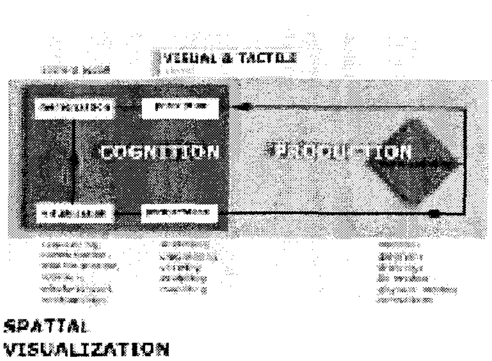
Beginners' IT Instructional Support Environment

ANTONIETA H. ANGULO
Texas A&M University

INSIGHT ON COGNITION

From a cognitive point of view architectural design can be regarded as a creative problem solving process that involves the external manifestation of available spatial abilities (spatial relations, spatial orientation, and spatial visualization) coupled with reasoning. In other words, as we design we contribute to our spatial cognition. We learn to design by practicing design. One learns through a cycle of subprocesses of "cognition, production, and resolve" (Wiley, 1990): by reasoning on the design task, by producing the corresponding representations, and by making decisions to resolve the task. In support of our spatial cognition, we can also describe the stages of perception, memorization, visualization, and performance (Angulo, 1995).



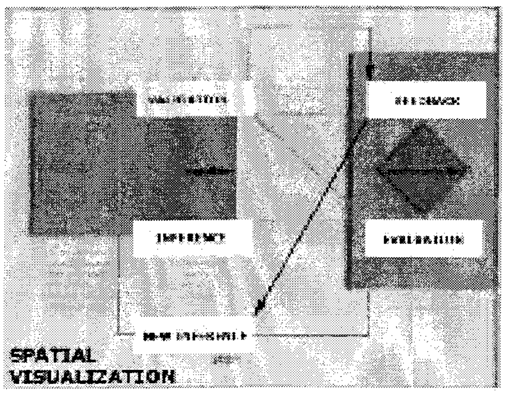
"Cognition and Production Cycles in Design"

In the stage of visualization we establish a basic understanding of the issues, and mentally manipulate images of the world in which we exist, and those that originate in our mind towards the greater goal of understanding or meaning-making. As for instance, we can see, sketch or imaging the front, back, and the side of a building and visualize what it would be like if we were flying over it.

Spatial visualization is not simply a visual process; it is a multifaceted, multi-perceptual sequence of events. By focusing primarily on the visual component, scholars in the field have developed a relatively broad model of spatial cognition. However, the impact of the addition of other senses beyond vision, in particular the tactile experience, has not been as extensively studied. Few psychological studies have examined the effects of prior knowledge/design experience and the tactile/visual stimuli to assess the spatial visualization ability of subjects (Deno, 1995). Despite the fact that they have acknowledged that activities like model-building, sketching and assembly of parts had the greatest positive correlation to spatial visualization, none of them have made exact reference to the impact of this aspect on our ability to perform architectural design inferences. One important assumption of this research is that one thinks with one's hands rather that predetermining a design in one's mind (McNeur, 1993). While the hands build, the eyes perceive and the mind learns, constructing more ideas for the hands to think about, while building. Thinking, making, perceiving, and learning occur in tight cycles during the handling of physical models.

It has been suggested that the impact of visualization on cognition depends on the use of representations (Gagne', 1985). In the practice of architectural design, we use representations to communicate design ideas to others, but also to establish an internal dialogue between our design and ourselves. We accumulate decisions in a process of added complexity and refinement.

Gagne' describes at least three types of representative knowledge; propositions, productions, and continuous knowledge, such as images and sounds. Regardless of how these representations are stored in long-term memory, they can be recalled in their representative form to short-term memory for contemplation or action. Through the observation of design processes it is possible to describe and interpret how we generate inferences that are then processed through relevant representations.



"Representations as Inference-Making Resources"

We rely on representations both as means of evaluation and as means of feedback. Following a process of evaluation of the representation, we take action and decide whether an inference is to be rejected or embraced. In the one case, if our decision is to refute the inference, at that point a new representation in the form of feedback is generated and this will trigger the creation of a modified or totally new inference. In the other case, if we do validate the inference, we can adopt the same representation to add upon and continue the process of design or we can use the representation as a means of suggesting a new improved inference.

We can summarize that the main assumption of this research is that spatial visualization skills could greatly benefit from the recognition of the important role of the representations in the design process and the fostering of the opportunistic use of adequate representations in all different stages; representations that may permit extensive and diverse perceptual handling.

