February, 2015

The Light Cube: Employing the Measurable and the Immeasurable to address Constrained Sites

Caryn Brause, *University of Massachusetts Amherst*
Naomi Darling, *University of Massachusetts - Amherst*

The Light Cube: Employing Constraints to Stimulate Innovative Thinking for Urban Infill Sites

Caryn Brause, Naomi Darling

University of Massachusetts Amherst, Five Colleges (Hampshire College, Mt. Holyoke College & University of Massachusetts Amherst)

Introduction

Light has the power to define space, to create presence, and to deeply affect our spirit. Sunlight connects a place to its location with respect to the solar system and its unique coordinates on earth. Through light, the temporal nature of space is revealed in a perpetually dynamic play of color, intensity, and movement.

The environmental imperative to address climate change through a reduction of fossil fuel use has renewed interest in the quantifiable aspects of daylighting in building. This can be challenging in urban sites where key contributors to daylighting such as building orientation, form, and floor depths may be given conditions. At the same time, re-densifying these underutilized properties through adaptive reuse and urban infill are critical to community redevelopment and supports growth management strategies that reduce automobile use and preserve existing natural areas and productive agricultural land.

Context

This paper examines creativity research to explore light, in both its sensorial and quantifiable aspects, as an armature for teaching students to employ constraints as a generator of innovative thinking. It proposes a method for teaching that foregrounds experimentation and then layers analytical methods onto this bodily experience. The paper then examines this approach through an analysis of learning outcomes as demonstrated in student projects.

Taught in the fall of 2012 at the University of Massachusetts Amherst in two sections of seventeen students each, the studio unfolded through three assignments of increasing scale and complexity. Site and program parameters, both hypothetical and actual, provided realistic constraints and rich opportunities for examining how focusing on light and bodily experience can prepare students to work with the current and future inventory of highly constrained urban sites.

Constraints as a Generator of Creativity

Research on creativity points to constraints as a generator of innovation by limiting the search for solutions within a defined "problem space." A problem space is defined as how a designer represents or structures a problem, and then how the designer defines project goals and sets forth criteria for evaluating whether these goals have been reached. For beginning design students, the complexity of architectural design can be overwhelming so initial projects seek to provide a well-defined problem space. Patricia Stokes PhD, Director of Barnard College's Variability and Creativity Lab, writes that "choices are confounding; responses rewarded in the past are repeated. Without constraints, composition takes place in a cul-de-sac of the customary (a familiar subject) and the successful (a style worth an "A" in the past, in this class)." (Stokes, 2007)

Problem spaces are positioned along a continuum defined by "well-structured" at one end and "ill-structured" at the opposite end. At the "well-structured" end of the problem spectrum, all the information needed for the solution is highly specified, a correct solution may exist as well as a process for testing the solution against established criteria. (Simon, 1973) By contrast, in an "ill-structured" problem, the information or criteria to solve the problem are incomplete, and the resolution of the problem can lead to different, equally correct solutions. One common condition of an ill-structured problem is that new resources or parameters are introduced through the process of attempting to solve the problem. (Simon, 1973) This condition accords with the design process, where project goals are rarely described in totality and the designer must generate additional information through the design process in order to define the problem space. Depending on the degree of openness of the project, the parameters might be redefined several times.

Constraints enable designers to structure problem spaces by limiting the search for design solutions to some parts of the search space, and directing or promoting the search for design outcomes in other parts.[1] Effectively paired constraints can inhibit the search among commonplace solutions while directing the search to innovative and unexpected solutions.

Problem-spaces are comprised of several different constraints, among them *source* and *task* constraints. Source constraints comprise the existing elements from which the designer may draw and are available for recombination and improvisation. (Stokes 2007) As designers, we increase our *source* constraints when we expand our proficiency in one or more domains of knowledge. In this studio, the instructors sought to enlarge the available *source* constraints by developing students' expertise in the domain of lighting through lectures, case studies and exercises.

Task constraints involve materials and methods. These comprise more traditionally understood constraints in design projects such as constraints imposed by the site, the program, or the available construction materials and methods. In early studios, a fundamental pedagogical objective is to demonstrate to students how they might selectively constrain or expand their problem space such that they are positioned to respond innovatively.

