Color in an Optimum Learning Environment

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Color is an important factor in the physical learning environment and is a major element in interior design that impacts student achievement, as well as teacher effectiveness and staff efficiency. Research has demonstrated that specific colors and patterns directly influence the health, morale, emotions, behavior, and performance of learners, depending on the individual's culture, age, gender, and developmental level, the subject being studied, and the activity being conducted.*

Color is part of a haptic environment. A haptic environment is the architectural integration of artistic experience, function, and technology to derive a meaningful perception. Color, in addition to interior form, space, light, and texture, also is a major design element that can be used to create a an enriched learning environment. How important is an enriched learning environment? It is so important that the 2003 Danish Act on the Educational Environment of Pupils and Students requires the creation of "such opportunities for experience, industry and absorption for learners to develop awareness, imagination and an urge to learn." Enrichment enhances the learner's capability to think, create, invent, express themselves, work together and organize (Kjaervang, 2003). In Reggio Emilia primary schools, an enriched environment is so important that it is considered a "teacher": children are resourceful, curious, competent, imaginative and social because they create meaning in their world by being part of a complex, enriched learning environment. The Reggio Emilia Approach, initially established in Italy post World War II, is based on the philosophy that children must have control of their own learning and that relationships plays a critical role in a successful education system.

Color Preference and Learner Age

Young children are attracted by warm, bright colors. As the child matures, preferences change from tints and pastels (elementary school) to bright medium-cool colors such as greens, blues, and green-blues (middle school) to darker colors (high school) such as burgundy, gray, navy, dark green, deep turquoise, and violet (Gale 1933). Similarly, as children mature into adolescence, there is less preference for large areas of primary color, which they tend to associate with immaturity. By high school, the most preferred colors are green (nature, trees, comfort) and light yellow (lively, energetic, happiness, summer). These colors were followed by blue (relaxation, calmness), red (love, romance), purple (relaxation, calmness, laughing), blue-green, red-purple, yellow-red, and purple-blue.

Color in the Classroom

Color in the learning environment provides an unthreatening environment that improves visual processing, reduces stress, and challenges brain development through visual stimulation/relationships and pattern seeking. Visual stimulation actually rewires the brain, making stronger connections while fostering visual thinking, problem solving, and creativity (Simmons, 1995). Color variety reduces boredom and passivity. Therefore, classrooms should incorporate a variety of colors (based on age, gender, subject and activity) to reduce monotony and visually refresh perception. However, overuse of color — using more that six colors in a learning environment — strains the mind's cognitive abilities.

** Please see the Appendix for a summary of the theory, history, physiology, and psychology of color.*

Color improves attention span by avoiding a monotonous environment and helping the student stay focused through mental stimulation, thereby increasing productivity and accuracy. Eyestrain, contrast, glare, minimal distraction, degree of stimulation and degree of concentration are impacted directly by color. Color can alter perception of time, increase school pride, reduce disruptive behavior and aggression, reduce vandalism, reduce absenteeism, and provide a supportive background for the activities being performed.