THE BEGINNERS' DESIGN STUDIO: CASE STUDY

We have proposed that the teaching of fundamental design skills in early design studios can be greatly improved if we recognize and upgrade the relationship between the creative process and the media that supports the design process. Consequently, our case study concentrates on a beginners' design studio.

By observing the way in which the beginner's studios are commonly taught (Cappleman & Jordan, 1993) we can produce a crude generalization and find that there are two distinctive ways to teach design:
- Teach the students little up-front information and let them design, thus learning by discovery, in a trial-and-error basis.
- Teach the students through drill exercises that would be eventually applied in future design tasks. These exercises would prepare the students in a way of thinking –a design attitude; prepare the students in the use of a specific technique for design; or prepare them to solve a well-constrained design problem following a problem solving method that can be replicated.

These two instructional methods lead to different techniques in practice and styles of design and it is certainly difficult to quantify the effectiveness of any of them. Nevertheless, there are certain deficiencies in both cases that need to be addressed.

In a beginners' studio instructional environment, the students' performance has been generally manifested by their reluctance to explore alternative solutions. It seems:
- The students don't know whether their ideas are bad or if the representations of their ideas are bad, and/or
- The students don't know whether they are slow generating design inferences or if they are slow creating representations.

Our challenge in this instructional environment is that our students learn to design at the same time that they learn to represent. One way in which we can aid our students in facing such a challenge is by improving their spatial visualization skills through providing them with adequate visualization technologies for the creation of representations. The main objective of this research is to find if the teaching and learning of spatial visualization skills can be aided by an instructional support environment and if so, what kind of visualization technologies are to be incorporated?

The implementation and analysis of the case study that follows validates the research's initial assumptions and helps us to envision new ways to support the teaching/learning process.

The Design Studio Project

This was a two weeks project corresponding to the first design assignment of the semester. The students, in their first Environmental Design Studio, were asked to design a pavilion that may serve as a light, ornamental roofed structure in the setting of a park. The building should encompass and represent human behavior: the pavilion should cover a small portion of the walking/jogging trail, and it could also be used as a place for dynamic and static activities, namely: training, resting, or as a shelter against the weather.

Considerable emphasis was placed on the manipulation of the pavilion's form in relationship to the given context. The pavilion should have a dual character: it should reflect a link with the urban fabric of the city (a park within a small city); being an outdoor structure, the pavilion should also be nature-friendly -not imposing but becoming part of the landscape.

Design Intent

The students were encouraged to discover the interaction between "the form of the structure" and "the structure of the form" by designing the visual form and the structural form of the same architectonic object.

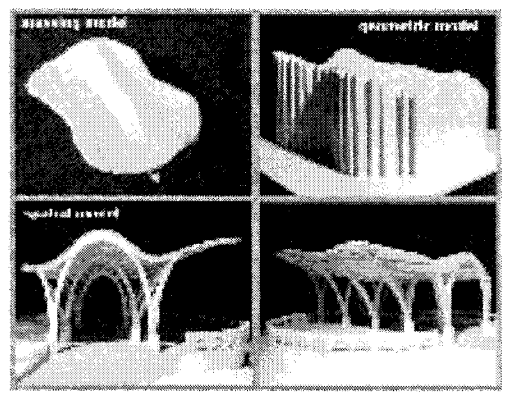
While trying to achieve this, the students needed also to discover the impact of the site on the design object: the landscape including the terrain and the neighborhood; and to design the aesthetics of the dynamic and the static feelings, representing them through the material components of the structure.

Working with Representations

One very important underlying objective of this exercise was to train the students in the use of a variety of representations that may support them in the production of relevant inferences. They used both 2d and 3d media: sketches and models.

In the initial stage of the design process, the students visited the site to gather individual observations and make personal interpretations of the landscape, the terrain, and the neighborhood. The students began to develop abilities to sketch, draw perspectives and take pictures. They also learn to articulate analogue and digital information, thus working in different media. All these allowed them to infer a "prime design idea" in the way of graphics and a "parti" diagram.

The project then focused on the use of 3d models to encourage their spatial visualization skills by means of different types of physical and/or digital models, while exploring the manifestations of the language of form. The 3d models provided support for an accumulative decision making process of increasing complexity: starting by the definition of a visual form (by means of massing and geometric working models) and then by transforming it into a structural form (by means of a final spatial model).

