Thought, Representation and Design in the Electronic Design Studio

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Abstract: The relevance of design thinking and cognition to the development of pedagogical approaches in the architectural electronic design studio is presented and discussed. In this approach we emphasize and demonstrate the role of the acquisition of explicit knowledge in design. The acquisition of knowledge is achieved through the explication of cognitive structures and strategies of design thinking. The explication process is implemented in a computational medium which supports the learning process as well as the potential re-use of the knowledge.

1. Introduction

In traditional design studio teaching the measure of learning is generally equated with the evaluation of the product of designing rather than on the learning increment. Studio-based approaches have been widely adopted as a general educational foundation for design education. Certain of these approaches see the studio as a simulation of the professional environment, the content of studio methodology as a series of steps of design process. The studio is considered a venue for making designs under the guidance of the design tutor who intervenes in the student's designing, generally in reaction to the student's explicit design. This form of teaching is not necessarily articulate of general design methodological principles, and, in most cases, the critical process is inefficient in the transfer of design knowledge. The nature of this traditional educational process is well symbolized in what is perhaps the Achilles heel of the traditional studio, that is, that evaluation is based on the final product rather than on a measure of increments of knowledge acquired as a result of the studio.

Following this approach, in most computational studio-based teaching, the emphasis on the use of CAAD has been so far, as a skill to be used in production work or as powerful means for 2d and 3d representations, modelling, visualization and rendering, or in performance evaluation.

Current research and the application of Web-technologies in design studio teaching have contributed to interesting developments in this a communication medium which allows designers to communicate, select, and share information. The development of distributed and virtual environments, and the use of Web tools have contributed to interesting applications in various fields such as virtual design, virtual design studios, web-based collaboration which supports synchronic and asynchronic design, and virtual space for education, etc.

However, despite numerous changes and the introduction of computational technologies, the design studio is still characterized by the faults of product orientation, creative design as a black-box, the pedagogical distance of the tutor,

the lack of explicit definition of the requisite knowledge foundations of design, and the neglect of design methodological process as legitimate pedagogical content.

In this paper we present an alternative foundation for studio teaching. An educational model is proposed in which the explicit learning of design knowledge structures and related cognitive strategies are the main objectives. This approach which we have termed, *cognitive design media*, is based upon the student's exploration of *the design problem's conceptual space and the formulation and computer implementation of knowledge structures which are related to potential solution spaces*. A series of learning exercises are reported and their results as a medium of design education are evaluated.

The following section relates to the theoretical bases in cognition and computation which appear most relevant to design teaching. The contribution of these theoretical approaches to design theory and their implications in design teaching are presented. Following this theoretical introduction, a model for the use of computers in studio-based design teaching is proposed. We demonstrate our work in the framework of a pilot educational program in which the computer-lab is exploited as a significant venue for design learning. Finally, we consider the significance of the venue and the medium from the point of view of their contributions to the subject of "computers in design studio teaching".

2. Thought, Representation and Design Computation

In our work we have elected to exploit the *computational design studio* as a unique form of pedagogical mechanism for design learning. As design educators we use computers as educational tools in teaching design processes and methods through modeling cognitive processes in design; explicating knowledge structures and even gathering and re-using their content in current design tasks. The practical techniques of this teaching methodology focus on the representation, structuring of design knowledge and their implementation in the process of computational design. This has proven to be a powerful, stimulating and innovative educational approach. On the basis of our work we believe that this new venue will prove itself as a unique medium for design teaching.

According to this cognitive approach, the human means to gain knowledge is for the mind to exploit acquired information that it has already stored as general schema by re-describing its representations. We assume that learning is a process of the acquisition of knowledge structures which are related to schema differentiation. In the process of re-representation, implicit knowledge of the schema becomes externalized in the sequence of representations. The process of re-representation involves conscious construction and exploration of the *cognitive structures of schema*. Global strategies in the cognitive sense refers

to the larger structures of cognitive phenomena which characterize the exploitation of knowledge in thought. We have been working on the explication and formalization of global strategies such as refinement in generic design and typological design, and of adaptive design. Both refinement and adaptation are global strategies which are based on formal schemas of re-representation. Refinement is based on a schema of staged particularization, while adaptation is based upon a structure of knowledge which supports re-representation. For example, our approach to the representation of typological strategies was based on the derivation of a set of generic representations which support typological design transformations.

By comparison, in global strategies of creative design, the strategy is less formally based on generic knowledge and developmental processes, and is more exploratory. In creative design, cognitive structures that are generated have emergent properties that can be explored, where some of the properties could not have been anticipated in advance. In this way one might generate radically new and unexpected ideas.