Color Recommendations

- Gymnasium: ACTIVITY — red, red-orange, light orange, warm yellow, apricot, orange, lime, medium green; no turquoise
- Hallway: REFRESH — green, blue, magenta, school colors
- Cafeteria: NUTRITIOUS — orange, red, green, lime, dark brown; no blue, no yellow-green, no magenta
- Auditorium: DIGNITY— violet, black, dark green, navy, warm neutrals, purple, burgundy
- Media Center: RESTFUL — light green, peach, rose, light green, aqua, peach, cream; no white, no dark colors, no bold colors
- Study Hall: STASIS — green, blue, brown, earth tones; no red, no orange
- Kitchen: HOME — green, brown, beige
- Toilets: COMFORT— white, blue,
- Counseling: HARMONY— green, lavender, peach, medium brown, yellow; no red, no bright yellow
- Offices: RELAX — turquoise, blue, brown, green, magenta; Sandstone, light gold, light green, blue-green, black; no red, no blue
- Entrances: SCHOOL COLORS
- Lecture: THOUGHTFUL— blue, green, violet, magenta
- Computer Skills Lab: ENCOURAGE — medium colors, provide visual relief; no bright colors
- Biology: NATURE — blue, green, teal, brown, beige
- Business: CORPORATE — blue, gray, black, burgundy, dark green
- Chemistry: LOGIC — blue, green, indigo
- Physics: ENERGY— blue, yellow, green, indigo
- Foreign Language: FRIENDSHIP — yellow
- History: AGE — amber, blue, yellow, sea green
- Mathematics: LOGIC — indigo, blue
- Social Studies: SOCIAL — orange, green, brown
- Drama: PASSION — orange, indigo, blue, violet, red, white
- Art: CREATIVE — green, violet, red, peach, pink, light yellow
- Choral: TEAM — green
- Band/Orchestra: TEAM — violet
- Dance: CREATIVE — orange, purple, violet, yellow
- Language Arts: COMMUNICATION — sea green, blue, green; no avocado, yellow-green, purple, chartreuse
- Government: ORDER — blue, green, indigo, silver, gold, mauve, violet, magenta
- Economics: WEALTH — emerald green, amber, violet, gold

- Athletic Facilities: VITALITY— red, orange, bold colors; no turquoise
- Clinic: CLEAN — sky blue, white, pink, green, light yellow
- Shop: CONSTRUCT — -peach, pink, light yellow, violet
- Culinary Arts: APPETITE — orange, light yellow
- Floors: BACKGROUND — -neutrals, tints, school colors, wayfaring patterns
- Walls: BACKGROUND — pale yellow (asthmatics), almond

Color in architecture has multiple aesthetic and functional applications. Warm colors can be used to reduce the scale and size of large spaces, making them more intimate. Cool colors visually enlarge a space, making it less confining. Color can be used to differentiate, contain, unite, equalize, and emphasize the design elements of a space. For example, color can make a high ceiling appear lower (dark colors), enhance visual interest and focal points while relieving eyestrain, accent entrances and exits for safety and identity, and ultimately create a unique sense of place that welcomes the learner and the community. Color can be used to modulate a building's appearance to bring it into harmony with its surroundings, make a building appear pleasant or oppressive, correct proportions, eliminate monotony, and establish individuality among like buildings or building elements.

Pattern is the repetition of shapes or forms and is an immediate concomitant of color. Patterns can be flowing (meandering), branching (deviating), spiraling (winding), geometric (rectilinear, angular, polygonal), or a mix of all of these. Floor patterns may be used to visually enliven, foreshorten, widen, or narrow a hallway. It can be used to denote entrances and exits, accent architectural elements and details, or create "rhythm" in a space. Patterns can establish visual focal points on wall and floor surfaces, imply static or dynamic movement, and convey a preferred emotional response. Large-scale spaces such as lobbies, cafetoriums, or assembly areas should have patterns to match the scale of the space, while providing a neutral background for seating. Lobbies and primary entrances should be inviting and exciting. In spaces for emotionally handicapped children, regular geometric patterns should be used to reduce visual stress and stimulates the brain in pattern seeking. Discordant colors and irregular patterns are disturbing visual elements that distract and confuse such learners.

Appendix

What is Color?

Color inundates every facet of our lives, primarily in the form of manufactured color. In ages past, however, colored objects were considered a luxury possessed by the wealthy. The remainder of the population experienced little color, only being able to afford natural materials in neutral colors. In a sense, color has lost its “specialness” today, and it and its effects are taken for granted.

