The AEC Virtual University

Design Oriented Knowledge Transfer Methods and Technologies

Mario de GRASSI[1], Alberto GIRETTI[1], Liliana BAZZANELLA[2] and Luca CANEPARO[2]
[1] *Università di Ancona, Italy*
[2] *Department of Architectural Design, Politecnico di Torino, Italy*

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Abstract: The paper introduces the Web based INtelligent Design Support (WINDS) European Project to support education in design, a.k.a. the AEC Virtual University. The Project is divided into two actions. First, the research technology action will implement a learning environment integrating an intelligent design tutoring system, a computer instruction management system and a set of co-operative supporting tools. Second, the development action will build a large knowledge base supporting Architecture, Civil Engineering and Construction Design Courses and to experiment a comprehensive AEC Virtual University.

1 INTRODUCTION

Present education paradigms in architectural education still largely rely on a two-century-old tradition derived from the French Academies. Several patterns from the Academies' tradition still persist in the studios: design exercise as simulation, educator's role, graphic formulation and continuous teacher-student interaction (Cuff 1991; Schon 1985; Argyris and Schon 1996; Oxman 1999).

In undergraduate and graduate curricula the intersection between design and technology is often prevented by a clear-cut division between course subjects, an excessive rigidity of curricula, and a pervasive difficulty in defining effective multidisciplinary courses or studios.

In University departments, especially the technical ones, the most successful courses tend to be those where there is a strong and deeply rooted research activity. This trend towards specialization causes the spreading of expertise over the territory as a direct consequence. The contribution of best practices from architectural firms and construction industries is loosely accomplished.

Restoring quality to multidisciplinary design teaching therefore needs the reorganisation of the didactic structure in view of rationalization and content

integration.

On the other hand great things are expected from the capability of information technology to contribute to innovative design education. As we look around Universities, we can see most professors lecturing using the chalkboard. A few use videotape and fewer are using the computers in the classrooms or studios. Overhead and slide projectors are probably the most used educational technologies. Therefore it is not realistic to expect that computers *alone* will innovate design education, because social systems, such as Universities and Schools, are difficult to innovate. On the other hand, the Internet - by which we mean the entire digital information infrastructure- is the living demonstration of the impact the technology has on social structure, insofar as the Net meets the business, productive, communicative and entertainment requirements of the contemporary society.

2 THE WINDS PROJECT

WINDS is a project funded by the European Community in the 5th Framework, Information Society Technologies programme, Flexible University key action. WINDS is divided into two actions:

- The research technology action is implementing a learning environment integrating an *intelligent design tutoring system*, a *computer instruction management system* and a set of *co-operative supporting tools*.
- The development action is building a large knowledge base supporting Architecture, Civil Engineering and Construction Design Courses and to experiment a comprehensive AEC Virtual University.

During 2000-2003 the WINDS project is spanning a total effort of about 150 man-years from 28 partners of 10 European countries.

In the third year of the project, more than 400 students all over Europe will attend the Virtual University, which, at present, offers 24 courses relating to 3 "Departments": Architectural Design, Environmental and Building Technology, Construction Management.

3 THE WINDS EDUCATIONAL FRAMEWORK

The WINDS educational framework is the set of theories and methodologies which are at the basis of the WINDS e-learning system. The WINDS educational framework has been designed to provide a frame of reference for the design and implementation of curricula and courses in an AEC Virtual University. It is based on three complementary psycho-pedagogical theories, respectively Goal-based Scenario (GBS), Issue Concept Form (ICF) and Concept Maps (CM).

GBS is an innovative curriculum design methodology developed by Roger Schank

(1994). GBS shares several principles with the current practice of curricula design in Architectural Design Courses and can be naturally integrated with the Competence Management framework. In WINDS, GBS has been used to put and to extend many current practices on a sound pedagogical basis.

ICF is a well known formalism employed in architectural design teaching. It has been initially developed by Rivka Oxman (1999). It captures the well-known practice of precedent based design in Architecture and relates it to sound pedagogical frameworks. ICF is concept based, therefore it integrates smoothly with the concept maps technology, which is the basic pedagogical framework of WINDS.

