COGNITIVE STRATEGIES FOR E-TEACHING AND E-LEARNING IN A VIRTUAL UNIVERSITY FOR DESIGN

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Abstract. Cognitive strategies for e-teaching and e-learning in a Virtual University for Design are introduced and presented. Among these are the following: conceptual navigation, content reconstruction and precedent-based navigation. We discuss and present how these strategies support a unique exploratory mode based on associative learning in the WINDS project. We demonstrate how these strategies are implemented and employed by authors and learners in the ALE system, the authoring-learning-environment component, currently under development as integral part of the WINDS project.

1. Introduction

Virtual universities are faced with the challenge of exploring the way communication and information technologies can be deployed in education. Since design has unique teaching traditions and particular pedagogical needs the design of a virtual university for design should address the exploratory nature characteristic of this field. Therefore a virtual university for design should support the domain knowledge of the field and make it accessible through appropriate pedagogy. Developing unique strategies for the design of a new VDU – a Virtual Design University have been a high research priority. We have accordingly sought to exploit new directions for the application, presentation, and accessibility of knowledge, direction which we believe makes a general contribution to this new communication and technological medium.

Most of the current strategies employed by virtual universities in constructing their curricula and course content in e-learning environments are based on traditional approaches. Traditional e-learning approaches are generally conceived in the framework of the creation and authoring of “single course content modules”. In such an approach each single course is a holistic structure that is constructed and organized independently according to the
teacher’s educational philosophy. Each course represents a “closed world” and is not linked directly with other courses. This approach supports the traditional expository style of learning. However, design teaching should be based on the ability of the learner to explore and find relevant knowledge according to his needs or design ideas. This kind of exploratory learning is usually associated with the traditional design studio framework. In order to support a similar learning style in an e-learning environment a new strategy is required. Rather than an environment for sharing “expository curriculum” in which one course leads to successive courses, we propose a curriculum-wide environment for sharing “conceptual content”. This approach is based on the organization of course materials around conceptual content in a form that might be shared and accessed freely in other course units.

In the following sections the unique pedagogical strategies that support and enhance creative learning in the WINDS project - a virtual university for design - will be presented. The design and implementation of these strategies in an e-learning environment for design was particularly interesting and meaningful, since it was the first large-scale experiment to implement and test these ideas. According to this pedagogical approach the material is organized in a particular way that supports cognitive phenomena in learning. This organization enables the learner to make free associations through connections among concepts, images, case-studies and precedents.

Among the objectives of this paper is to present the theoretical basis of the pedagogical strategies which were developed and employed in the design and the implementation of the WINDS project. WINDS is a virtual university for design. WINDS (Web-based INtelligent Design tutoring System) is a funded project of the EU-IST Fifth Framework: the Information Society Technologies Program. It is a research project that aims to build a comprehensive virtual university for architectural and engineering design. It includes 28 partners from 10 European countries. WINDS aims to provide a framework related to curricula design and the production, delivery, and evaluation of educational material in a virtual school for design. WINDS seeks to implement a unique electronic learning environment in the domain of architectural and engineering design, to create a rich ensemble of courses, and to develop within the course construction a domain knowledge base that is oriented towards conceptual content. WINDS is currently in the final phase in which a re-evaluation of course implementation, and redesign of the management system and course user interfaces are being undertaken.

The ALE platform is the main WINDS e-learning environment component which has been developed by Fraunhofer IT in Germany (Specht et. al., 1998; 2001). The ALE system provides a unique Authoring and Learning Environment for both teachers and learners and was designed to offer possibilities to accommodate a wide selection of curriculum of on-line courses for students of the virtual design university. The unique pedagogical
strategies behind WINDS (De-Grassi et al., 2002) are reflected in the design and implementation of the ALE system.

