Light and Form in Design - a Computational Approach

BECK, Mateus Paulo
Arquiteto e Urbanista, PROPAR, Faculdade de Arquitetura, Universidade Federal do Rio Grande do Sul, Bolsista do CNPq
mateus.beck@ufrgs.br
BRENER, Rafael
Arquiteto, MSc, PROPAR, Faculdade de Arquitetura, Universidade Federal do Rio Grande do Sul
rafaelbrener@terra.com.br
GIUSTINA, Marcelo Della
Acadêmico de Arquitetura, Bolsista Iniciação Científica Faurgs, Faculdade de Arquitetura, Universidade Federal do Rio Grande do Sul
arquitetura.marcelo@gmail.com
TURKIENICZ, Benamy
Doutor, Professor Titular, PROPAR, Faculdade de Arquitetura, Universidade Federal do Rio Grande do Sul
benamy@portoweb.com.br

The aim of this study is to discuss the relationship of light and form in architectural design from an aesthetical point of view. The paper presents a pedagogical experience carried out by twenty six 5th semester design studio students based on specific exercises whose main goal was to stimulate the student's awareness and the exploration of plastic aspects of light in design. The methodology combines the use of mockups, lamps and photos with computational applications to simulate light and its impact on architectural forms. The results obtained in physical and virtual environments are compared and reasons for further combined use are commented.

I. Introduction

This paper describes a pedagogical experience which has been carried out by 26 fifth semester design studio students from the Faculty of Architecture, Federal University of Rio Grande do Sul, Brazil. The teaching strategy as proposed by Turkienicz and Mayer (2005) is based on a series of exercises aimed at the progressive development of design skills to support the term project. This article is concerned with the use of natural and artificial light in architectural design from an aesthetical point of view, as opposed to the physiological point of view adopted in most of the Architecture Schools' curricula. The teaching strategy is based on the use of mockups, lamps and photos combined with computational applications as to stimulate the student's awareness and allow the exploration of plastic aspects of light in design. Light and form exercises are preceded by exercises exploring the relation between form and function using common daily objects (Westphal et al, 2006), exercises on proportion, two-dimensional compositions using symmetry operations with computer support as proposed by Celani (2003) and the creation of a minimal living space assigning functions to spaces originated from the former compositions (Mayer et al, 2005).

As far as perception is concerned, light and form have reciprocal influences over each other. These reciprocal influences are not totally explained by aesthetical theories. For example, each time we look at something, it is from a different point of view, nearer or farther, higher or lower, in a different color or shade of light, or against a different background. We need mind-constructed boundaries so as to recognize that an object is the same even when seen in different ways. These boundaries retain only the permanent information about the objects form and function and, simultaneously, discard changing aspects such as light shading, brightness, contrast, and reflectance (Minski, 1988). These are considered to be the plastic aspects of light, which might be perceived trough the identification of primary and emergent shapes. The method of shape emergence (Gero e Yan, 1994) turn out primary shapes as the ones explicitly represented and emergent shapes are the ones implicit in the former. In this way shape emergence is a method to reformulate our mind-constructed boundaries, producing new explicit representations from implicit shapes, as presented by Beck and Turkienicz, 2006. Stumpp and Turkienicz (2004) have used this method to describe aspects of visual symmetry and rhythm according to the impact of light in building facades.

This paper is divided in three parts. The first one describes the methodology, in the second part the results are presented and analyzed, and in the last part some conclusions are outlined.

2. Method

The exercises about light and form are preceded by lectures about the physical properties of light – transmission, reflection, absorption, refraction, brightness, contrast, color – and its impact on different materials, textures and shapes. There are also instrumental lectures on CAD modeling, rendering and light simulation, using AutoCad and 3Dstudio. Light and form exercises re-use a composition created during a previous exercise, a minimal living space. In the first phase of the work the students build a white mockup and expose it to different light sources (spotlights, incandescent and fluorescent lamps) in different positions. The impact of light on internal and external surfaces is captured with photography, attempting to emulate different light conditions on buildings, as follows:

1. Direct sunlight;
2. Diffuse skylight;
3. Artificial lighting from inside at night;

The second phase of the exercise is performed in the computational environment. The students build a virtual model to simulate the same lighting situations as described above. The results are presented trough renderized images of the model. Further on the students are asked to modify the obtained results, creating new alternatives considering plastic aspects of light and functions related to the spaces. This is achieved by changing the models form, applying different materials and colors, creating new openings, etc. After the computer simulation phase the students are asked to choose one of the virtual alternatives and then to build a mockup representing the chosen alternative. Pictures are taken from the final mockup under the three mentioned light conditions.