Concept Maps come from Ausubel's learning theory (1978, 2000). They can be viewed from many points: as a knowledge representation tool they share a lot with semantic networks. As a psychological model of mind they are related to mental models. In fact they result in a constructivist learning model and in a number of pedagogical tools suitable for distance learning.

3.1 Cognitive Models for Design

In the last decade, a considerable body of design research has begun to increase our understanding of the cognitive properties of design, and has provided new directions for the development of design education.

Cognitive approaches to design and the role of knowledge representation were studied by various design researchers (Bhatta 1996; Schon 1987; Eastman 1970; Akin 1986).

WINDS considers the cognitive aspects of design thinking as a basis for developing its educational approach. It considers learning itself as a cognitive function of the mind, and learning in design as a unique case. Special attention is devoted also to the issues related to the representation of design knowledge.

WINDS assumes constructivism as its reference psychological framework. The fundamental idea of constructivist psychology is that learning takes place by the assimilation of knowledge structures and experiences into the existing knowledge structures held by the learner. The assimilation is mediated in a very important way when concrete experiences are available; hence the importance of "hands-on" activities for learning with learners of any age and in any subject matter domain. Learning design is a very special case of learning by doing.

3.1.1 Mental Models

Design, as a cognitive activity, consists on the construction of a consistent model of the reality, where all the aspects, which are relevant to an effective design solution, are sharply represented.

Johnson-Laird (1983) defines these kinds of models of reality used by human being for reasoning tasks, mental models, and gives a number of effective procedures

simulating the human construction of mental models. WINDS assumes that design cognition falls into this rather broad category of human cognitive capabilities. It states that Design cognition is fundamentally an activity aimed at the construction and at the control of the mutual coherence of a number of mental models, concurring to the representation of the design domain.

3.1.2 Knowledge Model

A main WINDS commitment is to demonstrate that it is possible and valuable to integrate widespread design expertise so that it can be effectively used to produce a high level standard of education. To this aim WINDS gathers area knowledge, design skills and expertise under the umbrellas of common knowledge representation structures. A considerable research effort has been undertaken to develop a knowledge representation framework able to represent design expertise in domains ranging from well structured engineering (e.g. structural engineering, HVAC, etc.) to ill-defined scenarios emerging during architectural design conception (De Grassi et al. 1999).

Cases are one of the most valuable means for the representation of design expertise. Cases are noteworthy stories, which describe solutions, integrate technical details, contain relevant design failures, etc. (Figure 1). Cases are collections of *learning objects* (e.g. product models, HTML pages, pictures, videos etc.) that are indexed highlighting their relevant features. The set of indexes produced are gathered together and represents the conceptual framework. Indexes and documents are further qualified according to the *issue-concept-form* paradigm and arranged into networks, which are called *strategies*. A strategy is the representation of a fragment of expertise. It relates design issues to ideas, examples and solutions or failures, so that it captures design relevancies. A sequential arrangement of learning objects is also provided in order to support standard teaching techniques.

3.1.3 Expert Model

The WINDS expert model has been built according to the Issue-Concept-Form (ICF) paradigm (Oxman 1999) that has been adapted to support intelligent tutoring. ICF provides a cognitively plausible framework for representing design flow; it is particularly suitable to capture the conceptual phases of design ideation and conception. A fragment of typical ICF flow is shown in Figure 1. The four topics on the far left represent design issues (i.e. design a roof, remember trees, etc.). Issues are refined into concepts categories, which in turn recall forms. Forms are usually richly indexed, so that they provide relevant concept associations (i.e. structure). An expert ICF flow has been identified it can be encoded one to one into a WINDS strategy, thus becoming the knowledge source for tutoring.

