Technology in the Design Studio:
The Skyscraper Light Fixture

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Architecture is the masterly, correct, and magnificent play of forms in light.

– Le Corbusier

ABSTRACT

In the context of an upper-division computer-aided architectural design studio, students are asked to design and construct a prototype free-standing tower light fixture based upon principles abstracted from an assigned historically significant tall building. The fixture serves as a vehicle for exploration in four areas: the principles of skyscraper design, computer-aideddesign, principles of lighting, and tectonics/materiality. The light fixture is not the primary project for the semester, rather it serves as a four week introductory project while students simultaneously gain skills in design computing. The design of a lighting fixture is used metaphorically for the design of a skyscraper. A number of rules are included as a part of the assignment, and the students are expected to explore the use of the computer as a design and presentation aid. Guest faculty are brought in to add theoretical underpinnings to the lighting design, field trips are taken to a lighting research center, and a specialist is brought in near the end of the project to confirm that the projects adhere to electrical safety standards. The students level of enthusiasm for the project is extraordinarily high and the resulting light fixtures are astonishingly well crafted.

INTRODUCTION AND PEDAGOGICAL OBJECTIVES

The computer-aided design studio in the School of Architecture at the University of Southern California is a vertically-mixed elective studio offered when the students are in their third, fourth, or fifth years. Though the studio program and building type have varied in recent years, a series of these studios have been offered focusing on the architecture of the skyscraper. The semester-long projects involve the design of a tall building, often on a site in downtown Los Angeles near the university. Because many of the students have not used computers in adesign context prior to this studio, delaying the onset of the primary design project gives the students time to learn more about the skyscraper building type while simultaneously being introduced to some of the uses of the computer in design. In a 15 week semester, approximately four weeks are devoted to an introductory project: designing and constructing a light fixture.

The light fixture design project has a number of intentions. It is introduced at the beginning of the semester to give the students the opportunity to have a "test run" at using the computer as a design aid. The project requires that each student become familiar with a assigned noteworthy skyscraper, document and present their discoveries to the studio, and distill a set of first principles from the existing building to help guide them through the design of their light fixture. The light fixture works as a metaphor for the design of a skyscraper, engaging the students in thinking and discussing issues about the design of tall buildings. The dimensions of the fixture require that the students pay attention to issues of structure, construction and stability. Finally, the students must become knowledgeable about many of the issues related to lighting design, such as lamp types and visual comfort. The importance of understanding how difficult lighting design can be is often overlooked in the education of architects.

Tall buildings objectives

At the beginning of the semester, students are individually assigned a historically significant tall building and asked to seek information about the buildings' architectural and cultural significance. The students learn about structure, lateral stability, context, mechanical systems, construction materials and techniques, lighting (both lighting of a space and on a space), and historical context. As the students complete acase study on their skyscraper they must interpret the building within the context of a design for a light fixture. To help them learn first hand about skyscraper attributes, the studio takes a field trip to a local tall building where they are given a "behind-the-scenes" tour by the building engineer (Fig. 1). The tour includes examination of structural, mechanical, and other systems, as well as occupancy and management issues. When construction projects in the area permit, we also con-

Fig. 1. Students admiring the helicopter landing pad on top of the First Interstate Building, the tallest building in the Western United States.

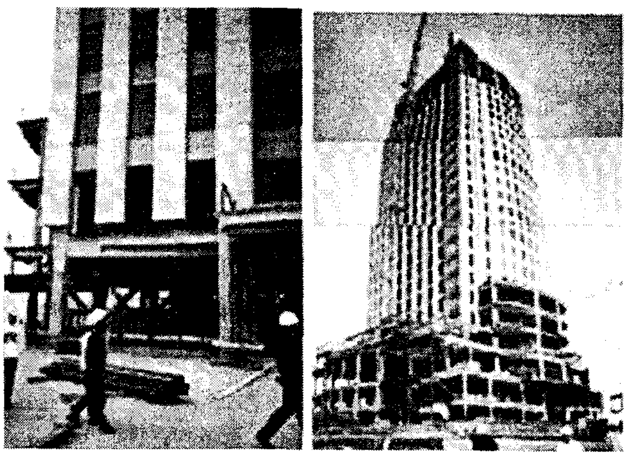

Fig. 2. Students touring the MTA Building under construction.