Figure one shows an example of a student's work. The student performed the series of exercises departing from a CD rack. The side view of the object was used to create a symmetry composition in the computational environment proposed by Celani (op. cit.) that originated the proposal for a minimum living space (1A). The white mockup was photographed under diffuse and direct light and with light from the inside (1B). The student then constructed a virtual model of his proposal, which he used to simulate tree alternatives, shown under diffuse light and with light coming from inside (1C). The first solution simulated concrete walls and wood-slatted openings for the openings on the corners. The second alternative inverted these materials, opening the larger walls and closing the corners with walls. The third alternative was similar to the first one, using white paint on the walls and wood on the corners. This was the chosen solution, used to construct the final mockup, shown under diffuse and direct light (1D).

3. Results and Analysis

The results of the method are exemplified in Figure 2, columns A to D. The upper images are renderings showing the chosen alternatives produced during the exercise. The lower images are photos from the final presentation mockups. The results are compared and analyzed as follows.

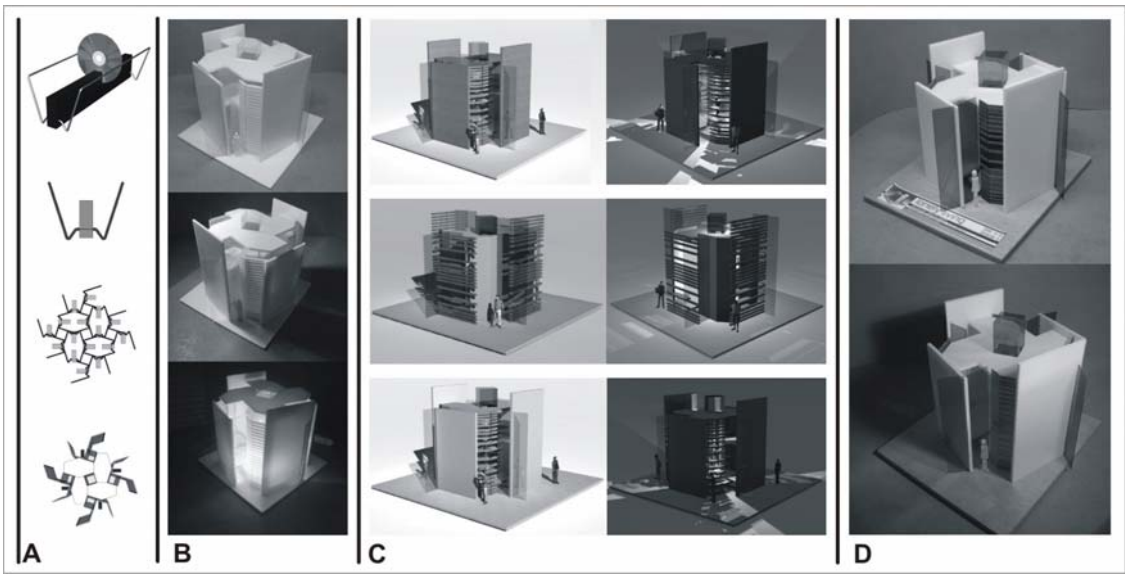

Figure 1 – the evolution of a light and form exercise

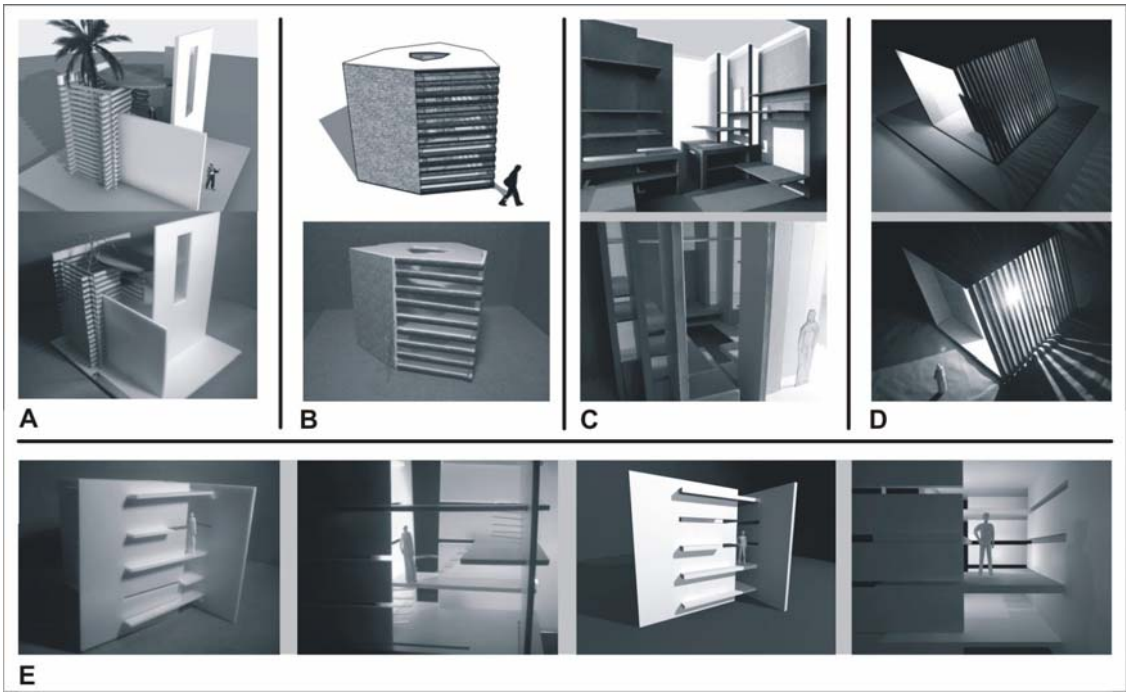

Figure 2 – examples comparing study renderings (A-D top, E left) and presentation mockups (A-D bottom, E right)

Figure 2A shows an external view of a student's composition simulating direct sunlight. The renderized image considered ray-traced shadows and radiosity contribution, achieving a result very similar to the presentation mockup (3Dstudio).

Figure 2B shows an external view of a composition simulating materials such as stone, wood and concrete. The final mockup was photographed under diffuse light; computational application has simulated direct sunlight only (SketchUp).

Figure 2C shows an internal view of the student's composition simulating direct sunlight. The mockup could not be folded apart. This has restricted the camera placement, whereas the renderized image allowed a better visualization of the internal space (Autocad and 3DStudio).

Figure 2D shows an external view of a student's composition simulating lighting at night. The renderized image has a better result than the mockup. Whereas the mockup restricted the size, position and number of lamps placed inside it, the work in the computational environment allowed a higher control of these features. The rendering shows the use of several light sources considering ray-traced shadows and radiosity contribution (SketchUp and Artlantis).

