments, no counter-arguments), while inactive positions are (temporarily) "rejected". Similarly, active alternatives correspond to "recommended" choices, i.e., choices that are the strongest among the alternatives in their issue.

Apart from an activation label, each constraint has a *consistency label* which can be *consistent* or *inconsistent*. Every time a constraint is inserted in the discussion graph, the system checks if both positions of the new constraint exist in another, previously inserted, constraint. If yes, the new constraint is considered either *redundant*, if it also has the same preference relation, or *conflicting*, otherwise. A redundant constraint is ignored, while a conflicting one is grouped together with the previously inserted constraint in an issue automatically created by the system, the rationale being to gather together conflicting constraints and stimulate further argumentation on them until only one becomes active. If both positions of the new constraint do not exist in a previously inserted constraint, its consistency is checked against previous active and consistent constraints belonging to the same issue.

Argumentation in our framework is performed through a variety of *discourse acts*. These acts may have different functions and roles in the argumentative discourse. We classify them in two major categories: *agent acts* and *internal (system) acts*. Agent acts concern user actions and correspond to functions directly supported by the user interface. Such functions include the opening of an issue, submission of an argumentation element (such as alternative, position, or constraint), etc. Internal acts are functions performed by the system in order to check consistency, update the discussion status and recommend solutions. These functions are called by the agent acts and are hidden from the end user (the complete description of the mechanisms for calculation of activation and consistency labels, which is beyond the scope of this paper, can be found in [Karacapilidis and Papadias 98a], [Karacapilidis and Papadias 98b]).

As a stand-alone module, the argumentation framework presented in this section can act as an assistant and advisor, by recommending solutions and leaving the final enforcement of decisions and actions to the participants. The system platform facilitates access to the current knowledge by making available all relevant data and documents. Each time one selects (using the mouse) an argumentation item in the upper pane of the *Discussion Forum* window (Figure 4, left window), all related information is given in the lower pane of it. By clicking on the Url entry, the associated HTML file appears in a new window. In the example given, the Url address corresponds to the full definition of exercise No 32 (Figure 4, right window). In such a way, participants may associate to their discourse elements any piece of information provided in the course.

The *Cooperative Workspace* also provides a tool for the creation, edition, storage and retrieval of frequently asked questions (there also exist *newsgroups* and *mailing lists* facilities, but we do not discuss them here since their concepts are trivial). Such questions can be brought up by a student and answered by one or more teachers. They are organised by categories and keywords, thus facilitating their retrieval. In many cases, such questions may raise an issue to be collaboratively discussed and solved through the argumentation and group decision making tool described above. Finally, answers to these questions can be annotated and electronically linked with other course documents.

5. The Exercises Workspace

The *Exercises Workspace* provides tools for various exercise methods, namely the *electronic homework, logically structured exercises* and *quizzes* (both *self* and *supervised training* facilities are provided for the first and third ones). Exercises are created and maintained by teachers. Particular care has been given to the ability of integrating mathematical formulas in web documents. The associated tools support LaTeX formats and can automatically convert such formulas into GIF images (to our knowledge, this feature currently exists only in MEDIT and *Cyberprof*).

The *Electronic Homework* tool replaces traditional homework methods by managing the electronic creation, solution and delivery of students homework. It also provides students the ability to use external applications, such as *Mathematica* or *Maple*, while working on their homework. Such a feature is especially required in engineering courses, where students need to prepare their homework by working on complicated calculations and plotting of the results. Using our tool, they can launch the required applications and easily fill in their homework documents with the results obtained.