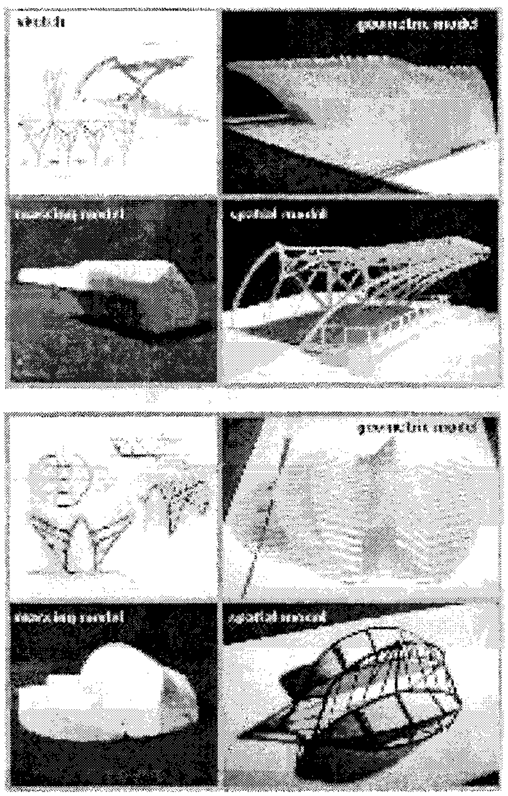


"A project's working and final models"

The students were asked to translate their parti diagram into a 3d "massing" model. If digital 3 dimensional modeling was not used, the alternative was the creation of a physical model made out of a flexible material like Styrofoam (white or green). The massing working model was then positioned over a (digital or physical) terrain model.

The basic characteristics of the massing models were subject of evaluation and feedback. Later these were transformed into "geometrical" working models. Their main purpose was to serve as an aid in the visualization of the specific geometric traits of the vi-

sual form. Two modeling methods were suggested:
- The repetition or gradation of serial planes. The 3D digital modeling of repetitive elements was suggested or the use of physical planes. The planes were made out of white foam core board to create a sequence of profiles (sections) of the structure,
- The interlinking of lines (on a flat plane, or in space). The linear framework (supporting the lines) must be a rigid material like balsa or bass wooden sticks. The interlinking lines may be of rigid or soft material like wire or cotton/nylon thread.



"Two examples depicting the developments in the project from sketches to final model"

After a thorough study on the building materials and systems to be used for their final proposals, the students were asked to create a "spatial" model. The students created solutions that revealed the interaction of concerns between structures, materials, circulation, and program. This was their final model. It could be produced with balsa or bass wood, metal, plastic, paper materials, or others that better represent each of the elements of the structure. The model was placed on top of a final model of the terrain, made out of white foam core boards.

Findings

- The typical deficiencies of beginner students in the application of design tactics and strategies were tackled by the inclusion of a compositional exercise that, in addition to promote focus on a specific design problem was also useful to demonstrate working methods that they would opportunistically use in the future.

- The positive outcome of this project includes a notorious increase in student's ability to visualize plastic solutions through the creation of many representations. The representations show not only alternative solutions, but different levels of development in the chosen solution.

- The preferred method was the creation of a serial planes model. This was a simple representation, removed from all aspects of materiality, tone, and color that accentuate the play of light and shadow, thus allowing the geometrical form to read more clearly.

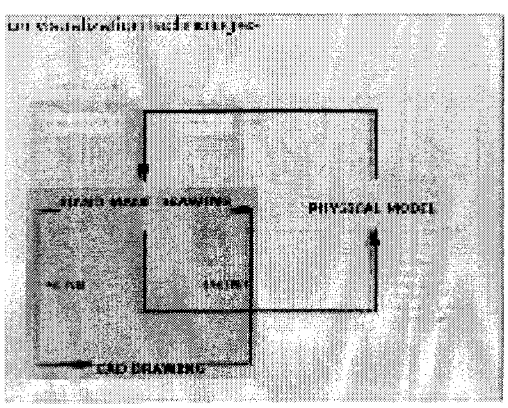
- Design solutions were fostered by the representations but at the same time the media of the representation constrained the students to visualize a limited number of options. The students were not able to achieve the level of formal complexity that was promoted by the exercise.

VISUALIZATION TECHNIQUES AND MEDIA INTEGRATION

Researchers and developers of instructional support environments for design have always been interested on the incorporation of ad-hoc visualization techniques. Nonetheless, improvement becomes evident with the implementation of media integration. For instance: before the advent of digital media we have used drawings and physical models switching back and forward between them on an opportunistic basis.