In the next section the theoretical basis underlying the unique pedagogical strategies implemented in WINDS will be presented and described. The following section will discuss how these strategies may contribute to the development of a unique learning environment and might be employed in a virtual university for design. How these strategies relate to the interface implemented in the ALE system, the current learning environment of the WINDS project, will be demonstrated and explained. Following this theoretical and methodological presentation, we will discuss and demonstrate these ideas in the framework of a single course unit. The final section will explain and demonstrate the full potential of this strategy within a whole design curriculum and multiple courses in a virtual university for design. We shall demonstrate how students might construct their own knowledge paths within a single course unit as well as within the whole curriculum. We believe this model suggests a new basis for the organization of course material and an effective application of domain knowledge in designing a virtual university for design.

2. Pedagogical and Theoretical Basis

The theoretical framework of WINDS attempts to integrate the following three aspects: pedagogical method reflected in the development of cognitive strategies; an approach to domain knowledge in design reflected in course and curriculum organization and structure; and an approach to the employment of the new technology of e-learning. In WINDS the pedagogical approach has attempted to achieve synergy at the level of the virtual design university by creating a knowledge system out of the multiplicity of courses. This basic framework has been termed as the “tri-partite ontology” (the integration of pedagogy, domain knowledge, and technology) of a virtual university for design, and it has been described in a prior paper (Oxman, 2003). In the present paper we focus on the pedagogical basis that underlies the unique cognitive strategies developed and implemented in WINDS.

2.1 FROM DESIGN PEDAGOGY TO E-DESIGN PEDAGOGY

E-learning for design cannot be effectively implemented without an explicit pedagogical framework and guidelines. Theoretical models for teaching method and learning processes are essential in order to implement new approaches for teaching and learning that take advantage of the nature of the Internet and the new e-learning technologies that are developing within it.
In the following sections the theories that have provided the theoretical foundations for the design of the VDU – the virtual university for design, will be described. Among the theories that underlie WINDS are: Conceptual Maps; Constructivism; Precedent-Based Design; and the ICF formalism. The significance of these theories to pedagogical approaches in design education as well as to the cognitive aspects of learning have been recently presented (Oxman, 2002).

2.1.1. Conceptual Maps
Conceptual maps in learning is an idea derived from Ausubel’s learning theory (Novak, 1991). A conceptual map is a special form of a linked graph for exploring knowledge and for sharing and gathering information. It was proposed as a tool to develop an understanding of a body of knowledge and a representation of the student’s comprehension of that knowledge.

A fundamental idea in learning theories is that learning takes place by assimilating new concepts and propositions into existing conceptual frameworks held by the learner. According to this approach incoming information is organized and processed by interaction with long term, existing knowledge. Concept mapping is a tool for organizing and representing the network of knowledge, as well as its expansion in learning.

2.1.2. Constructive Learning
Constructivism is among the dominant learning approaches in on-line courses. The philosophy behind constructivism is that the learner constructs his own knowledge based on his experience of, and relationship with, concepts. Learning implies that new cognitive structures are acquired. Constructivist theories of learning (Kolb, 1984) propose that the learner is not conceived of as a passive recipient of knowledge but is an active participant in the process of learning and in constructing these new structures.

In WINDS, the self-acquisition and construction of the body of concepts represented as a map derived from a syllabus is considered as a means to facilitate meaningful learning. Organization of courses and the provision of a template that renders their main concepts explicit, helps to organize knowledge and to structure it. The learner, in fact, is required to identify a context in which the structure of the concept map is constructed. Given a certain class of assignment, the student learns to identify concepts that are relevant to various problem contexts and to construct their conceptual map. This mapping illustrates the acquisition and construction of a personal body of theoretical and instrumental knowledge.

2.1.3. Precedent-Based Design and the ICF Formalism
WINDS has adapted the ICF formalism which was developed in the field of Case-based Reasoning as a formalism to represent the unique form of design precedent knowledge (Oxman, 1994). In fact, the ICF is a particular form of concept mapping of text and images that is suitable to representing design knowledge. It creates a linked conceptual mapping of concepts and images that constitute the relevant knowledge of design ideas in design precedents.

