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# Digital Media and Design Didactics in Visual Cognition

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*The cognitive properties of design learning have rarely been the subject of design education. Irrespective of the specific design domain, traditional educational models in design education are based upon the evaluation of the product of designing rather than on what might be considered a learning increment. Lately we have developed the concept of cognitive learning tasks as learning increments in design education and propose that digital media constitute the basis of uniquely powerful learning technologies. The research described in this paper addresses the confluence of cognitive learning tasks as a pedagogical approach in design education, its potential relationship to digital media in order to develop a digital design didactics, and the relationship of these developments in design education to current practices of digital design generation. In this paper, we focus on the cognitive aspects of visual cognition in design learning. An example in the domain of architectural design is illustrated.*

***Keywords:*** *Design Learning, Cognitive Design, Visual Cognition, Design Thinking, Design Generation*

## Introduction

During the last years, a large body of design research has contributed to our understanding of the cognitive and visual properties of design, and has provided new directions for the development of design education. In order to enable the construction of a general theoretical foundation, we argue the need to redefine the learning task in design education from an orientation to the production of design artifacts, to a cognition-based approach to knowledge and visual content. In such an approach we believe that the design student can be educated in designerly way. Furthermore, a cognition-based approach can be structured in levels commensurate with stages of design learning (Oxman, 1999).

Cognitive approaches in design and the role of knowledge and representations as a cognitive design thinking tool were discussed by various design researchers (Schon et. al, 92); (Eastman, 70) and (Akin, 86). Most of these studies are related directly to design thinking and visual design thinking rather then to the learning task in design learning and design education. In this paper we consider the role of cognitive content of design and visual design thinking as a basis for developing an educational approach. In order to do so we also consider learning itself as a cognitive function of the mind, and learning in design as a unique case.

Creativity, learning and development are significant body of knowledge with great relevance for design education. Bringing these issues in the context of design learning has raised the following questions: how can design knowledge be acquired and learned? How can internal representations of

knowledge be learned and taught? How can internal representational capabilities of the learner be increased? And how can the learning of knowledge and representation be evaluated?

In this paper, a conceptual framework is proposed in which the explicit learning of design knowledge structures and related cognitive strategies are the main objectives for design education and design learning. Thus the cognitive content of design thinking becomes the subject of the educational program. This approach is based upon the student's exploration and formulation of knowledge structures and reasoning in design, which are related to the particular design domain. We first propose a conceptual framework of the cognitive content of design thinking, which can function as a basis for design education. This includes the following four components: knowledge, representation, reasoning and cognitive models. We then present one possible framework in educational theory through which the cognitive content of design can be developed as an educational format. A series of learning exercises are described and their results as a medium of design education are evaluated. Finally we consider the problem of the evaluation of design learning, and the possibilities, which are inherent within this approach. In conclusion, we discuss the potential for programs of cognition-based design education.

In our research we have focused on cognitive issues regarding knowledge and visual representation. However, our assumption is that cognitive science in the provision of an understanding of how the mind works in such phenomena as knowledge acquisition,

## Cognitive modeling as a didactic medium

Despite the important focus on visual and formal content, the educational focus still remains on the representation of the design object, rather than on an explicit articulation of the knowledge to be derived from the educational process. There is a need for the development of an approach to knowledge acquisition, which may become more educationally meaningful than the design object itself. Especially in exploiting graphical and visual representations, such an approach stresses the understanding of the character and role of domain knowledge, structures of knowledge, and the exploitation of knowledge in the processes of design.

By contrast to the explicitness of knowledge that must become part of the design educational process, the design studio today is still characterized by the faults of product orientation, creative design as a black box, and the pedagogical distance of the tutor. In all of its institutions there is generally a lack of explicit definition of the requisite knowledge of design, and a neglect of attention to thinking in design as legitimate pedagogical content. Although there may be an integration of design concepts, formal skills and knowledge, which is learned, is practice in the studio, the explicit learning of the cognitive content of design is ignored and left to be gained implicitly through experience. In the studio there are no effective methods of assessment to measure the developmental processes of learning on the part of the student in his education (Oxman, 1999).

## Explication of visual cognition as a first step in design learning

As an initial step towards the this paradigm we propose a general theoretical framework for categories of cognitive phenomena in design which appear to be of central and formative importance to both design and design education. Secondly, if we wish to impact upon the traditional educational situation, we must first identify approaches to learning and educational methods, which appear relevant to the unique cognitive aspects of design. Finally, we must find a means of introducing these new methods within the ongoing frameworks of conventional design education.

Diverse intellectual disciplines, which study human cognition, attempt to develop models of cognitive performance in various behaviors. Cognitive modeling is a root concept in the study of mind and

one, which constitutes a common denominator among the diverse fields of the cognitive sciences. In psychology, for example, modeling can be employed to formulate such phenomena relevant to design as the way that people form and apply concepts, the speed of thinking with mental images and the performance of solving problems using analogies. In general, within cognitive psychology, cognitive modeling involves the formulation of information processing models, which can be evaluated with respect to a body of experimental data and empirical evidence.