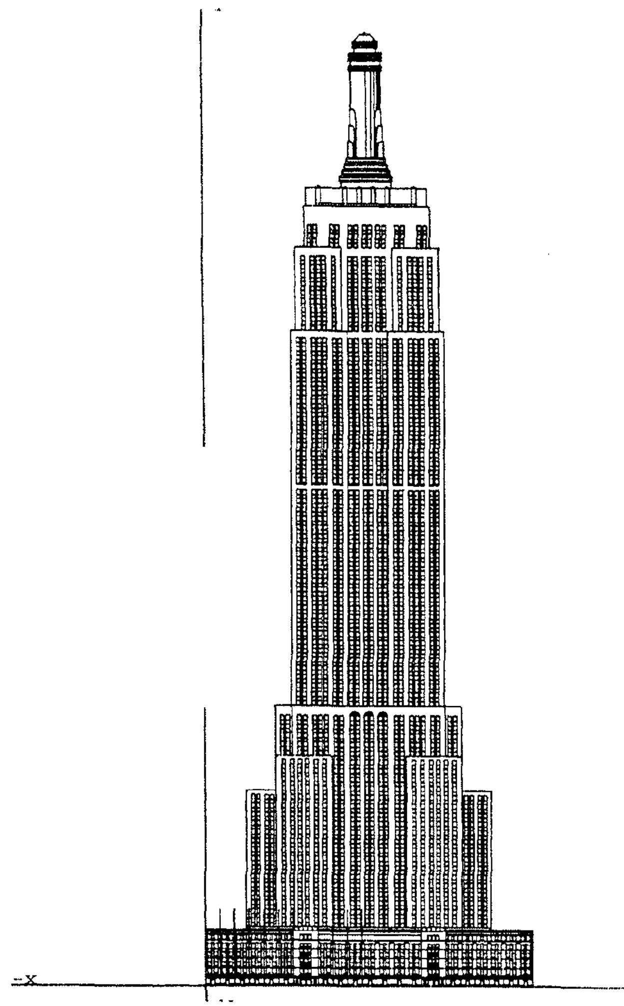

Fig. 3. Sample skyscraper case study computer drawings of Empire State Building by Tammy Jow.

duct a tour of a tall building under construction (Fig. 2).

Computing pedagogical objectives

The semester-long studio has as a goal immersing the students into a variety of opportunities to use computers in design. Over the course of the 15 weeks, students will use two and three-dimensional modeling, rendering, animation, presentation, and communication software to help them with their design projects. The light fixture project occurs at the beginning of the semester when the students do not yet have computing skills. Thus the computing intent of assigning the light fixture project was primarily to explore uses of basic two-dimensional and three dimensional geometric modeling. The other computing applications are taught after the completion of the light fixture project.

The students often have little or no graphical computing experience when they begin this studio, and so the first assignment asks them simply to document an orthographic view of their assigned building as accurately as they are able to within the limits of the resources available in our library and the capabilities of the computer (Fig. 3). By assigning only well-known case study buildings, the task of finding geometric data is made easier on the students.'

Lighting pedagogical objectives

The students in the studio have generally already taken a required course in environmental controls and systems in which they were introduced to artificial lighting issues. To reinforce this background, a building science faculty member is invited to give a presentation in the studio regarding issues such as lamp selection, glare, and task vs. ambient lighting. We have seen that the students pay much closer attention to this material when there is an immediate project at hand. In some semesters, we also visit the Southern California Edison research facility in Irwindale, California. This facility includes instructional seminar and lab rooms where the students can see and compare lamp technology, so that they understand color temperature of lamps and the characteristics of lamp modifiers, such as lenses, baffles, and reflectors.? Students are also shown historical examples of light fixtures of similar proportions designed by noted architects and designers. In the later stages of the design and construction of their light fixtures, consultants are brought in to verify electrical and wiring issues to maintain a standard of safety.'