In a traditional media environment young students are usually asked to work with physical models, manipulating physical materials on design projects based on few pragmatic decisions. In these cases, the physical media offers different possibilities that the students explore and embrace. Most of the times, if the projects are of considerable complexity and the physical materials pose limitations on their manipulation, the students tend to migrate into the use of 2-dimensional drawings for the further refinement of their ideas. In such a migration process the students are forced to translate important design decisions from a 3-d media environment into a 2-d media environment using only their ability to visualize the architectural synthesis at cognitive level. In the case of young design students this can be a very frustrating experience since their representation skills are still rudimentary. The most common result is that students fail to translate all the value of the architectural synthesis: the space, and end up falling back into the more pragmatic position of using orthographic projections as the media of choice.

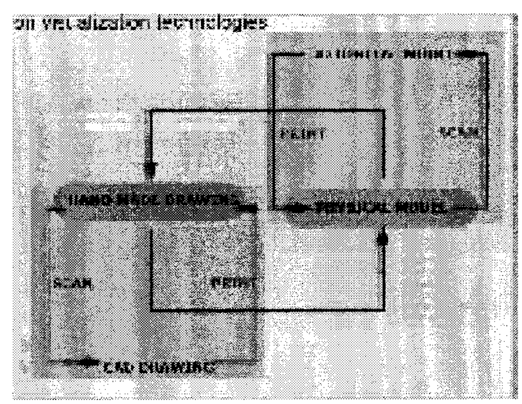
With the introduction of digital media in the design environment we have embraced the integration of analogue and digital 2d media, for instance: making use of flat media scanners and printers we have been able to combine our ability to sketch by hand and the power of image processing software. This processing can be through bitmapped editing of pictures or the use of vector-based drawing techniques to draw hard line drawings of a project.



"2D Digital / Analogue Media Integration"

In this context, we have also experienced the need of making use of 3d modeling software. Most commonly what we have been doing is to take CAD data and used it in the generation of digital models or vice versa. There is no doubt that 3D models add understanding to the project in similar way than the physical models do.

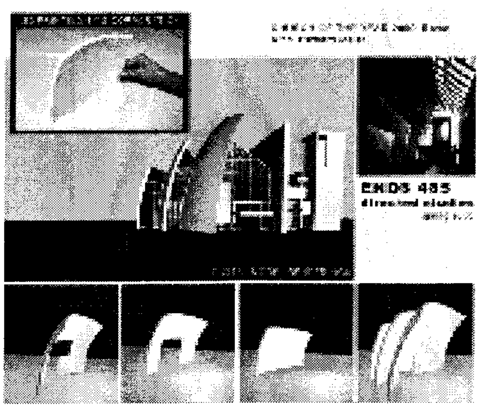
This current tendency suggests a model for an extensive integration of 2d and 3d media, analogue and digital instrumentation environment. If we take the current integration a step further, it is feasible and desirable to explore the possibilities of generating a 3 dimensional digital/analogue cycle similar to the one we currently use when dealing with 2 dimensional media. For this purpose we suggest the implementation of 3d scanning and 3d printing techniques. In operative terms, sketches can maintain a relationship with CAD drawings or physical models. The physical models through the possibility of 3d scanning can then not only relate back to the sketching phase but also can result in 3d digital models. The 3d digital models, products of the "shape grabbing" process, will be used to develop the design further. If these digital representations demand additional physical handling, the next step of the cycle is executed by "printing". The 2D and 3D cycles of Digital / Analogue Media Integration in this model are of flexible nature, so all well-established and new interactions between representations and media are possible; the designer could easily switch between the physical and the digital world.



"3D Digital / Analogue Media Integration"

Examples of this so-called "multimodal" integration -switching between the physical and the digital world (Zabel, 1999), have been implemented in part within certain professional offices (Arquitectura Viva #28). Also in a number of research institutions these processes are currently subject of research (Petric & Maver, 2003 & Hadjri, 2002). Yet we must mention that at professional and academic level these explorations have not been specifically oriented towards an understanding of their value in the teaching and learning of spatial visualization skills.