In 1666, Sir Isaac Newton discovered that when pure white light is passed through a prism, it separates into all of the visible colors — each color comprising a single wavelength that cannot be further separated. The full range of colors often is depicted in terms of a “color wheel,” with color segments arranged around a circle in the same order created by the prism: red, orange, yellow, green, blue, and violet. The National Bureau of Standards estimates that the human eye can distinguish more than 10 million colors. Color is the perceived wavelengths of the visible electromagnetic spectrum (400-700 nanometers) reflected by an object. Since color is not part of an object, it is “apparent” color that we actually perceive. Color is “perceived” because each of us views color differently, and because the same color appears differently off a textured or reflective surface. Not only are some learners more sensitive to color and its applications, while others do not consciously take notice, but also about 8% of males and 1% of females have some form of color impairment that makes them see colors differently than everyone else. Color impairment may manifest itself in “colorblindness” (seeing red and green as indistinguishable or having similar problems with other specific color pairs), the inability to perceive particular colors, or the functional misperception of particular colors. Some of these deficiencies can be corrected by wearing colored lenses or viewing objects under colored lights rather than white light.

The mixing of light and the mixing of pigments produce colors through different physical processes. Colors produced by *mixing lights* are either new colors (metamers) or cancel each other out to produce white light (complements), resulting from the additive sensation of different wavelengths. Colors produced by *mixing pigments* are new colors resulting from the subtractive process of different wavelengths being absorbed. The scientific description of color, or colorimetry, is performed by describing it *subjectively* by hue (position on color wheel or color name), saturation (richness of color compared to shades of gray), and lightness or brightness (value), or *objectively* by its dominant wavelength, purity and luminance. Color measurement standards are set by the Commission Internationale d’Eclairage, while the two most common color specification systems are the Munsell and Pantone systems.

Tints are colors with white added; *shades* are colors with black added. Color also exhibits visual *physiological/psychological phenomena* including contrast, afterimages, and advancing/retreating colors. Colors can also be described in “temperature” terms: colors in the red range of the spectrum are subjectively known as “warm” colors (active, stimulating); colors in the blue range of the spectrum are considered “cool” colors (restful, quiet) (Ballast, 1992).

Color harmonies describe the relationship certain colors have with one another on the color wheel, and how they can be selected to create a pleasing color selection. *Complementary* colors are two colors opposite one another on the color wheel; *triad* colors are three colors equidistant from each other on the color wheel. *Monochromatic* color schemes use a single hue with variation in saturation and brightness; *achromatic* colors are black, white, and shades of gray.

Color contrast involves both color and brightness. Contrast produce better images, more pleasing pairings and facilitates easier discernment. *Brightness* involves color intensity and wavelength; colors in the middle of the spectrum appear to be brighter than colors at each end of the spectrum. Brightness is also affected by color adjacency or the change in apparent hue due to interaction with other colors based on proximity or isolation.

Saturated colors are colors that are bright, do not have any other colors mixed in with them, and should be avoided over large areas. Saturated colors cause visual fatigue because every saturated color has a different wavelength that needs to be focused at different depths behind the eye lens; the lens must change shape and refocus for every saturated color, and this can cause the eye muscles to work harder and more frequently. Fatigue results in errors, decreased performance and accompanying physical exhaustion. Saturated colors also create depth perception problems; different colors are perceived to float in front of or behind other colors (chromostereopsis). Saturated colors should be used sparingly or for areas that require particular attention. Saturated yellow in particular is a difficult color to use, since the eye is most sensitive to this color over all others. Large areas of yellow cause visual fatigue and produce psychological stress.

Response to Color

Response to color is both physiological and psychological and is formed from a variety of sources (Wagner Institute for Color Research), which often are contradictory and overlapping:

- Inherited-physiological
- Learned-linguistic, religious, political
- Geographic-natural environment
- Regional-cultural
- Natural light-light modulation
- Climate-circadian rhythm and latitude
- Socioeconomic-social strata
- Sophistication-experience and style