It is our hypothesis that learning in design is the acquisition of the cognitive ability to manipulate the representations of design knowledge, to acquire basic schema in design thinking, to understand knowledge structures and to be able to manipulate characteristic strategies of design thinking such as generic and typological design, adaptive design,

analogical thinking and creative exploration. That is, the cognitive attributes of design cognition and learning can become the content of design education.

3. Cognitive Design Media

The issue of the learning content and of the relevance of the learning environment was raised by Habraken. We have elected to exploit the computer laboratory as a design learning environment. This form of teaching through the development of systems is based upon educational experiences in Constructionist theories. Our hypothesis of design education is that through modeling of knowledge structures and strategies the student gradually develops his conceptual understanding of design. The practical techniques of this methodology focus on the development and the design of computational systems which can represent the cognitive models. This has proven to be an innovative educational medium for the acquisition of knowledge. In this way, the computational system supports both the learning process and the potential re-use of this knowledge and the creative and learning increment of their work can be evaluated comparatively. On the basis of our work we believe that this new venue has proven itself as a medium for design education. The nature of the results of conventional educational activities can be compared to the potential value of knowledge permanence in the research-related character of this approach.

Through constructing representations of design thinking, the student gradually becomes richer in his ability to think in designerly ways. The constructional form provides a representation of the structure of knowledge which the student acquires. Design learning then may be considered a process of knowledge acquisition and development in which the knowledge is physically constructed. This contributes to an understanding of the cognitive processes which are characteristics of design, or as Papert has stated, this form of education contributes "to knowing rather than to knowledge". The goal of design education is re-defined as the acquisition of design knowledge through constructing the explication of schema, knowledge structures, and global strategies in design thinking.

We have developed a taxonomy of basic elements in cognitive processes. These include the characteristic interaction between design strategies and form generation. This taxonomic code enables the modeling of cognitive structures and strategies. These are modeled as network structures in the form of nodes and linkages. The network structures explicate, and enable comparison between, various classes of design knowledge and cognitive strategies in design.

The elements of the network are based upon a formalism previously developed for representing design thinking. The representational formalism termed, ICF (Issue-Concept-Form) addresses problems of representation of knowledge in design. ICF represents chunks of knowledge of designs, provides explicit linkages between the issues of a design problem (I), a particular solution concept (C) and a related form description (f). The formalism has been expanded in order to include analogy (A) and metaphor (M) as resources for ideation and to support design exploration processes which exploit these cognitive mechanisms.

According to Papert, "Constructionism, shares Constructivism’s connotation of learning as building knowledge structures. We are motivated by the general constructionist approach that learning through construction can be a medium for building knowledge structures in the mind of the student. By constructing models of these structures, the student acquires knowledge of design thinking. That is, he learns the cognitive processes of thinking design as well as the cognitive structures of knowledge which are employed in designing. Further the learner is consciously engaged in constructing a *public* entity. This work benefits from the public format in which the models constructed have a communicative, as well as a learning, value.

In our work we have elected to exploit the *computer laboratory* as a design learning environment. As design educators we use computers as educational tools in simulating cognitive processes; explicating knowledge structures and even gathering their content as potentially useful material for the designer, such as computer-based libraries, visual precedents, etc. This way, the computational system supports both the learning process as well as the potential re-use of this knowledge. In this case the computer is the medium for the construction and test of cognitive structures.

The practical techniques of this methodology in our experiment has focused on the use of internet technology. In the following section, specific examples of student's exercises are presented and the teaching program is evaluated as a contribution to a cognitive-based design education.

4. A teaching program

We tested our hypothesis with a group of graduate students from the industrial design and architectural programs at the Technion, Israel Institute of Technology. These were primarily upper level undergraduates and second degree students, who had both computational ability and some background in the theoretical design context of the exercises.

The techniques of modeling and the exploitation of the ICF formalism within the HTML environment (hypertextual language of the Internet) was part of the preliminary methodological work of the teaching program. This preparatory period was relatively brief, after which the students had gained the tools and the conceptual fundamentals of modeling design thinking.

It is difficult to develop an awareness of design thinking through conventional design activity. However, if taught explicitly, it is remarkably easy to understand. Virtually all of the students developed proficiency with this methodological foundation of design thinking. We will describe such learning processes in the following examples. In each of the examples we provide a brief theoretical introduction, present and demonstrate the use of the code for the representation of knowledge structures, and finally describe examples of computer implementations.

The diagrams illustrated below are schematic representations of one of the students work.