Tectonics, Materiality and Constructability Pedagogical Objectives

The light fixture project includes opportunities for the students to learn about skyscraper materials, construction techniques and structures and their relationships to computing, lighting and the supporting resources of the school wood shop. While the students in the upper division studios have already gained skills in model making and the uses of power tools, the objective with this project is to encourage the students to concentrate on planning for the construction and detailing.

The facilities and equipment in the shop are fairly good, but most of the equipment is intended for wood or plastics. Thus many of the light fixtures are constructed using these materials. However, even though there are limited resources for working with softer metals such as aluminum, many of the students eagerly choose to use metals as a part of their light fixtures in order to represent the metals of the skyscraper.

PROCEDURES

The assignment asks the students to design and construct a fully operational prototype light fixture within a 12" x 12" x 72" envelope. The four areas of the pedagogical objectives are interwoven throughout the four weeks of the assignment.

Skyscraper procedure

Students are required to derive a set of first principles from their case study buildings, and use these principles in the design of their light fixture. Principles were encouraged from structural, constructional, process or even social "issues" that are a part of their individual case study. The six-foot height of the light fixture was deliberately chosen to be higher than eye level as a way of reinforcing the idea that skyscrapers are rarely seen from above.

The students were expected to accomplish the following items during the course of the four week sketch problem: research their assigned skyscraper and produce CAD plans and elevations of it. Design a free standing 1' x 1' x 6' lighting fixture in three-dimensions on the computer. This fixture was intended to go into the existing skyscraper, but not be a period piece, instead a modern interpretation of the building and its important elements. It also had to include a minimum of two lighting elements or dimmers. Each of the projects was required to provide a conceptual explanation and a physical manifestation for a required datum line arbitrarily set at 9" above the floor.

The slender height-to-width ratio for the light fixture was inspired by the noted engineer William LeMessurier, who noted that tall buildings only start to become structurally interesting when the slenderness ratio approaches 7:1.[4] The fixtures had to be freestanding, six feet tall, with a 12" square base. This ratio is comparable to many tall buildings and necessitated the students clearly defining and solving the problem of structural stability. Many of the students' resolutions were inspired from their case study buildings: diagonal bracing, tube construction, massive bases, mass dampers, lightness of construction, curtain wall construction. Because of the lack of attachments at the ground, lateral stability was crucial to prevent overturning.

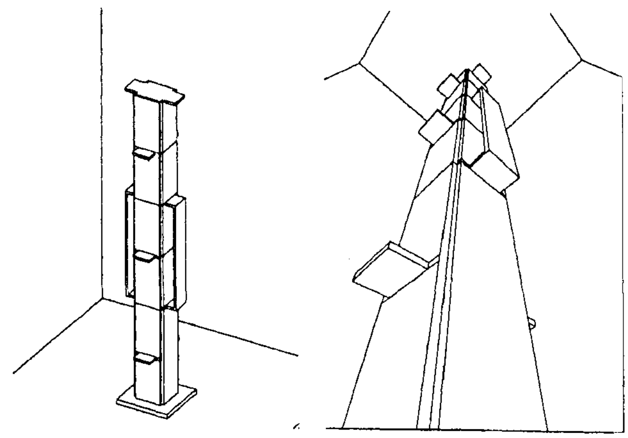

Fig. 4. Views of 3D geometrical computer study model of light fixture design.

Computing procedure

Since the students in these early experiments often come to the studio with little or no graphic computing experience, the students are given a brief introduction to two-dimensional computer modeling, and they worked through a series of self-paced workshops.[5] With these 2D skills, the students are asked to prepare a presentation drawing of their assigned skyscraper in the first week of the semester. In the second week, students are shown output devices. Finally, the students are asked to make 3D geometrical model of their light fixture design prior to its construction (figure 4). These computing activities represent only the beginning of their education in the applications of computer-aided design and visualization, and so the students are not yet capable of a range of computing visualization possibilities.[6]

Lighting Procedure

After receiving instructions about light fixtures and lamps, and taking field trips mentioned above, the students are asked to create a study model to be tested and explored using either the sun simulation machine or flashlights. The light fixtures must use at least two sources of light, and be adjustable to provide a low level ambient light (a sculpted light) and a higher level reading or task light. The request for a reading level light often manifests itself in a high-glare response.