Constraints: Light

In a well-structured daylighting problem, light is available from all orientations and able to be modulated in a variety of means. Students learn the phenomenological and quantifiable impact of light from each of the cardinal directions. From a formal perspective, students may be drawn to compose buildings with apertures distributed facing multiple orientations but they quickly learn that from a performance perspective, a southern facing orientation is optimal for passive daylighting strategies.

In this studio's series of projects, the *task* constraints were paired to identify what the constraint precluded as well as what the constraint promoted. Constraints concerned both lighting and programmatic spatial relationships, among them:

> Preclude direct lighting > promote indirect lighting taking advantage of reflection and refraction
>
> Preclude vertical south facing apertures > promote top lighting and indirect lighting with an attention to surface characteristics for scattering light
>
> Preclude vertical apertures in all orientations > promote architectural strategies that think about light sectionally through a building
>
> Preclude plan-based programmatic and experiential relationships > promote sectionally-based programmatic and experiential relationships

By removing students' default daylighting option of optimal southern exposure, the design-space was expanded to include a broader range of lighting possibilities.

Constraints: Urban Infill

While constraints were introduced in order to elicit more innovative design responses, these particular constraints were adopted in order to develop students' capacity to work with highly constrained sites such as urban infill parcels. Building on vacant urban infill sites provides multiple environmental, economic, and social benefits including reducing pressure to develop greenfield sites. Harnessing existing transit lines reduces reliance on automobile transportation, yielding significant environmental benefits. Quantitatively, a 2011 EPA study indicated that infill projects would result in thirty two to fifty seven percent less air pollution from vehicle emissions per capita than if conventional development had occurred.[2] From an economic standpoint, infill development capitalizes on earlier infrastructural investments such as water, sewer, roads, and transit. Developing vacant parcels can strengthen real estate markets by raising surrounding property values and renewing established neighborhoods.

There are statistically compelling professional reasons to introduce students to constraints that accompany urban infill sites in early design studios. During the period from 2000 to 2009, infill development accounted for one-fifth of new housing construction among 209 metropolitan regions nationally while in the northeast, thirty-two percent of all new housing units were built in previously developed areas. (EPA, 2012) Demographic forecasts indicate that to accommodate the projected US population of 2025 (67 million additional residents), will require 34.5 million new housing units along with 17 million housing units to replace existing occupied units. (Nelson 2006) Moreover, due to population shifts, notably a shift in childless households, projections indicate that there will be an oversupply of low-density suburban units, such that the "market demand for new homes through 2025 may be almost exclusively for attached and small-lot units." (Nelson, 2006, p. 397)

Significant barriers remain developing urban infill parcels including regulatory challenges, infrastructural improvements, site contamination, and public resistance. However, when local governments adopt policies to encourage such development, these barriers can be overcome. The site of the studio's concluding project is located a city with a supportive administration Holyoke, MA. (Fig. 1)

Fig. 1. Holyoke: Vacant Lot Study, Katie Elliot

Research Question

The authors began the semester with a guiding pedagogical question - how can reducing variables to focus on light and bodily experience prepare students to work with highly constrained sites? We hypothesized that by constraining lighting conditions, the catalog of lighting strategies would expand. Additionally, constraining the footprint of the design projects would privilege vertical, sectional, and volumetric relationships. Finally by privileging the spatial and temporal experience of interior space, the emphasis would be on experience over exterior form.

Method

The studio employed an organizing structure that enabled students to develop their ideas through three assignments of increasing complexity. Each assignment expanded students' expertise through a growing body of technical information. Beyond inspiring students, the intent was to expand their *source* constraints, providing known examples that could be drawn upon as tools for improvisation in their own experiments. Projects were then structured to facilitate discovery through personal, bodily experience.

The Light Cube

The first project, the Light Cube, provided students with the greatest freedom to investigate and experiment with the geometric and optical properties of light within the constraints of a one-foot cube from which light could enter only along one face. Students were asked to focus on one aspect of light – reflection, refraction, absorption and color and to consider the way light bounces off of textured and colored surfaces, the interplay of different beams of light, and the contrast between light and layers of shadow.