Exercises can be conceptually decomposed in items such as *definitions, keywords, hypotheses, data, solution methods, results,* etc. In other words, teachers are able to define their own (preferred) exercise segments. Our environment offers a tool for such a decomposition, thus permitting a highly segmented hypertext presentation of exercises while allowing students to access individual components. This structure renders efficient information retrieval during different learning phases. For example, a student may only need to check the results of an exercise after having solved it, or consult some solution methods while preparing himself/herself for the exams. Certainly, the definition of such segments depends on the course; an Archaeology and a Fluid Mechanics course will rather need different such decompositions. We believe that the approach suggested is meaningful; all teachers we collaborated with so far have admitted that they were accustomed to work in a similar way (when traditionally designing exercises for students). However, it still remains to test its suitability to less mathematical-oriented courses.

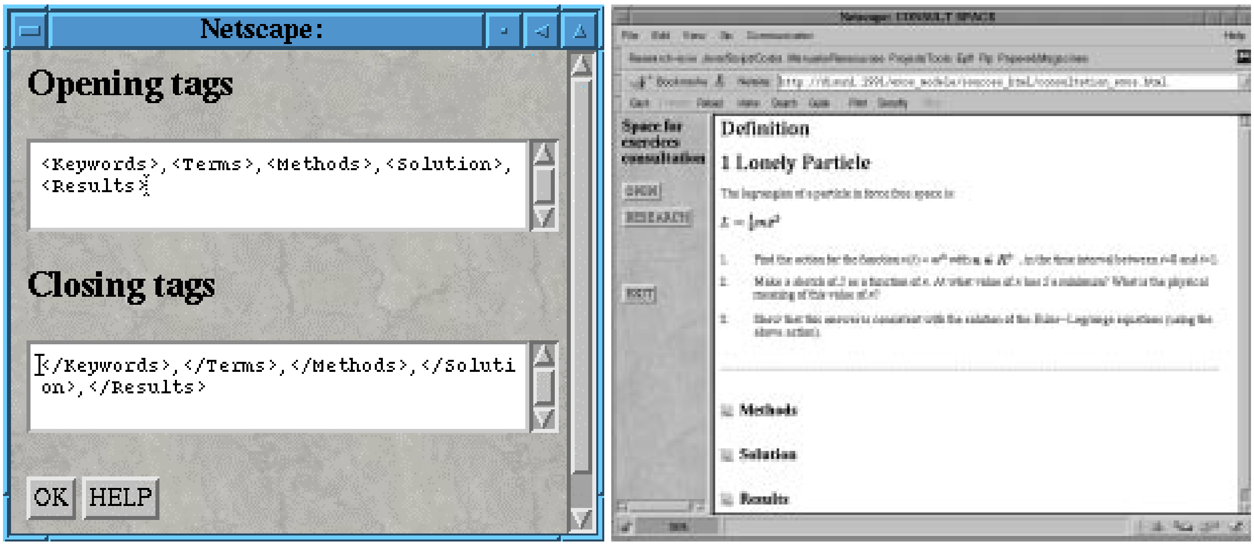

Figure 5. Logically structured exercises

Figure 5 (left) shows the dialog window with which a teacher may define his/her own tags used for the logical decomposition of the exercises (once the "opening tags" have been defined in the upper pane, the lower pane is automatically filled in with the "closing tags"). The right window of the figure illustrates an example of a logically structured exercise, segmented according to the tags defined in the left window.

The Exercises Workspace also includes a tool, namely *Xquiz*, for remote creation, access, solution and delivery of *Multiple Choice Question* exercises. Interesting features of the tool are the ability to integrate images and formulas, access management (teachers can make such exercises available to different groups of students), and automatic evaluation of results.

