



## **Indoor Lighting of the Classes and Its Effects**

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### **Abstract**

Lighting has an impact on behavior in education environments in many different ways. This paper looks at evidence of the impact of light on task performance using current research in addition to some backgrounds on the properties of light. It addresses intensity, glare, and the differences between natural, full-spectrum, and cool-white fluorescent lights. It also suggests solutions for improving classroom lighting. Many schools consider fluorescent lighting because they are generally the most cost effective, but considering the results of some of the studies, an increase in test scores by even five percent and in some cases many more may cause a school to see the value in effective lighting. The balance between the need for daylight, the need for ventilation, and the desire for a more sustainable environment can help influence school districts to embrace day-lighting as necessary, rather than a frivolous detail. Even in existing schools, where day-lighting may be impossible to add changes from cool-white to full-spectrum fluorescent can be markedly beneficial.

**Key words:** Lighting, interior design, classroom

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### **Introduction:**

#### **1. LIGHTING BASICS**

Light intensity can vary from eight to 1,000 foot-candles in a single room. (Gifford, 2007) Generally, the eye can adjust to light changes quickly. Given enough transition time, students could read just as quickly with a very dim three foot-candles (32 lux) of light as they could at 53 foot-candles (570 lux), which is the standard classroom light intensity (Gifford, 2007). However, a study showed that depending on placement in the room, and availability of natural lighting, this high variance within a room can create fluctuations of the eye causing strain on the eye. It also means that some students receive adequate light levels while others do not.

There are many reasons why daylight has the positive effects described above. One is the body's circadian rhythm. The body's internal clock is dependent on the daylight cycle to know when to release its hormones. Some of these hormones improve memory and others

improve concentration. For instance, it is recommended to study for a few hours after six in the evening because this is when a hormone that enhances long-term memory is released. Another hormone that improves concentration is released around ten in the morning. The presence of daylight allows the body to know when to release those hormones. In addition to hormone regularity, seasonal affective disorder (SAD) and depression is triggered by a lack of daylight. Children in windowless classrooms displayed symptoms of SAD including restlessness and irritability. SAD is believed to be a major contributor to absenteeism (Dudek , 2007; Djamila et al., 2011).

Despite the human body's ability to adapt to light levels quickly, more natural light from windows results in 7-26% higher scores, and faster completion times on math and reading tests (Gifford, 2007). In addition, there is some indication that individual preferences may play a role in performance as well. Generally, students who preferred dim light performed better in dim light. Likewise, students who preferred more light, performed better in a more intense light (Gifford, 2007).

## **2. LIGHT SOURCES AND THEIR IMPACTS ON VISUAL COMFORT AND BEHAVIOR**

The type of light source is another important factor in performance. Many classrooms use fluorescent lighting that emit x-rays, radiation, and radio waves. These emissions decrease productivity, cause fatigue, confusion, eyestrain, irritability, depression, and hyperactivity (Rapp, 1996). Poor air quality and the noise emitted from ballasts can also be a distraction. In addition, a small portion of the population may have sensitivity to fluorescent lighting. Known as photophobia, light sensitivity is usually a symptom of another condition such as corneal abrasion, uveitis, meningitis, retinal detachment, or others (Garcia-Hansen et al., 2002; Lee et al., 2009). The studies suggest the need for better lighting conditions in the classroom.

One inexpensive way of reducing the need for fluorescent lights is the utilization of natural light. However, there are trade-offs which must be studied carefully, such as an increased glazing area that may increase unwanted heat loss or gain if not designed properly. When designed properly, this method is a more sustainable practice that can save energy and money. Another possible solution is the use of full-spectrum lighting. Full-spectrum lighting has color rendition that is much closer to natural light than fluorescent lighting. Although it cannot capture the complexity of the natural light spectrum, it spikes at each of the primary and secondary colors on the spectrum, as opposed to cool-white which gradually rises in the blue area of the spectrum. Germany has banned cool-white fluorescent lighting in all hospitals and schools. Studies also suggest that shielding lighting and the use of incandescent lighting can improve attention as well (Rapp, 1996; Garcia-Hansen et al., 2002). Shielding also reduces glare, making reading and concentrating on other tasks easier.