The project lecture introduced students to fundamental properties of light through a discussion of objective measurable qualities of light such as quantity and color, physical behaviors of light including additive mixing of light sources, the fact that surfaces are subtractive, laws from optics including reflection and refraction, as well as the differences between specular and diffuse surfaces that scatter light. Finally the importance of human perception – color adjacencies and contrast were demonstrated using examples from Joseph Albers and Edward Adelson. (Adelson, 2000) The lecture concluded with a range of historical and contemporary architectural examples demonstrating how these optical principles have been deployed to shape, direct, enliven and differentiate space.

It was striking how many students chose to wrestle with color and with scattering light off of diffuse and specular surfaces. There are likely several reasons for this. Many students commented that they were excited to work with color, as it was the first time that they had been given the opportunity to do so. Also, color likely allowed them to see the light bouncing more clearly as the light entering their cubes was natural daylight and the shifts in color permitted students to directly see the results of their experimentation.

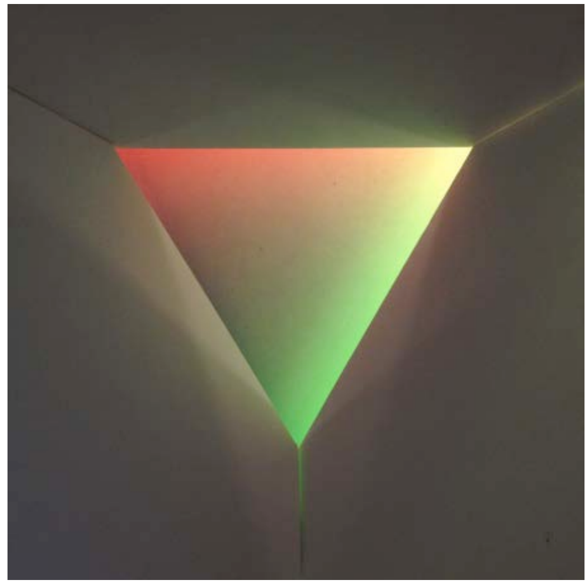

Fig. 2. Light Cube Study, Michael Struna

Fig. 3. Light Cube Study, Ryan Rendano

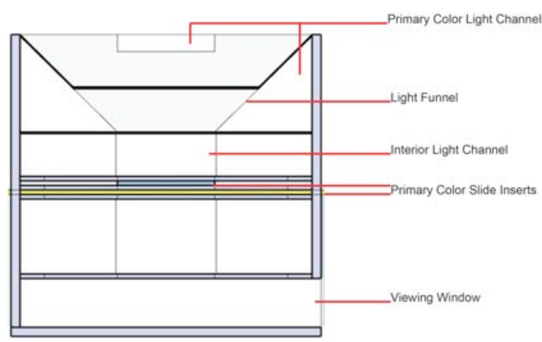

Fig. 4. Light Cube Study, section, Ryan Rendano

The strongest projects were able to control the light and define the parameters of their experimentation (Figs. 2, 3 and 4). Figure 2 shows daylight bouncing primarily off of three painted surfaces – one red, one blue, and one green, within a three-chambered interior. This student was able to experiment with light's additive and subtractive behaviors by controlling where light was entering into his three-chambered cube and observing the different resultant effects. In Figures 3 and 4, the student actively experimented with color mixing. By changing the filters being used, he was able to document the additive light within his light cube.

In the weaker projects, students did not control the behavior of the light to demonstrate optical principles and were unable to clearly articulate their specific intentions. By asking students to more strictly define their experiments and control the behavior of light, this assignment could be strengthened in the future.

Spatial Interlock

The second project continued to consider light by imposing constraints on light sources while also introducing ideas of constrained inhabitation and the scale of the body. Moreover, students had to propose a solution that would accommodate two distinct dwelling units within a tightly confined envelope of 16' x 16' x 16' - 4096 cubic feet. Focusing on the outer form of the dwelling was to be expressly avoided. Instead, attention was to be focused on the quality of the interior, the bodily experience of the inhabitants, the language of the construction, and the rigor of students' approach to daylight. The "site" for the design proposals was a cubic infill volume, elevated above grade with access from below, enclosed on two sides with access to light from above.