In spite of repeated explanations and demonstrations, we experienced a considerable amount of difficulty in convincing students to pay attention to avoiding exposed lamps and discomfort glare, and so the students are encouraged to mock up their electrical systems as early as possible in the process, so as to give us an opportunity to individually demonstrate the possible glare problems associated with the differing types of lamps.

	Week 1	Week 2	Week 3	Week4
Skyscrapers	Case studies + Derive Principles	Generic Issues Field Trip		
Computing	2D	More 2D+ Output devices	3D	Presentation Techniques
Light		Guest Faculty	SCE CTAC Field Trip	
Tectonics	Shop reorientation + Materials	Physical Model	Partial Assemblies + Electrical Consultant	Construction

Fig. 5. Calendar of activities in the four study areas of the light fixture design project.

Tectonics Procedure

The project explores the idea of architectural design as a series of both physical and virtual representations. The stated goal is "museum-quality" craftsmanship and construction intended to last to last 100 years. At least one physical model is produced (usually at 1/4 scale), and one detail of the actual lamp is built at full scale.

The advantage of the scale model is that it can reveal some of the pitfalls of the design before final construction. One common example is that student design can be seduced by the repetitive characteristics of skyscrapers and the ability of the computer to repeat geometry. The physical model can reveal this as the students try to construct objects that are repeated hundreds of times.

EXAMPLES AND RESULTS

Three examples of the students work will serve to demonstrate the level of results experienced by the studio. Each of these students were in their 4th year. Ryan Smith was assigned to study the Chrysler Building, Tony Kim was assigned Rockefeller Center, and Ivy Glasgow studied the Singer Building.

Ryan Smith • The Chrysler Building

As part of the analysis of the Chrysler Building, Ryan became enamored with the historically significant social event surrounding the surprise addition to the top of the Chrysler Building and he transformed the idea for the light fixture elements. The Chrysler Buildings' apex was clandestinely redesigned to be significantly taller, and was constructed within the frame of the tower and raised into place at the last minute, making the building the tallest building in the world at the time. Ryan's project contain a trace of this history by also being designed to be contained within the 1'x1'x6' required envelope, but then reflecting the same "race for height" as it is capable of unfolding to become almost 10 feet high (figure 6).

Ryan used aluminum stock, aluminum bar, and stainless cables and rollers to construct a structurally triangulated all-silver light fixture that interprets the color, texture, and form of the Chrysler Building's upper floors and spire. The low-voltage halogen lamp uses the structural cable for its power supply and can be located on any of the three elements of the light fixture.

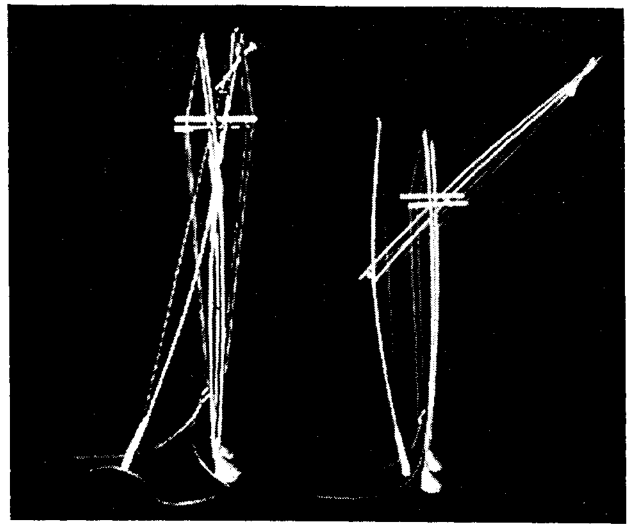

Fig. 6. Chrysler Building light fixture partially unfolded.