Color Physiology

Colors produce different physiological responses in blood pressure, heart rate, respiration, digestion, body temperature, and brain activity. Even blind individuals, as confirmed by neuropsychologist Kurt Goldstein, have skin that "sees" in technicolor, (dermo-optic vision), and they experience different physiological sensations under different colored lights. Colorblind and blind-folded subjects also can distinguish color and shape. Since electromagnetic wavelengths below red (infrared, radio waves) and above violet (ultraviolet, X-rays, gamma rays) have a physiological impact, there is evidence that the electromagnetic waves we actually see (visible spectrum) can also impact our well-being. Understanding these effects is the result of research on melatonin and serotonin, both hormones produced by the pineal gland in the brain. Melatonin, a depressant, is produced at night and is associated with responding to light, the reproductive system, and time synchronization of bodily functions. Serotonin, a stimulant, is produced by day and is an important neuron transmitter. Research has confirmed that certain parts of the brain are not only light sensitive, but also respond differently to different wavelengths (colors). It is believed different colors interact differently with the endocrine system to stimulate or reduce hormone production.

Chromotherapy, or using color to heal (also known as light therapy or colorology) has had a long and difficult history. Originally developed by the ancients (India, Greece, China, Egypt), it is increasingly being used today to complement both conventional and holistic/alternative medical treatments.

Paracelsus, physician and alchemist during the Renaissance, regarded light and color as essential to good health and used them in treatments. In 1876, physician Augustus Pleasanton published *Blue and Sun-Lights*, reporting his findings on the effects of color on plants, animals, and humans. He particularly was noted for his studies of the effect of blue light on grape production. In 1877, another physician, Edwin Babbitt, advanced a comprehensive theory of healing with color. In the 20th century, color was introduced into the classroom for therapeutic effects. This practice was based on the work of Rudolph Steiner, founder of the Waldorf school system.

Steiner's work was continued by researcher Theo Gimbel, who explored the claims of Max Luscher, head of the Institute of Psycho-medical Diagnostics in Lucern, Switzerland. Luscher was convinced that color preferences demonstrated a state of mind and were related to metabolic rate, glandular secretions, and autonomic responses. In the 1940s, Russian scientist S.V. Krakov established that the color red stimulated the sympathetic nervous system, while blue stimulated the parasympathetic nervous system. During the 1950s, Dr. Mhairi G. McDonald treated neonatal jaundice successfully with blue light. In 1958, psychologist R.M. Gerard found that red produced feelings of arousal and was disturbing to anxious or tense subjects, while blue generated tranquility and well-being. Gerard also discovered blood pressure increased under red light and decreased under blue light, relating blood pressure changes to changes in light wavelength. Harry Wohlfarth, late president of the International Academy of Color Sciences, found expanded relationships between color and changes in blood pressure, pulse, and respiration rate. In 1990, the annual conference of the American Association of the Advancement of Science reported on the successful use of blue light in the treatment of a wide variety of psychological problems, including addictions, eating disorders, impotence, and depression.

Color can have a positive or negative affect. Therefore, specific colors and amounts of colors are used to treat specific parts of the body. Light therapy is used to treat depression and sensory affective disorder. In the 1970s, German naturopathic physician and acupuncturist developed esogetic colorpuncture, using light similar to acupuncture to restore the body's health. Color has been shown to alter alpha brain wave activity (alertness) and the production of hormones that affect mood, energy level, and mental clarity. As a result of NASA research on space shuttle plant growth, PDT or *photodynamic therapy* using LED (light emitting diode) technology has been shown to speed the early phase of wound healing (Medical College of Wisconsin), activate light-sensitive cancer drugs to increase their effectiveness, and improve human cell functioning to counteract the debilitating effects of weightlessness experienced by astronauts. There also have been promising medical research results with light on a variety of cancers and tumors, and pulsed LED red light has been used to reduce the pain of radiation therapy in breast cancer treatments. To increase the therapeutic affect, experiments have been undertaken to associate particular sounds with colors or translate particular colors into sounds or sound patterns to provide a more comprehensive treatment experience. There also is evidence that physiological arousal may be more related to color saturation and brightness than hue, or be a result of mood associations to light (Vining 2003).