The second project's introduction focused on ergonomics and anthropometry. This project highlighted that in order to design tools, products, and spaces, they must fit the needs of end users and to do so, designers need to understand the size and shape of people. The lecture concluded with successful examples that capitalized on tight spaces by incorporating program into typically underused spaces such as stairs and wall cavities or by providing multifunctioning elements.

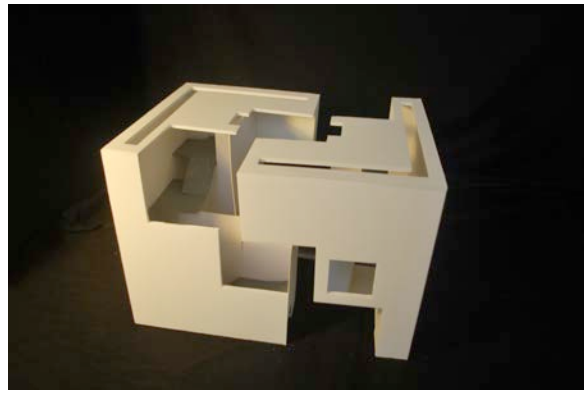

Fig. 5. Spatial Interlock, Bryany Burke

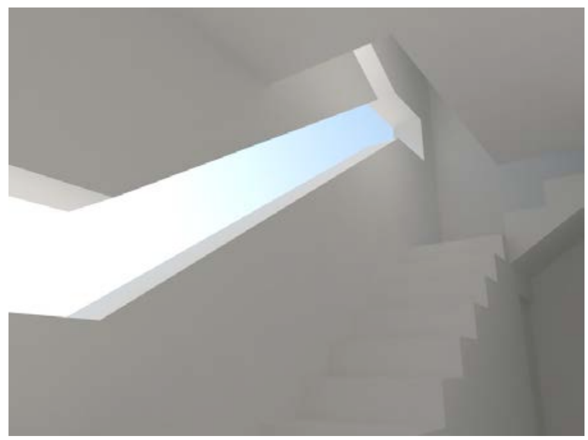

Fig. 6. Spatial Interlock, Michael Struna

The necessity to provide two units, each with its own internal circulation, took a considerable amount of the students' design energy. The most successful projects addressed light and ergonomics through a strong sectional and interlocking design strategy. Due to the limited space, students combined vertical circulation with a sectional light strategy. (Figs. 5 and 6) Other students provided a source of direct light, such as a skylight, and then permitted adjacent spaces to "borrow" the light through translucent materials, internal apertures, and partial height walls. Still other projects directed the light by composing shaped openings, sculpting interior volumes, or screening and baffling direct light.

(Fig. 6)

Urban Infill: Parcel 033-07-004

The site for the semester's final project, Parcel 033-07-004, lies on Main Street, in Holyoke, Massachusetts. Located along the Connecticut River beside Hadley Falls, the city had grown steadily through the industrial revolution as one of the United States' first planned industrial communities, powered by a sixty-foot high waterfall. As one of the world's largest paper manufacturers, the population peaked in the 1920s at 60,000 and has been in decline ever since, with a current population of just under 40,000. Today, Holyoke is a racially diverse city with a large Latino and Puerto Rican community, and the third lowest median income in the state. In recent years, Holyoke has made great efforts to revitalize the downtown and bring new creative economies to the city center. Parcel 033-07-004 is situated in one such area, near a new train station, and targeted by the city planning officials for eventual urban infill. (Fig. 7)

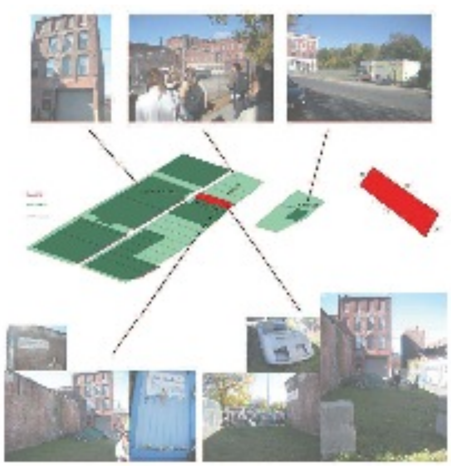

Fig. 7. Site Study, Katie Elliot

The students were tasked with developing a program that was mindful of the larger context of Holyoke and its community development needs, while serving two proposed live/work residents and the general public. The confined urban infill site measured 23'-6" wide and 73'-4" long. For solar exposure, we established that there would be a one-story structure to the south-southwest and four stories to the north-northeast. Main Street runs along the east-southeast facade.