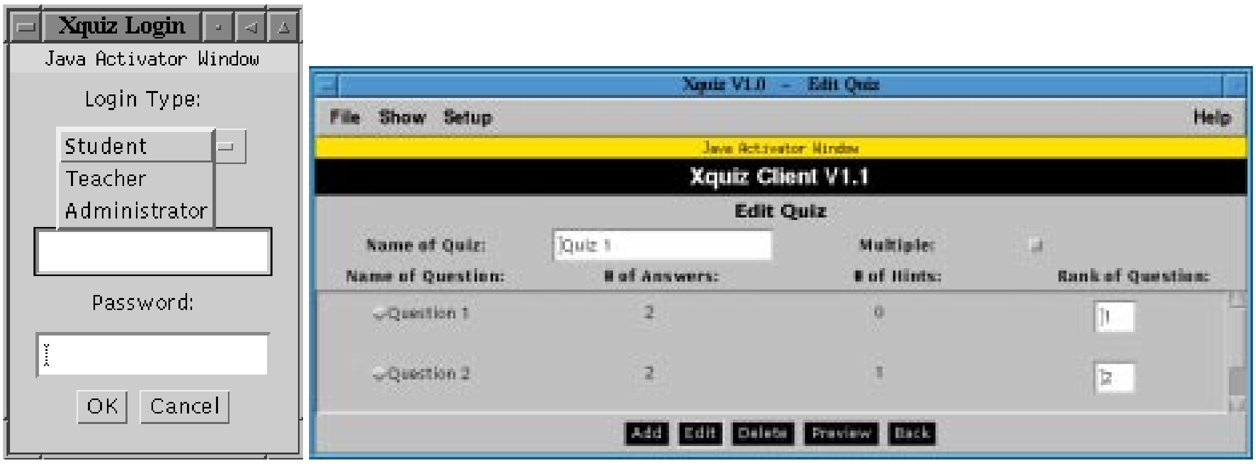

Figure 6. Quizzes

Figure 6 (left window) shows the authentication dialog box, where three types of actors are supported: teacher, student and administrator. In the right window, a teacher can edit a quiz (this window is slightly different when viewed by a student or the administrator). The teacher fills in the quiz, and is able to give multiple answers and hints to each question. The quiz may be accessed by the students several times or only once, depending on whether the Multiple box (middle right) is checked on not, respectively. In the first case, the quiz is to be used by the students for their self-training, while in the second one, as (a part of) an official examination.

6. Evaluation

To get the users acquainted with the system, an introductory presentation of less than an hour for students and about two hours for teachers is sufficient (teachers have access to more tools of the system). A member of our development group had to supervise and assist the users during their first try. MEDIT has been evaluated through two undergraduate courses (*Fluid Mechanics* and *Vibratory Mechanics*) at the Swiss Federal Institute of Technology, and another one (*Databases*) at the University of Geneva, Switzerland. All three courses took place in the Spring '99 Semester. The evaluation was performed with the participation of 7 teachers (3 professors and 4 assistants) and 53 students. The related data, which correspond to two series of questionnaires distributed to all of them, are given in Figures 7 and 8.