ICF also supports cross-domain linkages, or linkages between similar concepts from different design domains. Links between different domains of knowledge help to illustrate how ideas and forms in different domains are related to one another. Once students begin to focus on cross-domain links, through the larger body of cross-course links, they learn about conceptual relationships and larger conceptual structures contained in significant precedents in the field of design. When the process is done well, concept mapping becomes a means to achieve high levels of cognitive performance in education. Furthermore, the implementation of the ICF ideas in WINDS may enhance the capability of associative learning.

Associative learning is supported by the provision of a curriculum concept-index (Voss et. al., 2000). Individual courses are placed within the overall WINDS concept index at a particularized level of detail. This supports free navigation through the training material and enables cross-referencing through, and within, the conceptual network.

3. Cognitive Based Teaching and Learning Strategies

The following section introduces and discusses the cognitive strategies and the unique approaches that are currently reflected in certain features of the WINDS project.

3.1 LEARNING TO READ A NETWORK OF ASSOCIATED CONCEPTS

Current strategies that are employed by virtual universities in constructing their course content are based on traditional approaches. Most virtual e-learning environments focus on teaching textbook knowledge and professional skills that are applied directly to a singular course (for example, see the well-known Web CT). Such current traditional e-learning software provides tools for authoring textual material that support an expository style of learning. However, we already know, even in traditional teaching class lectures, books, textual material, visual material, etc. do not assure acquiring design thinking skill. Although they are available in an expository form, they are not necessarily accessible for use, or in a form that supports knowledge acquisition. If information is stored and encoded in a way that makes it readily accessible and usable in design, it is more likely to be used.
Latest emphasis in education suggests that the organization of knowledge is at least as important as the amount of knowledge. The quantity of knowledge and information is not the most pedagogically useful construct. It has been suggested that the organization of knowledge is at least as important as the amount of knowledge in understanding any knowledge domain (Baron and Steinberg, 1987). It is the development of the thinking skill that is critical in design education. Thus the organization of knowledge view appears to be more relevant than the quantity of knowledge view. Clearly then, in order to organize knowledge one needs to have a model of how to organize knowledge.

Design learning, like thinking, has been characterized as an exploratory process (Oxman, 2001; 2003) that is based on the ability of the learner to explore and find relevant knowledge according to his needs or design ideas. In order to support and acquire an exploratory thinking style a new learning strategy is needed.

In WINDS the strategies that are implemented intend to enhance an associative thinking and learning style. This is reflected in the way courses are authored in WINDS. Rather then supporting a “shared presentation format” we have developed authoring tools that can represent the “conceptual basis” of each course. This unique presentation intends to support an associative thinking and learning style as we shall demonstrate in the following sections. That is, the content may be described through a network of conceptual content rather than through conventional hierarchical organization of sections and sub-sections.

Course content in WINDS is constructed to provide a choice between the two styles of learning, the expository and the exploratory. The traditional organization of course structure around sections and sub-sections allows the learner to access material in an expository way. Alternatively, the organization around relevant concepts that might appear in several course units organizes course material into a larger network of concepts.

Figure 1 illustrates the course content as a list of units and sub-units. The content is presented in two complementary ways. The middle screen presents the course content. The left screen presents the course paragraphs in a hierarchical and sequential way. The right screen presents how the course content is organized around the significant concepts of the specific subject or field.

This structure is composed of the concepts that the author has defined and specified as a network structure. These concepts are termed in WINDS authoring language, index terms.
3.1.1. Index Terms

The index term is a knowledge organizer that enables identifying the occurrences of terms despite their syntactic differences. For each course several entries of conceptual content are introduced to the index. Furthermore, index terms can be linked to external documents or applications in which index terms are used as annotation tags. This supports free navigation through the knowledge resources and enables cross-referencing through the conceptual network.