After initial site research and a site visit, the final lecture returned the focus to light and the potential of the sun for daylighting. A workshop introduced sun path diagrams and adjacent building overshadowing. To insure that each student could read a sun chart prior to starting work, students calculated solar availability on the site for all four orientations. (Fig. 8)

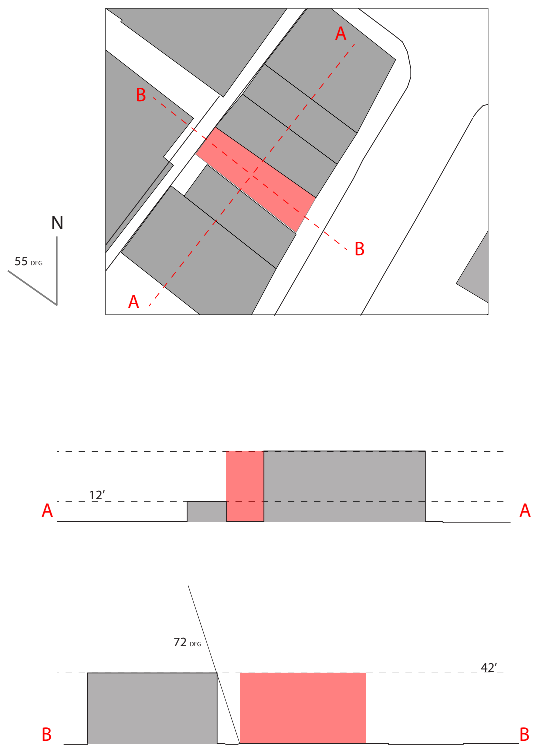

Fig. 8. Overshadowing workshop

The final project challenged students but the skills developed in two earlier projects gave them a compendium of strategies on which they could depend. Although some students relied heavily on the three upper floors that had access to direct southern exposure, most students applied lessons from the earlier exercises to successfully bring light into the first floor public space. (Fig. 9)

Building upon the Spatial Interlock project, many students aligned circulation and lighting strategies, wrapping the perimeter with light and movement. Others carved away from floor plates to create light-filled interior volumes while some projects shifted floor plates to create gaps into which daylight could slip. (Fig. 10)

In some projects, the building splits along a fault line with light filtering in through this rift, aligning the daylighting approach with a programmatic strategy. Several projects built on earlier work by bouncing light off diffuse surfaces. Finally some projects used vertical light-wells, baffles, screens, and louvers. (Figs. 11 & 12)

Fig. 9. Urban Infill Project: Light Wells, Deven Riley-Marini

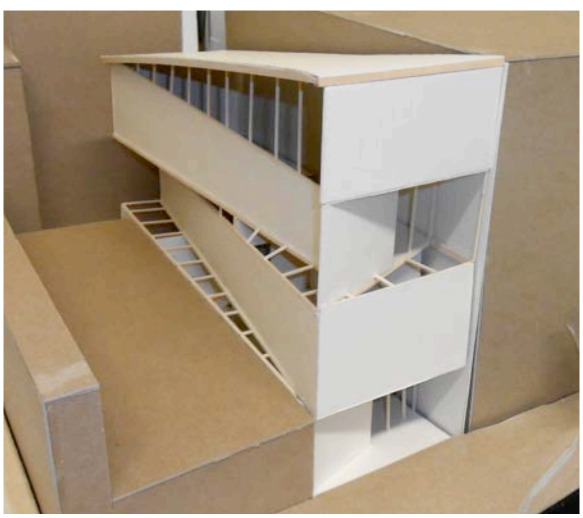

Fig. 10. Urban Infill Project: Light Wells, Stephanie Cano

One pervasive weakness became evident in the final presentations. Although light had been a strong focus threading through the entire semester, and although students had made many design decisions based on daylighting concerns, daylight was not consistently or convincingly represented and diagrammed in many of the final project boards.