In early 2003, we were able to conduct a short implementation of part of the multimodal integration we are hereby suggesting. In the context of a graduate independent study, the 3-dimensional models of a relevant architectural building were produced. The representation of the building implied a substantial 3d geometric challenge and in order to help in the visualization of its complex shape, we made use of 3d printing techniques: one wall was printed by a rapid prototyping machine. This short exercise allowed us to test the interfacing procedures that allowed us to create a 3d physical model from a 3d digital model, to test the manipulation of the physical model, and envision the potential return of the resulting geometry into a digital model (after a potential scanning process).



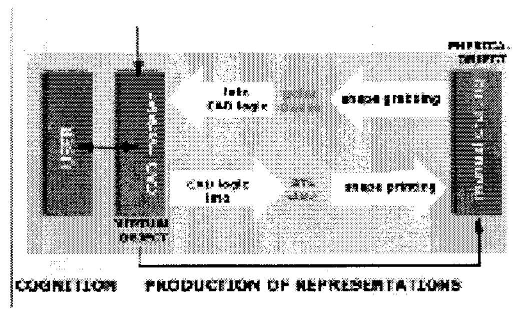
"3 D Modeling and Printing Project"

TOWARDS THE IMPLEMENTATION OF AN IT MEDIATED INSTRUCTIONAL SUPPORT ENVIRONMENT

As a vehicle for improving the teaching and learning of spatial visualization skills in beginners' design studios, our research point towards the potential benefits of a "Multimodal and Media-Rich" support environment in addressing the management of complex forms.

The "multimodal" nature of the support environment would allow for the manipulation of physical and digital models; at the same time that its "media-rich" character would provide for the integration of all forms of relevant analogue and digital representations and manipulation techniques.

From an implementation point of view, a pedagogic method that proposes embracing the tradition of "parti" model-making, at physical level, can be supplemented with the introduction of 3-d shape grabbing technology, appropriate digital model manipulation, and 3-d shape printing.



"The Multimodal / Media-Rich Support Environment"

This study recognizes the multiple technologies available in the process of interfacing between physical and digital objects (Novitski, 1999; Entous, 1998; Streich, 1996). For instance in the case of shape grabbing there are a number of technologies that can be used and translate into a CAD modeling environment. Each one implies a different set of conditions of use and delivery of the digital representation. The same can be said when it comes to the task of shape printing, where for instance we need to decide if additive or subtractive processes are more relevant to the beginners' studio design task.

REFERENCES

- Angulo, A. (1995) *"On the Conceptual Feasibility of a CAAD-CAAI Integrated Decision Support System: a computer aided environment for technical decision making in architecture"*, Den Haag, ISBN 90 5269 175 4.

- Arquitectura Viva #28, *"Maquetas Digitales: el ordenador en el studio de Gehry"*

- Cappleman, O. & Jordan, M. (1993) *"Foundations in Architecture: An Annotated Anthology of Beginning Design Projects"*, Van Nostrand Reinhold, New York, ISBN: 0 442 00764 7.

- Deno, J. (1995) *"The relationship of previous spatial visualization ability"* in the Engineering Design Graphics Journal 59, pp. 5-17

- Entous, M. (1998) *"Developments in 3D Scanning and Digitizing: New Strategies for an Evolving Design Process"* in ACADIA 1998, pp 213 - 221

- Gagne', E. (1985) *"Cognitive Psychology of Education"* Boston, MA: Brown Little and Company.

- Hadjri, K. (2002) *"Bridging the gap between physical and digital models in architectural design studios"* in the International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol XXXIV-5/W10.

- McNeur, L. (1993) *"Thinking Hands"* in Foundations in Architecture: An Annotated Anthology of Beginning Design Projects, pp 52-53.

- Novitski, B. (1999) *"Rapid prototyping, a process borrowed from industrial design, lets architects make scale models from computer files"* in www.archrecord.com/DIGITAL/DA_ARTIC/DA12_99.ASP

- Petric, J. & Maver, T. 2003 "Virtual Reality, Rapid Prototyping and Shape Grabbing", Proceedings of ECAADE'2001, Education in Computer Aided Architectural Design in Europe, Helsinki – Finland. ISBN 0 9541 183 1 6, Graz – Austria.

- Streich, B (1996) *"3D scanning and 3D printing for Media Experimental Design Work in Architecture"* in ACADIA 1996, pp 183-190.

- Wiley, S. (1990) *"A Hierarchy of Visual Learning"*, Engineering Design Graphics Journal, 54 (3), pp 30-35.

- Zabel, A., Deisinger, J.,Weller, F. & Hamish, T. (1999) "A Multimodal Design Environment" in http://vr.iao.fhg.de/papers/ess99.pdf.