Constructive Learning Techniques and Color Application in Design
Sharon Refvem

Abstract
This paper presents some of the results of my work in the area of architectural education and color application. “Constructive Learning” techniques are the framework within which a course in color theory and application has been developed for architectural students and professionals. Constructive learning theory designates three main learning phases: introductory, advanced and experienced; each of which has a unique set of requirements that must be addressed by those seeking to teach or develop meaningful tools for a given task.

The introductory level is represented by those who possess little if any prior skills or knowledge in the subject area. Here it is advantageous to carefully guide the knowledge acquisition process in order to help build a knowledge foundation upon which a personalized learning process can take place. Advanced students are those that are ready, through a more focused, context related approach, to expand their capabilities. Finally, experienced learners can be defined as those capable of critically applying and innovatively using the knowledge, skills and tools that they have obtained through the introductory and advanced phases of the learning process.

Because computers introduce the issue of color at a much earlier stage of design than might previously have been the case, a new set of skills and tools are needed. The proposed course seeks to define an appropriate learning methodology for designers that can provide them with not only knowledge of the subject area being covered, but also skills with which to approach it.

1. Introduction
The subjective nature of color makes it, like design itself, a difficult topic to define and formalize. Never-the-less it is an inherent part of a human being’s perception of the environment and thus, in combination with light, an important factor in any successful architectural design. If it is so important, how can it be transformed from an often purely intuitive or accidental by-product of design to a studied and intentional component of the design process and its built result? How can the topic best be taught to aspiring designers, mastered by architects and integrated more successfully into the design process?

This project proposes answers to these questions by first defining the goal in architectural terms, second laying out a teaching strategy and third by proposing an applicable working methodology and set of tools for the purpose.

2. Color in Architecture: A Brief Discussion
"A first step in an expanded more effective use of color is simply to see color and all its subtlety wherever it may be, particularly in the natural world."

-Joseph Eshrick, Color in Building

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1 Chair for CAAD - Architecture Department, Swiss Federal Institute of Technology, Zürich, Switzerland
As human perception is generally more heavily influenced by the discernment of surfaces rather than edges, the importance of color and light can be identified as crucial components to the perception of any given space. They are both important aspects to the success of any design and should be pursued as rigorously as formal definitions in design.

Traditional methods of architectural design rely heavily on line drawing and models. Line drawings, especially orthogonal ones, serve well to communicate various design considerations, including: formal structure, organization, use, dimension, proportion and construction detail. However, they tell us little about surface and light. Models, on the other hand are excellent tools for understanding: surface, volume, three-dimensional proportion and something about light. Unfortunately, both traditional drawing and model media impose significant obstacles to color exploration. The mechanisms required to change, alter or adjust a color palette using these media are generally quite tedious, inadequate or even impossible to handle in a satisfactory way.

If a designer relies on sketches, such as the one illustrated below, to study, among other things the application and selection of color, one can identify certain advantages of a digital medium that allows for quick changes, variations and updates. Such changes can be made without destroying the original version, nor redrawing the entire sketch.

*Electric ArtBlock Artist's Housing - sketch, Koning Eizenberg, Angels & Franciscans*

Likewise, a digital version of the model for this project could be used to much more fluidly change color and lighting aspects of the design. Variations can be produced in a matter of minutes without effecting the original model. This leaves the opportunity for comparison open, an aspect of learning that, with traditional model building methods, would require more than one physical model.

*Electric ArtBlock Artist's Housing - model, Koning Eizenberg, Angels & Franciscans*
The architects of the previously illustrated project have definite views about the role of drawings and models in the design process; which, at least in their case, are well suited to digital media.

We see drawings in architecture as a tool, not an end in itself. We draw to design, to test approaches, and to generate ideas ... They [drawings] are, in fact, done very quickly, after careful composition. Their abstraction focuses on the fundamental compositional strategies that are a signature of our work.

Architecture, for us, is an opportunity to reassess simple pleasures - light, air, view, color, and natural beauty. We strive for accessibility to design and our drawings reflect this.