In design, cognitive models of design thinking, which can be empirically verified, constitute one important platform for cognitive psychology in design research. For example, concepts and methods, which have been developed in cognitive psychology, have been applied to design in, among others, the work of Akin (Akin, 86), and the work of Schon (Schon, and Wiggins, 92) particularly on visual thinking through interaction with the conceptual processes of design thinking. Cognitive models of design constitute a general approach for modelling cognitive process in design as global processes of thought and reasoning. For example, cognitive modelling in design has been employed in knowledge-based systems (Coyne et. al., 90), rule-based systems and case-based systems (Oxman, 96) in which such cognitive phenomena as classes of knowledge, domain expertise, and experiential knowledge can be symbolically formulated.

Cognitive modelling is the symbolic representation of phenomena in design. We can also employ cognitive modelling as a didactic medium, which enables the student to better comprehend the richness and complexity, as well as the formality, of thought in design. Based upon design protocols, or self-protocols, the student acquires knowledge about design thinking by formulating models of the reasoning processes, which underlay his, and his colleagues own design. Thus cognitive modeling of design thus offers a research-oriented approach to design education.

Through our past work in the research of design processes and on the basis of our understanding of cognitive phenomena, which are relevant to design, there appear to be many subject areas in design, which are amenable to teaching through modeling. However, we believe that there are three seminal areas of cognitive studies, which can be very profitably introduced as design educational content (Oxman, 1999). These are:

- Representation, including the various symbolic representations of designs, and their manipulation during design, and particularly visual representations;
- Reasoning, including the symbolic representation and formulation of thought processes in cognitive phenomena such as reasoning from past design solutions (cases) or reasoning with analogy and metaphor, reasoning with visual images;
- Knowledge, including the representation and formulation of the various classes of knowledge in design such as typological knowledge, and the cognitive building of knowledge into larger structures.

## The annotating experiment

In this paper and annotation experiment that emphasize the subject of visual cognition in design is demonstrated. The annotation experiment was an experimental program in the annotation of self-protocols in a process of design emergence. The designers were graduate architects and architectural students in advanced years of undergraduate study. Each student selected a building, or project, to analyze. On the basis of the final configurative system the participants were requested to model the process of design emergence including the attept to differentiate between perceptual and cognitive emergence. They were also requested to attempt to identify how cognitive emergence may have influenced their design processes, and what type of knowledge was involved. The participants were required to annotate the process graphically and to explicate the content of complex operations. The

distinction between perceptual and cognitive emergence proved possible to annotate the process. Classifications of kinds of visual schemas were made and rules identified to account for shape transformations. Particular attention was given to identifying classes of domain knowledge that influence visual reasoning in emergence. A case study is illustrated.

The formal annotations are employed here as an externalization via formalization of an internal cognitive model of visual reasoning in design. In combining both the study of emergence and a theory of visual cognition, we have attempted to represent both the perceptual and cognitive learning of emergence. It employs the extended model of emergence that has been developed in our work (Oxman, 2001) that distinguishes perceptual events from mental imagery and high-level cognitive processes. It became clear from the case studies that such distinctions are justified by their ability to support a rich cognitive model of emergence. In fact, in the complex configurative world of architecture from which we have drawn the case studies, it does not appear possible for emergence to occur without distinguishing such perceptual-cognitive mechanisms. It therefore appears that these conceptual distinctions regarding visual reasoning in emergence may have some general relevance for visual reasoning.

The modeling of the cognitive process attempts to take into consideration that emergence is built on the phenomenon of perception-cognition as solving a problem of shape ambiguity. In the process of drawing shapes perceptual ambiguities are clarified and high-level cognitive schema guide the resolution of ambiguities and of conditions of multiple available interpretations. However, ambiguity was also found to be something to use and explore. An integral part of designing is to solve shape ambiguities as they are related to visual and cognitive structures as the design develops. Stiny's position regarding the attributes of ambiguity that, "The novelty it brings make creative design possible" (Stiny, 2001), imposed a challenge to the participants. In order to model a sequence of emergence, they found it necessary to accommodate ambiguity resolution at a cognitive, rather than a perceptual, level. That is, consistent with our position, creative design is less a perceptual accident than the activation of some form of design intelligence. Such intelligence as the clarification of a schema in structuring a design image is a form of cognitive activity that is consistent with theories of vision and visual reasoning.

In our experiments we have emphasized shape and schema ambiguities, per se; this is in contrast to the perceptual ambiguity that is frequently the content of perception in ambiguous hand sketch drawings. We specifically emphasized the resolution of shape ambiguity through high-level conceptual schema. This is an important distinction. It is not the lack of geometric clarity in the sketch that either supports, or inhibits, emergence. Ambiguity resolution, according to the position that we have developed, is significantly a cognitive, rather than exclusively perceptual, phenomenon. On the contrary, we would like to emphasize the role of what we have termed "re-cognition" as an integral attribute of visual cognition in design thinking.