Index-terms are constructs in WINDS that define the conceptual content and the meaning of the course. This kind of organization supports an associative learning style. In WINDS associative learning is supported by provision of the cross-links between lists of index terms. For example, the following concepts describe the main index terms that are related to the course entitled: “Internet, Cyberspace and Architecture”. The terms are: Cyberspace, Internet, Verisimilitude, Virtual Architecture, Virtual Space, Virtual Place, Digital Architecture, Navigation, Orientation, Hyper-Reality, New York Stock Exchange, Guggenheim Virtual Museum, Amazon, E-Bay etc.

When the learner clicks on one of these terms on the left menu a term-map appears (see figure 3). By clicking on the term map, the learner can...
navigate from one term to another and explore their related content in related course paragraphs. This organization of related material supports an explorative style, in which the learner may guide his interest by reaching each one of these terms.

We relate to this as *learning to read the network of associated concepts*. This style of learning adds to learning gained through traditional expository material.

### 3.1.2. Term-View Content

Figure 2 illustrates some viewing options. Once the learner clicks a term-index there are three options that can be viewed. They can be viewed as a visual map; they can be viewed according to their occurrences in different paragraphs; and they can be viewed as textual information. Figure 3 illustrates a visual conceptual map of the Guggenheim Virtual Museum. This map combines the ideas behind the concept index and the visualization power of an interactive map. The learner can click on any of the related index-terms and navigate through the material. Figure 4 illustrates another viewing option. This option specifies exactly where there are occurrences of the index terms in related paragraphs.

3.2 LEARNING TO NAVIGATE THROUGH CONCEPT-BASED NETWORKS

The exposition of material by conceptual linkages is supported in the system by concept-based free navigation. This allows the learner to navigate and make cross-referencing through the whole conceptual network according to his interest. This promotes *individualized learning* and the support of *diverse learning styles* in which each student can navigate and explore multiple paths to support his ideas during the conception of a project.
Concept-based Navigation allows the discovery of particular conceptual terms by clicking on the term on the right menu. For example, clicking on “Guggenheim Virtual Museum” will illustrate a specific conceptual network presented in Figure 3.

![Figure 3. Visual conceptual map of the Guggenheim Virtual Museum](image)

3.3 LEARNING THROUGH RECONSTRUCTION

Concept-based Navigation allows the learner to navigate among course paragraphs on the basis of conceptual occurrences. Furthermore, the learner can reach a particular concept in different paragraphs related to a specific course according to his interest. In fact, he can reconstruct the meaning of a particular term in multiple ways – by tracking the semantic content suggested by the teacher. For example, learning about virtual architecture can be linked with subject related to cyberspace, or looking at specific known precedents such as the New York Stock Exchange, etc. This strategy allows an exploratory learning style in which the learner himself discovers the content according to his own “way of thinking”.
3.4 PRECEDENT-BASED NAVIGATION

Precedent-based Navigation and the Issue-Concept-Form structure is currently partially implemented in WINDS. The ICF will enable the representation of significant precedents. Precedents will provide an example of relevant design ideas and are activated in a similar way to the activation of the index term. The learner will be able to navigate and explore multiple precedents through their design ideas, issues, and concepts in a navigation window.

![Diagram](image)

**Figure 4.** Synonyms, relations and occurrences in course and external documents

In the ICF formalism (Oxman, 1994), _issues_ stand for high-level goal statements, or starting points in the design process, _concepts_ refer to domain-specific methods of achieving certain issues. Holistic precedent knowledge is decomposed into separate chunks. A typical chunk, then, provides explicit linkages between issues, concepts, and a related form. The relationship between these chunks is not presented as a strict hierarchy, but rather as a semantic net. In the WINDS framework, the ICF is activated as a network of index-terms when dealing with specific design projects.

Conceptual links in the semantic network can connect different chunks from different precedents. From any index, related chunks can be retrieved.
which in turn, call up their content chunks in other precedents. The semantic network structure of design precedents can also function as an additional lexical basis for search and navigation.