- Koning Eizenberg, Angels & Franciscans

Consider the work of another architect whose simple, bold forms are enhanced by a strong and forceful use of color - the Mexican architect, Luis Barragan. Although he himself claimed only to have considered the color palette for a project near the end of his design process, sometimes only after the building had been built, he too could have made use of methods made possible with digital media. He often took inspiration from painters, attempting to capture the mood of a painting by borrowing from its color palette. Such experiments with the composition of surface, color and light lend themselves well to current methods of computer simulation.

Las Arboledas; Galvez House; Luis Barragan House - Luis Barragan. Armando Salas Portugal Photographs of the Architecture of Luis Barragan

The effects of color choice can often be quite dramatic as in the Corazon de Maria Chapel, by Barragan. Here a strong, warm color palette is used on the interior. It intensifies as it reflects its own vibrant colors and thanks to the light filtered through colored windows and grids; creating a truly striking impression.

To choose a single color or white, is to choose a color palette as well. It focuses an observers attention on the form of the object - on all it's simplicity or complexity. In architecture, the color signals of objects in a space take on a significance of their own. In the following examples of “white” spaces, one's attention is drawn to the dramatic architectural forms of the ceiling, the items in the exhibit, the diagonal of the stair and even the plant on the table in Meier’s Ackerburg residence.
In all of these examples one can observe a tendency to perceive in terms of shape and surface; form and color; light and shadow. It is for these reasons that the method and prototype tools for exploring some of these elements during the architectural design process have been proposed.

3. Color in the Computer Medium

Computers allow designers to more quickly and easily change a project’s color palette than traditional media. Therefore, with the proper tools and techniques, color could be more consequently pursued as a design issue much earlier in the design process than is generally the case now. Recent advances in digital media have made new and useful techniques for color and light exploration, as well as three-dimensional design, more feasible for designers and architects in particular. Tools for controlling two-dimensional design and graphic solutions have been available for some time. Such tools facilitate the manipulation of a designs color palette in a number of ways, including multiple methods for: direct color selection and assignment; saturation and value adjustment; hue range determination and so on.

Light simulation software has also advanced to such a point that it is now possible, with the help of a three-dimensional model of a project, to simulate lighting for a project according to scientific models of light and its behavior. The ability to repeatedly adjust or radically change a project and quickly learn how the changes effect the lighting conditions of a proposed project represents a significant advancement in architectural design tools related to lighting.

This relatively new access to workable color and light applications and methods, makes the teaching of color theory and phenomena even more topical for architects than before. For how effective can such tools and methods be without at least a fundamental understanding of the elements that they are manipulating? Thus, the next question that one must ask is, how to best present and communicate the underlying principles and effects of color and perception to a designer. And, more especially, how to make that knowledge useful and accessible during the design process for both students and professionals.

4. Constructive Learning

Constructive Learning is both a theory and description of an educational strategy focused primarily on advanced level students; that is, adult students with at least a rudimentary knowledge of related subject areas. The constructivist approach is based on the premise that
different types of learning techniques and methods are suitable to the various stages of a learner’s
development. Introductory, advanced and experienced stages are identified as the three main
phases of learning. Other factors play a considerable role in the efficacy and speed with which
students are able to learn new skills or acquire new knowledge. Individual aptitude, social and
contextual variables, as well as instructional approaches can help to explain the often wide
ranging rates of success.

Students’ prior knowledge and ability in the given subject area, must be a fundamental
consideration in the design of any effective learning environment. The needs of students with
various levels of expertise differ greatly. Common to all, though, is the need to provide a
stimulating, context driven reason to learn. In the case of architectural students studying color
theory, phenomena and application, a course must be designed that both builds a knowledge base
and provides tools that can be foreseeably applied in practice on real design problems.

4.1 Introductory Learning Phase

“In order to use color effectively it is necessary to recognize that color deceives
continually. To this end, the beginning is not a study of color systems.”

- Josef Albers, Interaction of Color

Introductory level learners can be assumed to possess little if any prior skills or knowledge in the
given area of study - in this case, color application. At this level, knowledge acquisition must be
more carefully guided by the learning environment in order to insure progress toward the
development of a personal knowledge base; founded on which, further, more personalized
learning can take place.