Even if ICF is a valuable tool to capture almost completely the conceptual design expertise, it is not so comprehensive in the representation of the expertise in well structured domains like for example in structural engineering. In that case expertise is mostly related in the control of well-defined (sometimes standard) design

scenarios (e.g. bracing techniques, load paths, etc. for structural engineering), so that it mostly concerns figuring out and managing system behaviours from a design choice. In this case conceptually based simulation tools are the most valuable means to represent expertise and support tutoring. WINDS simulation tool is based on Bayesian Networks (BN). BN are used to represent the causal network underlying noteworthy cases in engineering design and to simulate their behaviour according to a number of boundary conditions. In the WINDS knowledge architecture BN are considered as basic learning objects and, therefore, they can be indexed so that they can be embedded inside a design flow, like any other reference or example.

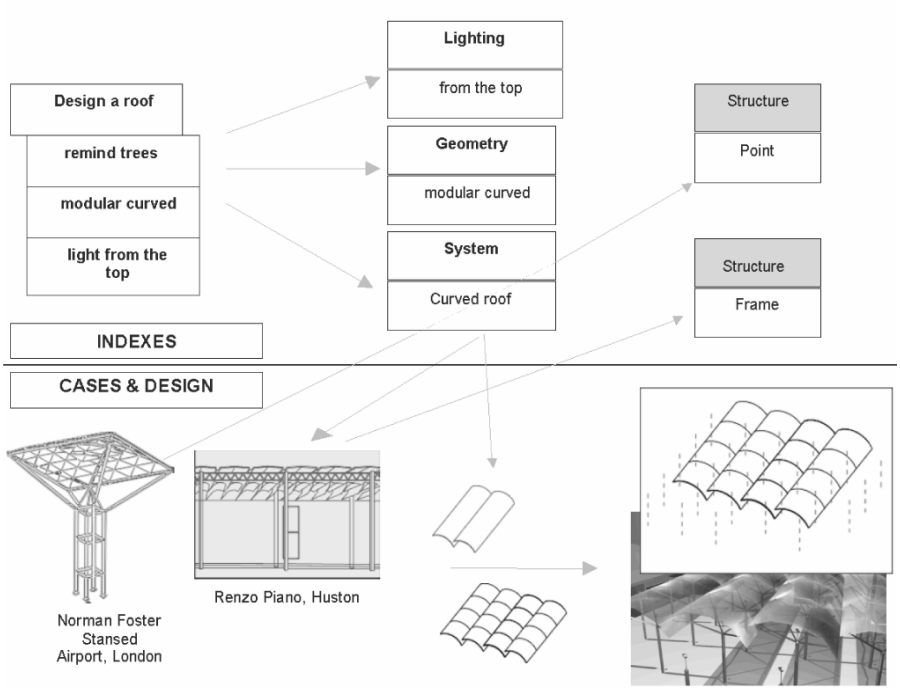

Figure 1 Example of a Design Flow With Concepts (Indexes) and Cases

4 ADAPTIVE LEARNING ENVIRONMENT

Some important aspects distinguish the WINDS platform from the most widespread e-learning systems and from other courseware (ARIADNE; Brusilovsky et al. 1997; Goldberg 1996; WBT Systems 1998; Lotus 1999; CourseInfo 1997; ToolBook; Docent Software 1997; Interactive Factory 1997; liveText Publishing 1997; madDuck Technologies 1997; CourseNet; WebCT).

WINDS presents students with a co-operative environment for project development,

which is integrated with the traditional design supports. In the Virtual University, knowledge acquisition and studio work are two complementary and closely linked activities. The students of the Virtual University have access to a networked design-tutoring environment, which provides educational resources typical of Campuses: administrative offices, courses, teachers, reviews, cooperation with other students and libraries. The system opens its educational services through the Internet by means of shared instruments, web-browsers (Figure 2) and the most widely used CAD systems. It promotes co-operation both among students (peer tutoring) and between students and teachers (remote tutoring). The system can also autonomously assist students during design courses - studios by means of intelligent tutoring techniques. Collaboration spaces implement the collaborative environment to provide the students the access to the basic functionality of the Virtual University. Students can access administrative services, obtain personal workspaces where they safely store their documents and assignments, access Departments, where they can enrol on courses, interact with teachers workspaces to obtain work revision and so on. Collaboration spaces allow students to co-operate by means of shared resources and asynchronous communication tools. A special workspace containing the university library is provided too. The university library allows the students to freely browse the university educational material.