Students were given a brief theoretical introduction to generic design and typological design. Generic design was presented as a form of knowledge structure that connotes the body of prior knowledge which enables the designer to evoke generic representations, or to extract schema from specific images. It includes both the derivation of generic representational schemas as well as the knowledge of exploiting these schemas.

Students were asked to represent typological knowledge as a set of generic representations which are associated with specific problem types, and to organize the variables of the type in a hierarchical order of which the highest level is that of the schematically represented class description.

The construction and the final implementation of generic representation of the student's work was dynamic and interactive. The user could interactively modify the form according to the typological variables and the generic structure of knowledge That is, the student in preparing the representation, understood and respected the potential user. This is a form of metacognition which can be materialized in the particular computational medium which we exploited.

The implementation in this example was of a chair design which supports generic and dynamic back and forth particularization through navigation between hierarchical levels of abstraction. An interactive environment employing the VRML (virtual reality modeling language) on the Internet provided for design zooming which simulates the generic representational levels of a specific class of chair designs. In this way, the user can alternate between a schematic and

particularized representation through the medium of zooming. Each of the abstraction levels may be elaborated by adding more specific details.

This exercise has provided a significant medium for understanding the role of representations in adaptive design. In the theory of design adaptation a specific design is selected and, through adaptation, transformed into a new design. In comparison to generic design it is represented as a specified design representation. Adaptation processes can be defined as successive modifications through a series of representations which are executed upon the original design. We have referred to this process as *re-representation*, exploiting the term which has been applied to the cognitive phenomenon as well as to the cognitive capabilities which make these complex processes possible.

Students were asked to identify and present these classes of representations as well as other sources with which designers can interact, and modify. This is an example of the coding of multiple representations. The representations may be derived through interacting with exploratory visual resources such as analogies and metaphors.

It was suggested to the students that one way to support adaptive change was by providing a medium to interactively construct explicit multiple representational of sub-structures.

Precedent based design is accepted as one of the cognitive phenomena in design creativity as a source of ideation. The generation of a conceptual basis for the inception of design is one of the most interesting of the cognitive phenomena of early design. The students were asked to consider series of issues such as how precedents should be represented, indexed, and organized in order to support the process of ideation.. Rather than selecting specific precedents, it was the exploration of their conceptual structures which were to be supported. Students were asked to construct a *resource for design ideation* in which the conceptual content of design precedents acts as a vocabulary of design ideas within the framework of a particular class of design problems. They were asked to employ a *concept vocabulary* of the resource base of selected precedents in the construction of a semantic network of ideas which can be browsed by the designer as a cognitive resource for design ideation.

An implemented system of design precedents was developed which included a set of Web pages. An example of browsing and exploration modes in this system is illustrated by the following series of steps. The first step is the selection of an issue from the set of all currently existing domain issues. Once an issue is selected, the second page appears with related concepts. The user than selects relevant conceptual linkages by activating related windows. By activating the window which connects concepts to forms the user may explore how a similar design concept may be realized by different form elements in two designs. Through this, the user may browse to explore how a similar conceptual form may be realized in different designs. Conversely, by selecting specific precedents the user may explore other concepts which were not expected and emerge as a result of the navigation process.

5. conclusions

In our experiments, it was possible to demonstrate that the derivation of design knowledge through constructive processes, in itself, provides a medium for design learning. Though the observation of the process of construction we have identified such phenomena as *depth of understanding* of the task in the development of modeling skill, and the efficiency in modeling representation. The qualitative assessment of learning as the development of concepts and knowledge structures in design learning was measured in our experiment by an evaluation of modeling performance. We have traced the use of concepts according to their ability to draw inferences concerning the acquisition of design knowledge. We defined linkages and terms of the knowledge structures. For example, in employing conceptual linkages

we assessed the collection and organization of knowledge through such indicators as the type of linkages, and the degree of development of the structure of knowledge represented. Such measures include the types and the number of conceptual linkages, employed.

A growing level of complexity in the representation indicates the acquisition of a deeper understanding of relevant concepts and the mastery of their interactions in design thinking; the sophistication of integrating and implementing concepts in complex structures may be interpreted as an indication of metacognitive insight which is perhaps an indication of a high level of general knowledge regarding the interaction of knowledge in design strategies.

This approach transcends the educational logic of conventional venues of the classroom and the studio. It suggests that special design learning environments must be developed which can enhance and supplement formal education and foster personal development in design learning. As for the potential of future applications of this methodology, we believe that the resulting relationships between cognitive models of design, design domain knowledge and the incorporation of computational technology has theoretical and practical implications for design education in the broad spectrum of design domains.

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