Tony Kim • RCA Building at Rockefeller Center

For Tony Kim, the vertical slab geometry of the Rockefeller Center's RCA Building is combined with progressive lightening of elements towards the top of the light fixture. Tony used separate types of halogen light sources to create a light fixture with several capabilities, from reading light to directional light to sculpted reflector.

Through experimentation, Tony discovered that the most inexpensive MR-16 halogen lamps actually produced a separately colored yellower light that "leaks" through the cheaply made reflector at the base of the lamp. This results in a whiter (almost blue) light being projected out the top and sides of the light fixture, and a yellow softer glow being projected down at the base (figure 7). He uses three different lamp locations, and each is separately dimmed.

Ivy Glasgow • The Singer Building

Ivy concentrated on the used of reflected light and highly reflective inexpensive materials. While her two sources of light are screened within the base and capital of her tower, the shaft of the light fixture appears to give off most of the light due to the strategic positioning of the lamp and the curved surfaces of the wire structure (figure 8).

CONCLUSION

The excitement generated by the actual construction of the light fixture was extraordinary. Light lends an extra dimension to the design project that often results in effects that go well beyond the intentions. The students have learned how difficult light fixture design can be, and how important the role of lighting designer is.

As with their original case study skyscrapers, the lighting fixtures were extremely well lit, not only in intensity of light, but also in the drama of the lighting. The fixtures were not always well-designed to provide even illumination (though a separate course is offered to help the students improve their abilities), and many of the projects concentrated on spectacu-

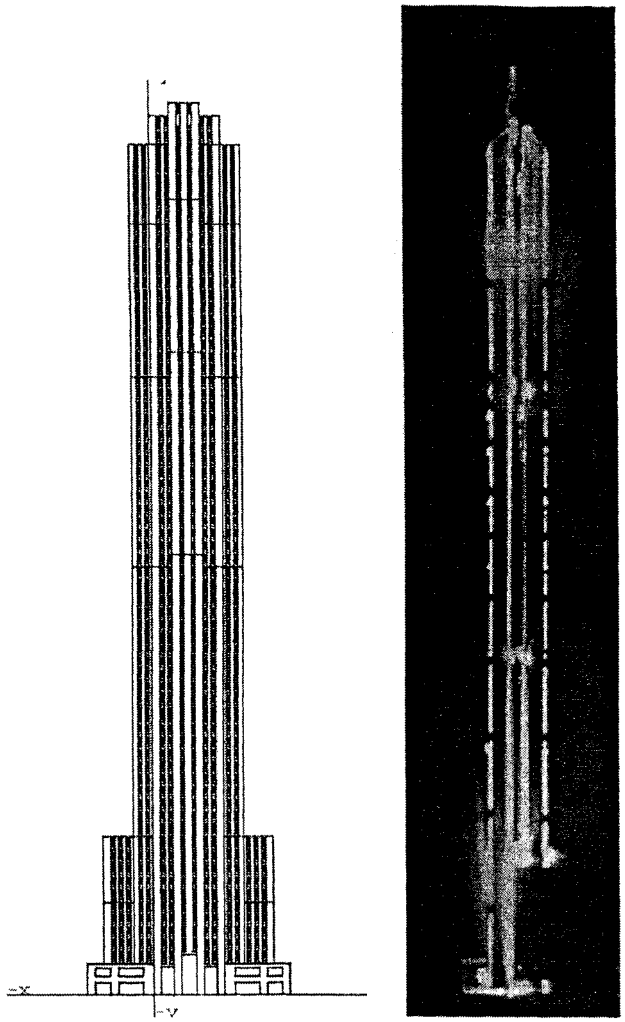

Fig. 7. RCA Building case study drawing and light fixture design by Tony Kim.

lar effects over useful illumination. Providing power through electrical cords to the outlets often proved to be the most ungainly aspect of the students' designs. As the fixtures had to be freestanding and our presentation room did not have floor mounted outlets, this was not considered a major problem.