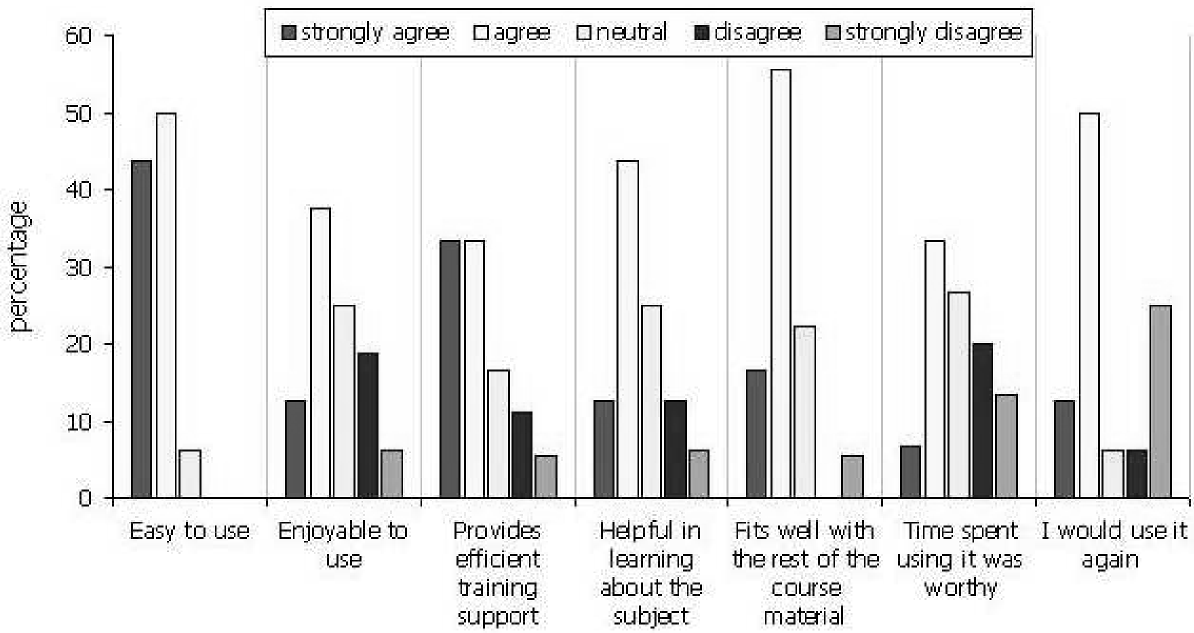

Figure 7. Evaluation data - Part 1

The objective of the first questionnaire (Figure 7) was to evaluate the users' overall opinion about the system. Users were asked whether MEDIT is easy and enjoyable to use, provides efficient training support, is helpful to learn about the subject, and fits well with the rest of the course material. Also, whether the time spent working with it was worthy and they intend to use it again. To fill the questionnaire in, users had to give an answer from the [strongly agree, agree, neutral, disagree, strongly disagree] scale. The feedback we received is certainly encouraging. In most of the issues raised above, the percentage of the positive answers (sum of the strongly agree and agree percentages) is more than 50%. As for the last but one issue (namely, whether the time spent was worthy), users seemed to be sceptical. Having further elaborated their answers, we concluded that this is due to the change of the way they are accustomed to work. However, we argue that this is an issue that does not only concern MEDIT; on the contrary, it concerns WLSs as a whole.