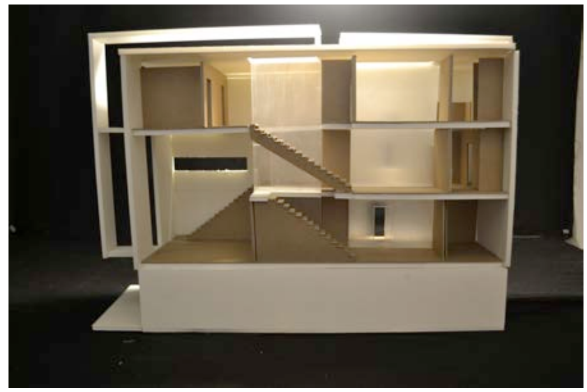

Fig. 11. Urban In fill Project: Light Wells, Allison Walsh

Fig. 12 Louvered strategy, Michael Struna

Discussion

Constraining lighting and spatial conditions over the course of several assignments was a successful strategy to prepare students to work with highly constrained urban infill sites. Moreover, experimentation coupled with lectures and workshops increased students' toolbox of deployable elements for recombination and improvisation. For example, students moved away from a limited vocabulary of direct southoriented daylighting strategies. Additionally, they shifted from considering apertures as "shaped openings in walls" and began to consider first the way in which the light passing through the aperture would be experienced. At the same time, there are several ways in which these assignments can be improved for their next iteration.

The first assignment, the Light Cube, was successful in immediately orienting the semester to sensory and spatial experience rather than form. However, the assignment's structure may have been more successful had students been required to be more scientific in their experimentation. In many cases, the projects were not sufficiently rigorous to provide continuity with later projects. Students were attracted to heavily optical and sensational effects. However, students clearly relished this assignment's primary objective - to experiment with and experience light first hand.

The constraints of the second assignment, the Spatial Interlock, gave students a solid understanding of how much space the body needs to accomplish daily activities. Nothing went to waste. However, this assignment was so constrained that, for many students, their focus was directed away from daylighting strategies as they struggled to arrange the program into the small volume.

The preliminary assignments came together successfully in the urban infill project. Many projects successfully deployed light and circulation strategies from the spatial interlock assignment. Students applied lessons gleaned from the light cube assignment by designing surfaces that reflect light into spaces without direct access to daylight. Many projects featured spaces that borrow light through material choices and sectional strategies. While the visual representation of daylighting strategies was weak at the final presentation, student concept statements, process drawings, and sketchbook documentation all demonstrate detailed thinking on this topic.

Conclusion

The experiments outlined here represent a model for pairing typical beginning design studio project constraints in a manner that directly aligns with project constraints found in contemporary real-world challenges. As students advance professionally, they can incorporate this method into their own design process to elicit innovative responses to professional challenges.

References:

Adelson, E.H. "Lightness Perception and Lightness Illusions". In The New Cognitive Neurosciences, 2nd ed., M. Gazzaniga, ed. Cambridge, MA: MIT Press, pp. 339-351, 2000.

Nelson, A.C. 2006. "Leadership in a New Era: Comment on 'Planning Leadership in a New Era.'" *Journal of the American Planning Association* 72 (4): 393–409. doi:10.1080/01944360608976762.

Nelson, A.C., and Lang, R.E. 2007. "The next 100 Million: Reshaping of America's Built Environment." *Planning* 73 (1): 4–6.

Simon, Herbert A. 1973. "The Structure of Ill Structured Problems." *Artificial Intelligence* 4 (3–4): 181–201. doi:10.1016/0004-3702(73)90011-8.

Stokes, P.D. 2005. From Constraints to Creativity: The Psychology of Breakthrough. New York: Springer.

———. 2007 "Using Constraints to Generate and Sustain Novelty." Psychology of Aesthetics, Creativity and the Arts 1 (2): 107–13.

U.S. Environmental Protection Agency. 2012. *Residential Construction Trends in America's Metropolitan Regions: 2012 Edition*.

Notes:

[1] This pattern of problem solving using paired constraints is adapted from Walter Reitman's 1965 constraints model. The model has been applied to various domains, particularly in Stokes' publications.

[2] U.S. Environmental Protection Agency. Air and Water Quality Impacts of Brownfields Redevelopment: A Study of Five Communities. 2011