The students' solutions for ventilation were often less successful than their structural solutions: lamps scorched wooden surfaces, non-tempered glass shattered under thermal stress, and although no problems resulted, we were worried when a few students incorporated water elements like small aquariums as part of their lighting fixture.

As a test of the capabilities of visualization software and the capabilities of novice computer users, we are conducting an experiment where photorealistic renderings were attempted before the light fixtures were built. In future semesters, the interaction between computer methods and manual methods will also be explored more thoroughly, especially in the use of scanning and digital photography, both two-dimensional and three-dimensional. We are also interested in using Computational Fluid Dynamics (CFD) software to explore heat dissipation from the lamps. As equipment permits, we will also explore computer-aided design/computer-aided manufacturing (CAD/CAM) and have students manufacturer at least one element of their lighting fixture directly from the computer.

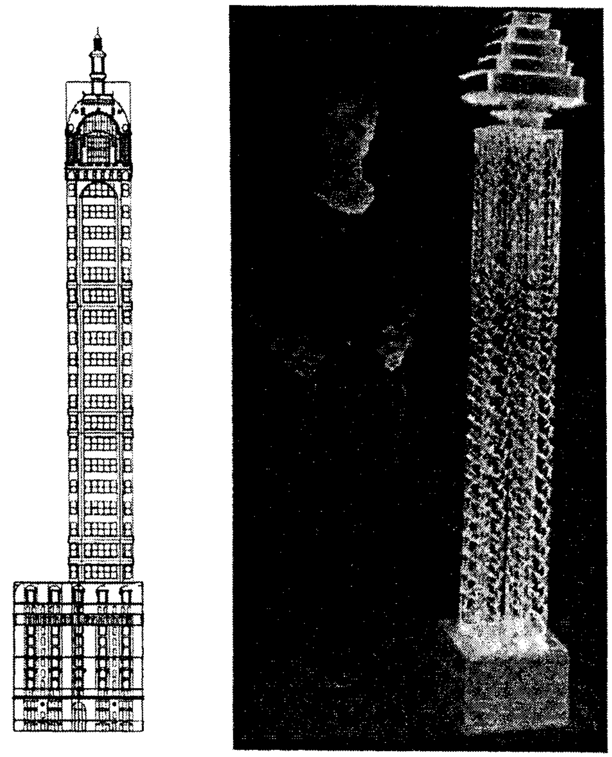

Fig. 8: Singer Building case study drawing and light fixture designed by Ivy Glasgow.

NOTES

[1] The pedagogical intent has evolved to include other computing activities in more recent semesters as the students are beginning to come to this studio with significant computing skills already. We have also conducted the light fixture exploration in studios that do not use the tall building as the building type for the primary project.

[2] Southern California Edison CTAC facility, Gregory B. Sharp, Architect and lighting designer.

[3] Some students can be encouraged to use electrical systems of UL approved lighting fixtures because of their designs. Both these and the custom fixtures are examined by electrical engineer Joseph Pingree, Ph.D., for safety considerations.

[4] LeMessurier, William. Lecture at the University of California, Berkeley, (March 1985). William LeMessurier, the noted tall buildings engineer, suggested that the measure of tall buildings is in their slenderness ratio. A building must be at least five times taller than its widest dimension in order to qualify. A building of the ratio 7:1 was considered to be closer to the true definition. Although the light fixture projects do not quite approach a slenderness ratio of 7:1, we take some consolation in the fact that the fixtures cannot have permanent attachments to the ground.

[5] The students are guided through a series of workshops also developed by the authors. Kensek, Karen and Noble, Douglas 1990, *A.01, A.02, A.03, Introduction to a Layer-Based CAD*

System: AutoCAD, Center for Environmental Design Research, College of Environmental Design, University of California, Berkeley. Workshop, 1990.

[6] We have recently also been conducting an experiment involving three-dimensional computer visualization as a part of the light fixture project, and moving the project to the end of the semester.