The explicit representation required that the protocol be explicit about manipulations that generate emergence. Important transitions in the transformational processes of emergence indicate cognitive processes which the protocols attempts to describe and characterize as well as to annotate. This form is also consistent with the requirements of a potential computational representation of the process in which the designer does not re-draw an emergent shape, but makes a certain operation on a shape. In the case study, the annotation of emergence articulates the emergence of patterns, structures, or other cognitive properties that support visual cognition in design.

## Annotating visual cognition

We have proposed that learning through the structuring and manipulation of visual knowledge in design may be considered a significant educational

objective in design education. We believe that the cognitive attributes of design cognition and learning can become the content of design education. In order to develop an educational framework for design education, we must first attempt certain basic definitions regarding what one learns when learning to do design. We propose the following as preliminary propositions. (figs 1 & 2)

1. Learning in design is the acquisition of the cognitive ability to represent design knowledge, to acquire basic visual schema in design thinking, to understand knowledge structures such as generic and typological design, adaptive design, analogical and metaphorical concepts and images.
2. Learning in design is the acquisition of the cognitive ability to manipulate the representations of design knowledge, to understand knowledge structures and their associated manipulation strategies such as refinement and adaptation, concept formation, etc.
3. Given the first two hypotheses regarding the content of design learning, we propose that design education is the processes and media, which contribute to design learning. An effective medium of design education is in modeling the representation of design thinking. Through modeling of knowledge structures and strategies the student gradually develops a conceptual understanding of design. We have found that such a research-oriented approach to design education can be a lucid medium of design education. Furthermore, the three paradigms of design education may be seen as a complementary set.

The case study annotates emergence in the evolutionary generation of the configuration of the form of an architectural floor plan. Here the plan is treated as a schema whose diagrammatic evolution evolves to the point of a completed schema. In architecture, this design task is one of the most elemental and important processes of early, or schematic, design. Beyond this point, the design task changes substantively to one of materialization.

## Conclusions

We believe that the resulting relationships between cognitive models of design, design domain knowledge and the incorporation of computational technology have theoretical and practical implications for design education is very promising. Though the observation of the process of construction we have identified depth of understanding of the task in the development of modeling skill, and the efficiency in digital representation.

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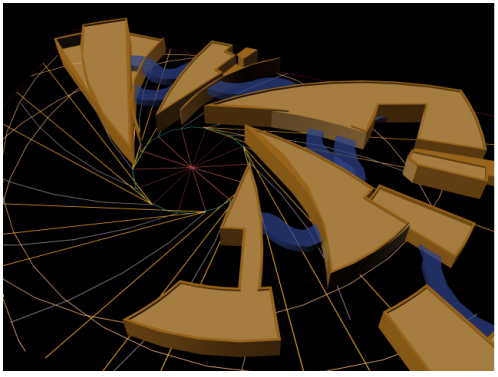

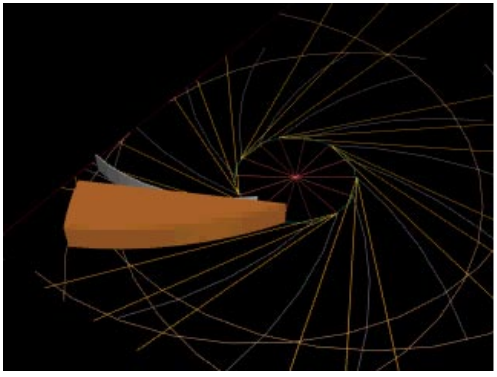

*Figure 1 (left). The architectural schema*

*Figure 2 (right). Annotating schema emergence*

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## References

Akin O, (1986) Psychology of Architectural Design, Pion, London

Coyne R D, Rosenman M A, Radford A D, and Gero J S, (1990) Knowledge-based Design Systems, Addison-Wesley, New York

Eastman C, (1970) On the analysis of intuitive design processes, Emerging Methods in Environment Design and Planning, G T Moore ed, MIT Press, Cambridge

Oxman R E, (1996) Design by re-representation: a model of visual reasoning in design Design Studies Butterworth-Heinemann, Vol 18, No 4 pp 329-347

Oxman R E, (1999) : “Educating the designerly thinker,” Design Studies, Butterworth-Heinemann, Vol 20 No 2

Oxman R E, (2001) “The thinking eye: visual re-cognition in design emergence” submitted to Design Studies

Schon D, and Wiggins G, (1992) Kinds of seeing and their functions in designing Design Studies, Vol. 13, No. 2 pp 135-153

Stiny G. (2001) “How to calculate with shapes” (working paper) Department of Architecture, MIT.