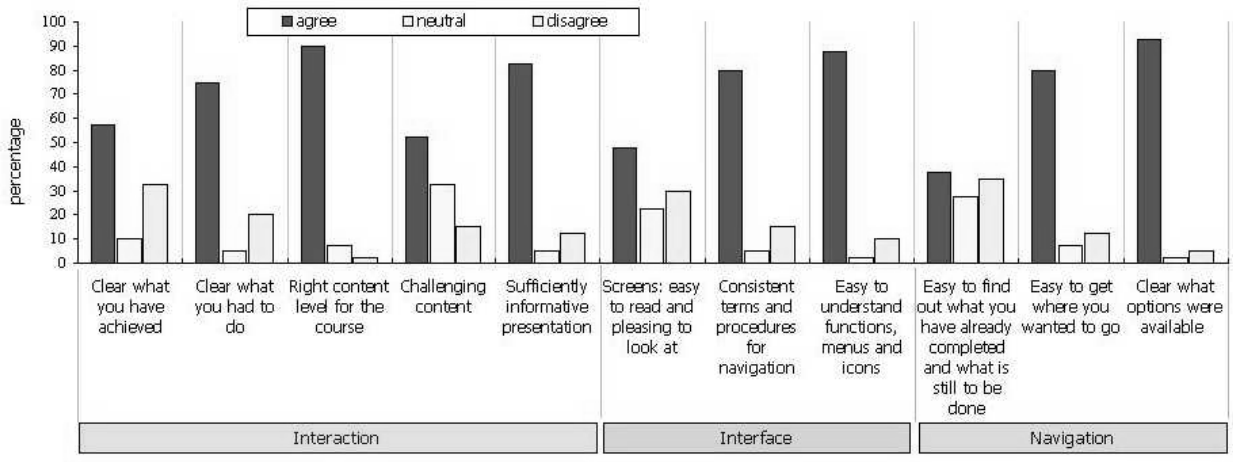

Figure 8. Evaluation data - Part 2

The objective of the second questionnaire (Figure 8) was to get users' assessments about the effectiveness of the suggested learning environment. More specifically, users had to evaluate the levels of *interaction* (answering whether what they had to do and had achieved using the system was clear, the content level was right and challenging, and the presentation was sufficiently informative), *interfaces* (answering whether windows are easy to read and pleasing to look at, terms and procedures for navigation are consistent, and functions, menus and icons provided are easy to understand) and *navigation* offered (answering whether it was easy to find out what they had already completed, what it is still to be done, where they wanted to go, and what options were available). For all these issues, users had the [agree, neutral, disagree] choices to select from. As of the percentages shown in Figure 8, this part of evaluation data is also positive.

Apart from the results given above, the evaluation brought out that 83% of the students (44 out of 53) liked the idea of having their own customised workspaces, while 66% of them (35 out of 53) that of having tools for on-line solution and delivery of their homework. A total (concerns both teachers and students) 88.3% liked the way of course decomposition, while 81.7% the multiple view representation ability. The discussion forum tool, with its group decision making and problem solving features, was used by all 7 teachers and 42 students. Almost all of them (91.8%) are already convinced that the appropriate integration of collaboration-based tools in a web-based learning environment has a high potential to enhance its effectiveness.

7. Discussion

Various comparisons of Web-based learning systems exist presently on the Web (see, for instance, http://www.ctt.bc.ca/landonline/, http://www.geocities.com/Eureka/Gold/6012/compare_web_tools.htm, and http://sunil.umd.edu/webct/). A problem when performing such comparisons is the definition of the evaluation criteria. To our opinion, such criteria have to take into account the different actors' roles while, at the same time, they must first focus on the pedagogical value and not on the technical features of the systems.

Teacher	MEDIT	WebCT	TopClass	CyberProf	Virtual-U	Learning Space	CourseInfo	Course Web Toolkit	Web Course in a Box
No HTML knowledge required	✓	x	x	x	✓	x	x	✓	✓
Upload to server ability	✓	✓	x	✓	✓	x	✓	✓	✓
HTML format supported	✓	✓	✓	✓	✓	✓	✓	✓	✓
LaTex format supported	✓	x	x	✓	x	x	x	x	x
Automatic Glossary and Index	x	✓	x	x	x	x	x	x	x
Search Tool for course material	✓	✓	x	x	x	x	x	x	x
Individual and Group Management for course content	✓	x	✓	x	✓	x	✓	✓	x
Tele / Video-Conferencing	F	x	x	x	F	F	✓	x	x
Course planning ability	x	✓	✓	✓	✓	✓	✓	✓	✓
Mail / Newsgroups supported	✓	✓	✓	✓	✓	x	✓	x	✓
Chat supported	x	✓	x	x	F	F	✓	x	✓
Whiteboard	x	x	x	x	F	F	F	x	x
Interface customization ability	✓	✓	✓	x	x	x	✓	x	✓
Help provided	✓	✓	✓	✓	✓	✓	✓	✓	x
Remote access tools provided	✓	✓	✓	✓	✓	✓	✓	✓	✓
Timed Quizzes	F	✓	✓	x	x	x	x	x	✓
Quizzes: Automatic Answering	✓	✓	✓	✓	x	✓	✓	x	✓
Random generation of questions	F	✓	✓	x	x	x	x	x	x
Multiple course view ability	✓	x	x	x	x	x	x	x	x
Multidimensional content structuring ability	✓	x	x	x	x	x	x	x	x