Color Psychology

Color is an inseparable part of our lives and is a part of everything we perceive. Color has a strong impact on our emotions and feelings (Hemphill, 1996; Lang, 1993; Mahnke, 1996). There is a direct connection between the brain and the body, and reactions to color take place independently of thought or deliberation (Birren 1989). These reactions are:

- Warm/active vs. cool/passive
- Light/active vs. deep/passive
- Warm: external environmental contact
- Cool: internal withdrawal

- Red: autonomic nervous system stimulation — longer wavelengths
- Blue: sedation effect — shorter wavelengths

Very bright, intense colors draw a response from the so-called "primitive" brain, the limbic system. This is an emotional response linked to our biological heritage of color as communication. The left brain's role is to tag colors with names and attributes (lemon yellow), to translate into words or emotional reactions to color, and to sequence the steps in making colors. The right brain is specialized in the perception of color relationships of one hue to another and to discover patterns of coherence: combinations of hues that balance opposites-red/green, blue/orange, dark/light, dull/bright. These are learned, culturally conditioned cognitive responses that evoke material (word associations, symbolism, objects), sensory (tactile, visual), and emotional (mood, feeling, memory) associations (Burnham, 1963).

The relationship between color and emotion is closely tied to color preferences, i.e. whether the color elicits a positive or negative emotion. Particular colors have been found to be preferred regardless of age, ethnicity, or culture (Adams, Osgood, 1973). Josef Albers, a 20th century abstract painter who was famous for his studies of color interaction, once said that if one says "red" to 50 listeners, there will be 50 different reds in mind. This is because color has deep roots in personal feelings and cultural associations.

Some colors may be associated with several different emotions (Wexner, 1954), and some emotions may be associated with more than one color (Linton, 1999, Saito, 1996). Emotions can be divided into moods and feelings. A *mood* is a state of mind, an attitude, or a disposition (American 2000) that may take into account memory, language, context, and physiological state. Mood not only depends upon the color, but also the saturation and area covered (Elmer 2001). A *feeling* is an emotional state that is the result of sensation, a more immediate perceptual response.

These color associations are formed when learners are young, and these associations have only a small range of plasticity with experiences as an adult. Strong associations hold over time; weak associations never get strong because of varying experiences with certain colors; intermediate associations might evolve over time based on one's experience (Schaie, 1961). Since color-mood associations are learned rather than innate, the design of an optimal learning environment should take into account these associations. More correctly, it may make perfect sense to have learners, based on age and ethnicity, complete a survey to accurately determine the most effective color palette for a particular school.

Data obtained from a variety of sources reveals many intriguing color responses. Helen Irlen, a psychologist, discovered that color-tinted eyeglasses can be highly effective in treating a variety of learning disorders, including dyslexia. In 1993, British opticians used the Intuitive Colorimeter to measure which tint (bright pink, yellow, green or blue) would best help dyslexics. Research on prison behavior showed increased violence occurred in red and yellow painted wings, rather than the blue and green wings. Pink also has been found to have a tranquilizing and calming affect, suppressing prisoner hostility and aggressiveness by reducing energy levels. Red light has been found to increase strength by 13.5% and is used to increase athletic performance for athletes who need short, quick bursts of energy. Blue light assists those athletes who need more steady energy output. Bright yellow is the most eye-sensitive color, and it encourages hostility and aggressiveness, suggesting that the use of yellow high-pressure sodium street lighting may not be appropriate for exterior lighting.

Color and Culture

Color conveys different expectations to the learner depending upon his/her cultural background. Confusion and false perceptions will occur if color is used in a way that is contrary to learner expectations and environmental requirements. For example, red can initiate feelings of danger (U.S.), aristocracy (France), death (Egypt), creativity (India), anger (Japan), or happiness (China). Blue can mean masculinity (U.S.), peace (France), faith (Egypt), and villainy (Japan). Green can mean safety (U.S.), criminality (France), fertility (Egypt), prosperity (India), and youth (Japan). Yellow" can mean cowardice (U.S.), temporary (France), happiness (Egypt), success (India), and nobility (Japan). White can mean purity (U.S.), neutrality (France), joy (Egypt), and death (India and Japan).

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