Figure 2E also allows a comparison between mockup photos and computational renderings, although they do not show the final result of the exercise. The images on the left-hand side are photos of the white mockup under direct light, and the ones on the right-hand side are renderings produced with computational application (Artlantis). Comparing the photos from the white mockup with the renderings the student attempted to reproduce the different light conditions within the computational environment.

4. Conclusions

The work with mockups, lamps and photos improved the students' awareness of the impact of light on form. Even simulating different lighting conditions on buildings, the students worked with mockups in a real environment, operating directly with lights and forms. At this environment the use of photos contributes to the emergence of the plastic aspects of light. However, the visualization of the interior of the mockup is restricted as well as the simulation of artificial lighting coming from inside the building at night.

Computational applications allow better visualization of the interior of the models, from the observer's point of view. The computational environment also increases the speed of simulation and evaluation of alternatives, with the test of different materials, alterations on the form, number and position of light sources, especially inside the form, simulating artificial lighting. However the quality of the work

depends on the software capability of simulating light (shading, raytracing, radiosity, etc.) and on the students' ability to use the program. The comparison between them allows the improvement of the students' ability to use the software, which is considered to be a calibration of the computational application. The combined work with mockups and computational applications accelerates the understanding of the impact of light on forms. The method stimulated the exploration of plastic aspects of light in architectural design from an aesthetical point of view trough the creative use of computational applications in design.

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Figure 1 – provided by student Alexsander Coelho
Figure 2A – provided by student Pablo Brum Morales
Figure 2B – provided by student Mariana Guardiola Bogarin
Figure 2C – provided by student Rodrigo Renner dos Santos
Figure 2D – provided by student Juliana Ziebell de Oliveira
Figure 2E – provided by student Marcelo Della Giustina

Keywords
Architectural Design, Lighting, Design Simulation, Virtual Environment