Table 2. A comparative analysis from the teacher's point of view

In line with the above, this section presents a comparative analysis of MEDIT against eight well-used WLSs, the aim being to guide users in finding the one that best matches their requirements and find the pros and cons of our approach. These are: *WebCT*, *TopClass*, *Cyberprof*, *Virtual-U*, *Learning Space*, *CourseInfo*, *Course Web Toolkit*, and *Web Course in a Box*. The systems selected for this comparison offer services that fall in the categories described in Section 2.1. Tables 2,3 and 4 illustrate our analysis with respect to each actor involved (teacher, student, and system manager, respectively). In these tables, the "checkmark" symbol denotes that the related entry is currently supported, the "x" symbol declares its absence, while "F" stands for informing that it is foreseen (developers of some systems were asked to fill in the related table cells, when the case was not clear to us).

Student	MEDIT	WebCT	TopClass	CyberProf	Virtual-U	Learning Space	CourseInfo	Course Web Toolkit	Web Course in a Box
All entries from Table 2	*As in Table 2*								
History available (student access and progress)	F	✓	✓	x	x	x	✓	x	x
Special plug-ins required	✓	x	x	x	x	x	✓	✓	x
Multiple course view ability	✓	x	x	x	x	x	x	x	x
Private annotation of course material	✓	✓	✓	✓	x	x	x	x	✓
Private course management	✓	x	x	x	x	x	x	x	x
Customized information access (by theme)	✓	x	x	x	x	x	x	x	x

Table 3. A comparative analysis from the student's point of view

The comparative study shows that, even if the majority of these eight systems offer various well-implemented features, they do not address higher-order pedagogical skills, as MEDIT intends to do. More specifically, it is only MEDIT that provides teachers with multiple course view and multi-dimensional content structuring abilities; it is also among the few that provide interface customisation, enabling teachers to include the desired services when building a course. In addition, MEDIT and CyberProf seem to be the only ones that allow the edition of mathematical formulas (in LaTeX format). However, compared to WebCT, it does not provide "chat" and automatic glossary tools. From the students' side, MEDIT is once again the sole system that offers multiple course view, private course management and customised information access features.

System Manager	MEDIT	WebCT	TopClass	CyberProf	Virtual-U	Learning Space	CourseInfo	Course Web Toolkit	Web Course in a Box
Authentication required (password and username)	✓	✓	✓	✓	✓	✓	✓	x	x
Crash recovery tool	✓	✓	x	x	x	✓	✓	x	x
Remote access tools	✓	✓	✓	✓	✓	✓	✓	x	x
Special plug-ins required	x	x	x	x	x	x	x	x	x
UNIX platform	✓	✓	✓	✓	✓	✓	✓	✓	✓
Apple platform	x	x	✓	x	x	x	x	x	x
PC platform	x	F	✓	✓	✓	✓	✓	✓	✓

Table 4. A comparative analysis from the System Manager's point of view

Speaking about future work directions, we intend to deal with the *tracking of the student acts* during the creation and maintenance of their customised workspaces, the aim being to extract valuable information about their profiles, interests, and learning attitudes. This information will aid teachers to re-evaluate their course conception, design of exercises and projects, and in general, the full course environment. We also plan to enhance the group discussion and decision making tool in order to provide assistance to the students during their participation in a project. The idea is to aid them in constructing robust arguments and, consequently, finding the right solutions through the consideration of *similar cases* which could be retrieved from previous projects, course documents, external Web information, etc. Similar tools have been recently integrated in *Belvedere* to address various students' tasks, such as retrieval and use of information, when there is a scientific controversy [Toth et al. 97], [Suthers et al. 95].

Concluding, we argue that the design of a WLS is admittedly not a widely prescribed process, since it leaves room to different interpretations and uses of the Web platform. Most systems use it to provide a virtual classroom with all traditional course components. On the contrary, MEDIT aims at giving innovative features to traditional learning in order to support the acquisition of higher-order skills for the actors involved. It provides tools for a customised "tailoring" of course-related information and groupware facilities to further promote interaction and collaborative work between teachers and students.

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