Architectural students can generally be assumed to have a better than average understanding of
the factors involved in solving graphic and three-dimensional problems. As far as color is
concerned however, this may often be related to a certain innate intuition rather than any specific
color strategy or intentional practice. At this level, it is important to provide students with a
general awareness of color phenomena - that is the factors that are at play in color perception;
how colors, light and the human optical system can effect ones perception. For instance, the
Hermann grid can be used to illustrate the phenomena of the influence of adjacencies. The grid of
black squares on a white background enhance the brightness of the white bands between each pair
of squares in the array. The intersection points of the white bands are relatively unaffected by
the black squares and thus, appear grey in contrast to the "brighter" horizontal and vertical
bands. By creating colored variations of the same grid, students are able to discover the varying
effects of color on adjacencies for themselves.
Constructive Learning Techniques and Color Application in Design

The Hermann grid illustrates the influence of adjacencies.

Hands on experience is an essential element of effective learning, especially at the introductory level. That is, a chance to explore the components of a color composition or an illustration of a color phenomenon first hand facilitate learning. Active participation in the learning process leads to a higher retention rate and thus, to more useful knowledge for future applications. This also leads to another advantage: the acquisition of a subject related vocabulary that enhances communication and contributes positively to learning interchanges between students and educators.

An example of a lesson built on these principles might include the presentation of certain color phenomenon, such as the Hermann grid illustrated above, followed by an exercise in which the students attempt to create their own compositions that even more strongly illustrate the phenomenon. The important final step in such an exercise is the comparison of both successful and unsuccessful results in a group setting and, above all, a discussion among participants about those elements that most directly effect the appearance or absence of the phenomena under scrutiny. By initially presenting a phenomenon, but not the reasons for the resulting illusion, students are forced to make their own discoveries; focusing on such factors as the relative importance of shape, size, color, value and contrast on the success of a given exercise. From these experiences they should then be able to draw conclusions as to the cause and effect of various components in a composition.

Most of the introductory exercises in the proposed color application course are based on those created by Josef Albers for his course, The Interaction of Color, offered at Yale in the 1960s. The exercises in his course depended on the meticulous creation of color compositions using Coloraid paper. A computer application has been written that makes this process not only faster, but also more conducive to the creation of alternatives and subtle variations in a student’s search for the ultimate color combination and composition. Students are able to
store their work in an archive, from which they can retrieve a solution at any time for reworking, discussion or submission.

4.2 Advanced Learning Phase

“Practical exercises demonstrate through color deception (illusion) the relativity and instability of color. And experience teaches that in visual perception there is a discrepancy between physical fact and psychic effect.”

- Josef Albers, *Interaction of Color*

The second phase of learning, advanced learning, stimulates students to solve increasingly complex problems using the methods and tools that they have been introduced to during the first phase of a course. Learning is most effective at this stage when the problems posed are not only solvable using skills and knowledge obtained during the introductory phase, but also related in some way to a student's personal learning goals. In this case, the advanced color theory exercises must be based on graphic and three-dimensional problems that correspond to the field of architecture - our students’ primary educational and career goal. Establishing this connection is of crucial importance to students’ ability to motivate themselves and ultimately to retrain the skill or knowledge involved.

At this stage the color application course exercises focus on specific color related phenomena that occur in three-dimensional space. Examples of such phenomena include: miscues related to the relative size or position of objects in space caused by the objects’ color; shifting of the visual focal point due to color assignment; and the altering of a spatial impression through purely color related stimuli.

![Different colors (here illustrated in respective values) can effect ones perception of the relative size and height of a room.](image1)

Light is a key factor in any study of three-dimensional space and color and often plays a strong role in the deceptive nature of color perception. For this reason, the exercises in this portion of the course also deal, either directly or indirectly, with the effects of light on color perception.