All the functionalities and modules are accessible to professors and students without any programming or multimedia design knowledge.

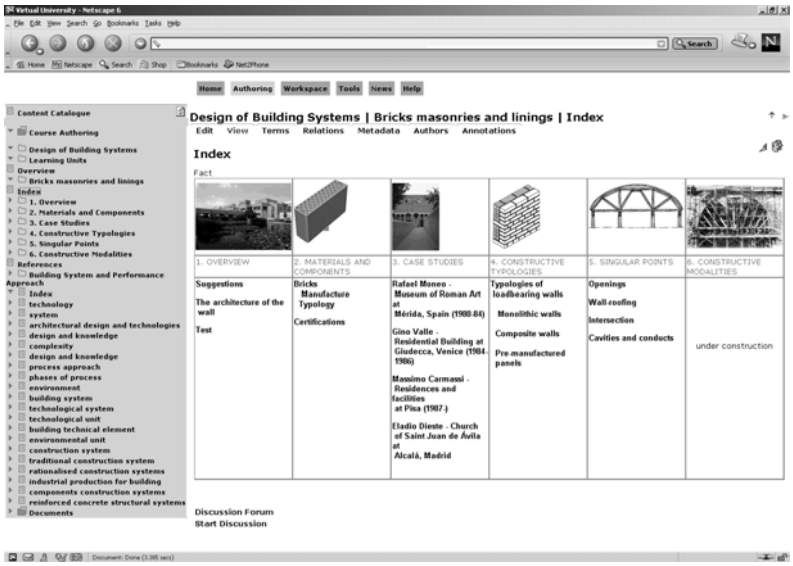

Figure 2 A Screenshot of the WINDS System

The main functionalities of the WINDS platform are the Adaptive Learning Environment, the Reflective Learning, the Learning in Context, Goal-based Scenarios and Design Rationale.

4.1 Reflective Learning

In the reflective learning environment a combination of computer-aided authoring, sketching, drawing and modelling is used to support reflective learning styles. The sketches, drawings and models are indexed in the WINDS system.

Indexes are a medium among different kinds of knowledge: they implement networks for navigation and access to disparate documents: HTML, video, image, CAD and product model. Concept indexes link-learning topics to learning objects and group them into competencies. Index relationships are the base of the WINDS reasoning processes, and provide the foundation for system coaching functions, which proactively suggest strategies, solutions, examples and avoids students' design deadlock.

Some courseware includes facilities for an automatic index, but this is an index of terms, rather than of concepts. As far as we know, managing the associations of concepts with the design media (e.g. drawings, CAD and product models) is a unique feature of the WINDS system.

The system can use the indices to create connections to the semantic layer. For learning three main use cases are implemented:

4.2 Learning in Context

WINDS allows for the visualisation of concept occurrences with the displayed learning materials, when reading a paragraph, working on a practice element or making an assessment the learners can always highlight all involved concepts in the current learning materials. This allows for finding involved topics and finding helpful and related learning materials from the current learning context.

4.3 Goal-based Scenarios

When browsing learning materials of the concept network the WINDS system displays all related concepts and all learning objects and external documents where the current concepts occur. This allows the learners to set goals on different levels. The learner can specify a concept as the current learning goal and the system will collect all learning objects and external resources where this concept occurs. Additionally the system keeps track of all resources and learning objects that have already been inspected by the user and annotates the listed learning materials in an individualized view.

4.4 Design Rationale

The ICF paradigm allows teachers to connect concepts, learning objects and forms in a special format.

Issue: The issue part mainly describes the issue of this paragraph in a text content block.