5. Cross Contextual Conceptual Search Across Course Curricula

5.1 CONTEXTUAL CONCEPTUAL NAVIGATION

As previously mentioned, most of the current strategies employed by virtual universities in constructing their curricula and course content are based on traditional approaches. Traditional e-learning software promotes the creation and authoring of single course modules. In such an approach, each single course is a holistic structure that is constructed independently according to the teacher’s educational approach.

By contrast, we believe the exploratory learning approach presented in the last sections provides a new methodology to design syllabus and course
units in a way that maintains the complexity and richness of content provided by a university. The course authoring and learning environment in WINDS support the exploratory learning style not just within a single course, but rather across the whole curriculum.

The technological approach in the WINDS platform is designed to serve a modular structure of didactic material and the dependency network among the university course modules that allows for dynamic acquisition of special curricula modules according to individual student needs. The index term enables finding occurrences of terms in individual courses as well as within the overall curriculum.

Another contribution of this approach to the usage of knowledge is its potential utilization in a typical design studio situation. The conceptual content modules of all the courses are designed to support design thinking in a studio situation. The content modules are related to the conceptual content of design problems, issues and types in such a way that they can be re-used and combined according to the needs of the design learner in a particular situation. This way the content material embedded in the course modules provides an explicit structure of the knowledge of the design field that can be acquired as part of the learning process. Learning is both the acquisition of modules of knowledge as well as exercising their implementation in the design studio situation.

This should allow the construction of very effective pedagogical material for the design thinker/design learner. This approach promotes individualized learning and the support of diverse learning styles in which each student can navigate and explore multiple paths to support his ideas during the conception of a project. So conceptual mapping can become a medium for the representation of precedent analysis, knowledge acquisition, and conceptual construction, all of which characterize conceptual design. Figure 5 presents an example of a selection of multiple courses in the WINDS curriculum. As illustrated, the ability to navigate across conceptual content exists both within the single course and across the whole curriculum.

Figure 2 illustrated the facility of the term-view course content illustrated before, while figure 6 illustrates another search facility in the ALE system. By clicking on the search button the learner can search for any concept and find occurrences across the whole curriculum.

These two mechanisms enable the student to learn and reflect upon different contexts in which a certain term is playing a role. For example: on the left menu illustrated in Figure 7 by clicking on the topic button the term “Cyberspace” can be searched across the whole curriculum. This term was found in the following courses: "Design and Computer Design and Contemporary Architecture” as well as in the course “Internet, Cyberspace and Architecture”. The screen presents the occurrences of the term “Cyberspace” in related sections of current courses in the curriculum.
6. Conclusions

The paper presented unique cognitive strategies that are currently implemented and tested in the WINDS project. These strategies are based on cognitive theories that are applied in the development of an e-learning environment for design teaching and design learning. We believe that cognitive strategies may contribute to the development of unique learning environments and, furthermore, that they should be a basis for teaching in a virtual university for design. The contribution of these ideas is significant both to the development of pedagogical approaches as well as to university-wide course factors such as organization and the construction of the knowledge domains. We believe that the integration of the pedagogical model and e-technology suggested and demonstrated present a new approach to the organization of course material as well as an effective use of domain knowledge in designing a virtual university for design.

In WINDS the pedagogical approach has attempted to achieve synergy between pedagogy and knowledge at the level of the design university by creating a knowledge system out of the multiplicity of courses.
The implications of this approach to the evaluation of the WINDS project and its implication for the achievements of unique learning strategies in design are currently under continuing development. In the future, evaluation studies will be employed in order to test our assumptions regarding the efficacy of conceptual mapping as a learning medium, conceptual indexing as supporting an exploratory learning environment, and conceptual learning and the acquisition of domain knowledge in design. We believe that following the findings in the theoretical and experimental sources on which they were based, the WINDS experiment will prove to have pioneered certain pedagogical advances not only in e-learning, but in design learning in general.

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