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2 These images are from an elective project currently being written by Frank Felix and Annigna Guyan titled *Visual Perception of Computer Generated Pictures* at the Swiss Federal Institute of Technology. For more information about the project see: http://caad.arch.ethz.ch/~w95ws013.
One exercise that pursues the relationship between color and light is divided into three parts. In the first part of the exercise, students are required to produce two alternative coloration schemes for a given space that create sharply contrasting spatial perceptions using only color to obtain the results. Once this has been successfully done, students are then expected to create sharply contrasting effects in one of the two resulting models with alternative lighting solutions. Finally, primarily as the catalyst for further discussion and thought, the alternative lighting designs are directly applied to the remaining, contrasting color solution. In this way a student can discover how the lighting schemes, designed for and applied to a specific color solution, effects a strongly contrasting color solution. This should raise the following questions, among others: Are the same strong contrasts in perception still created? If not, why not? And so on.

The advanced exercises in color application are designed to facilitate goal oriented problem solving in an architectural context and promote further thought on the subject of color in architecture. The assignments depend on severely limiting the scope of tasks and goal definitions in order to isolate and focus on the subject being treated. In the example outlined above, for instance, students are provided with a model of a known, but not too famous space. Viewing points are also fixed in order to save time and make later comparison and discussion of results easier.

4.3 Expert Learning Phase

The expert phase of the constructive learning model describes the final and continuing phase of learning, in which students are able to build creatively on their fundamental and experiential knowledge. Once this level has been achieved, students are able to apply their skills in innovative ways to solve new and broader problems, often drawing form other areas of knowledge perhaps only marginally related to the original topic. Ideally, tools that have been mastered and knowledge won through the experience of the preceding phases of the course can now be used in concert with other types of tools and knowledge to solve a wide ranging number of design problems.

The third phase of the proposed color application course, requires students to provide a design problem of their own; preferably a current design studio project or an actual project that they are currently involved in finding a solution for. The less artificial a project description is, the more likely it is that students will be motivated to search for solutions by creatively applying the tools, methods and knowledge obtained in the earlier phases of the course. The structure of this portion of the course resembles that of a design studio - moving consciously away from the weekly exercise cycles that define the preceding phases of the course.

The educators role shifts at this point even more towards that of a consultant or partner - encouraging or even suggesting promising individual problem solving strategies. Goal specification, problem solving tactics, presentation and discussion still play an important role in this phase of the course, just as they do in any design studio.
A formally structured third phase of learning is actually optional, because it is the ultimate goal of the first two phases to prepare students for expert - a process that presumably continues indefinitely. Expert learning, describes the life-long cycle of applying knowledge, having new experiences and deriving new knowledge as a result. Ideally, this can occur independently. At such a point, students should feel sufficiently comfortable with the tools, techniques and basic knowledge involved to strike out on their own.

5. The Tools
A key to any workable tool is the ease with which it can be mastered and used towards a specific end. Because earlier available tools, materials or methods for studying color are relatively inflexible, color studies have rarely been a part of the architectural design process, especially the earlier stages of design. Therefore, in order to make color application in architectural design more manageable, new tools must demonstrate a previously unknown ease and flexibility.

The computer tools that have been developed for the two-dimensional exercises of the color application course were created based on the following specifications - the software must: be easy to learn and use; make color assignment and modification relatively intuitive; facilitate the creation of variations; allow one to archive solutions in order to follow promising directions without losing previous work; and support the restoration of previous solutions in the archive for reworking or other purposes. The three-dimensional tools, that are not yet a reality, are based on the same clear model. That is, the ease and functionality that is found in the tools for two-dimensional problem solving must also be implemented in the tools for three-dimensional problems; clearly a more complex task.

6. Conclusions
Much work remains before the already well developed two-dimensional color application tools are adequately retooled for three-dimensional use. An encouraging confirmation of the basic philosophy behind the tools that have been developed thus far, occurred during a trial exercise conducted with a group of masters students in CAAD at the Swiss Federal Institute of Technology. Though stemming from diverse backgrounds and possessing a varying amount of knowledge about the nature of color and perception, all were able, within the limits of the two hour lesson, to: quickly grasp the basic structure and functionality of the software; apply it to the sample problem; develop alternatives; narrow in on a feasible solution and formulate opinions about the factors that most effected the relative success of their solutions. Perhaps most gratifying was the fact that some of students, after completing the exercise, began to vigorously explore a series of their own graphic questions using the software - innovatively using the software to solve other, unrelated color issues.
7. References


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