Concept: The concepts can be listed or integrated in normal text in a first content block and will be automatically detected by the parser. Additionally the users can explicitly insert references to other learning objects and describe their relation to the used concepts and to other learning objects.

Form: Professors and students can upload examples to system and integrate additional examples of arbitrary type via added content blocks.

5 WINDS COURSES

At the end of the second year WINDS has written 24 courses in the AEC domain, which entail about 500 learning units and thousands of learning objects. The writing of such a large knowledge base is aimed to develop a "critical mass" of contents largely exceeding the capabilities of a single professor or student. In that way professors and students can effectively benefit from the knowledge base during the course preparation through the setting of references and the reuse of knowledge in course units and design cases created by the others participants.

The WINDS course structure is designed to support both natural learning pedagogical requirements and dynamic curricula management. In order to implement a Goal-based Scenario, courses are always constructed around skills. Target skills are simply the set of skills the course designer wishes to convey using the course as a vehicle. They are the pedagogical goal of the overall course.

The *Mission* of a WINDS course states the kind of goal students are trying to accomplish. For instance, in a studio - design course the kind of design the student is going to pursue.

The *Cover Story* establishes the scenario of the WINDS course. It defines the subject, the context and the requirement under which the student pursues the mission. In effect the cover story is a real-world design assignment, which very naturally maps into a Goal-based Scenario. The *Course Plan* contains the actual course structure.

Learning Units are the building blocks of the WINDS courses. They are sets of self-contained educational material aimed at the acquisition of a well-defined set of skills. Learning Units are designed to pursue well-defined pedagogical goals (i.e. acquisition of skills on design, diagnosis, discovery, control, pure knowledge transfer etc.).

Learning Units are activated when their set of preconditions is satisfied. Learning Units arrange self-contained learning material, which only has indirect reference to the Cover Story problem. Learning units are controlled according to two pedagogical strategies (Figure 3). They can be either expository or exploratory. Expository learning units are traditionally conceived as a quite fixed path among different learning objects (Figure 3 left). Exploratory learning units are built of a set

of strategies and support free exploration of the conceptual space they define (Figure 3 right).

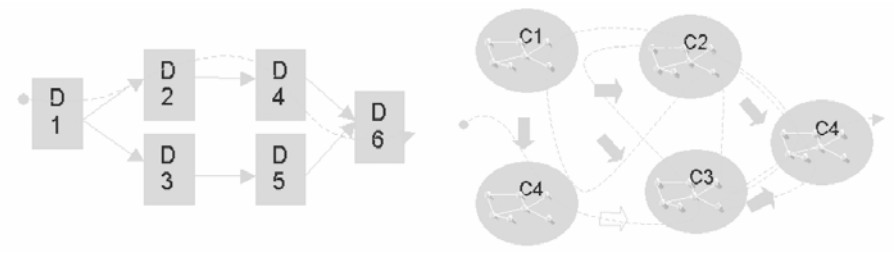

Figure 3 Student's Expository (left) and Exploratory (right) Path in Arrangement of Documents

6 CONCLUSIONS

We consider the AEC Virtual University a laboratory where new paradigms for design education are experimented. In this laboratory information technology is a catalyst for innovation: it provides the medium to implement and experiment pedagogical paradigms.

The ultimate goal of the laboratory is to provide answers to the questions raised by our present rapidly evolving society. On the one hand, are increasing the requests of specialization and decentralization in education and training. On the other hand, this can produce an increased fragmentation of knowledge, avulse from any enabling "cultural" framework.

There are major challenges in deploying any new paradigm in reality of Architecture and Civil Engineering Schools. Economical viability is certainly one of these. While education is potentially one of the largest information industries in the world, at present it still lacks critical mass. Moreover the educational paradigms for the information age are not yet perfectly clear. To experiment new teaching models and curricula organisation and to achieve critical mass, the European Community decided to allocate resources to the WINDS project to implement the information system and to create 24 on-line courses in the Virtual University as a result of the collaboration of 28 partners from 10 European countries.

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