In one study (Mayron, 1974) of the differences between typical fluorescent lighting and full-spectrum lamps, 98 first-grade students in four classrooms were filmed during routine classroom activities. Each classroom was windowless, two had cool-white fluorescent lighting, and the other two had full-spectrum fluorescent lighting. Full-spectrum students

paid more attention and were less fidgety. Reading and other tests were inconclusive (Garcia-Hansen et al., 2002; Gifford, 2007).

The study described above leaves the door open to other questions. Although the study has been confirmed by other studies, it fails to account for certain variables such as light intensity variations between rooms. In addition, behavior in the classrooms may have been determined by pre-existing social dynamics or differing teaching styles. Time also may have been a factor because restlessness can fluctuate throughout the day (increases just before lunch and recess). Other studies are needed to corroborate the imbalances of this one. One such study looked at a women's college (Dalezman et al. 2007). It accounted for all of the shortcomings listed above, and even controlled reflections in the room. It concluded that basic information processing related to decision-making is better in full-spectrum lighting. Another study found that cool-white fluorescent lights are more physiologically arousing, and increase the hyperactive behavior of children already prone to autism and other psychological disturbances (Gifford, 2007). Absenteeism is also reduced in schools with full-spectrum lighting (Gifford, 2007).

One study found that classrooms with natural light or full-spectrum light caused two-month delays in the production of a stress hormone called cortisol, typically produced on spring mornings (Gifford, 2007). This finding is significant because it demonstrates an actual chemical reaction to light that is based on natural biological processes. Whereas other studies measure instances of comfort and other subjective feelings about the space, this study focuses on chemical response and suggests that like plants, humans are chemically dependent on light to live a healthy life.

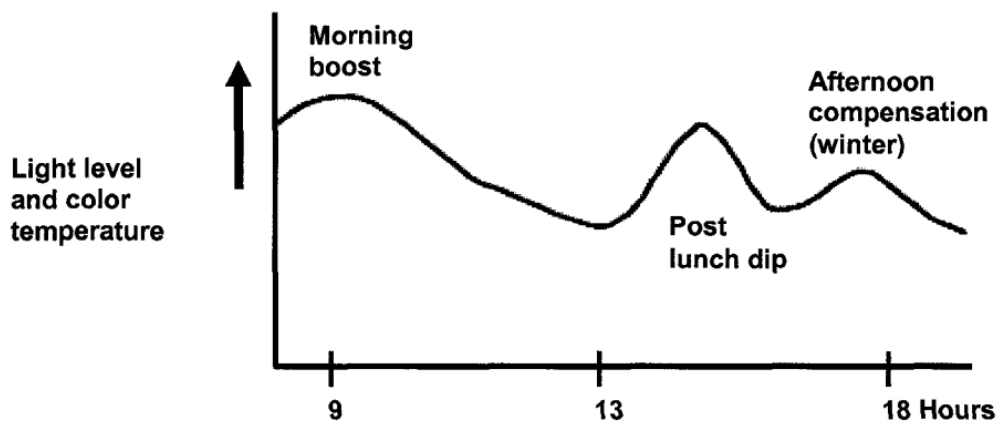
Another quantifiable statistic measuring the effects of lighting is the use of performance tests. The test gives sufficient evidence of the learning process and the effect light has on it. In a study of 21,000 students in the U.S., it was discovered that students in classrooms with the most daylight performed 20% faster on math tests and 26% better on reading tests. Rooms with larger window areas correlated with 15-23% improvement. Classrooms with skylights saw 20% faster rates of improvement. A separate study of 1,200 elementary school students found a 14% improvement in performance for students in classrooms with operable windows (Dudek, 2007). Although it is possible that there are methodological flaws (e.g., socioeconomic factors may be influence test scores in wealthier school districts, that happen to be able to afford better quality architecture with more natural light), these studies are strong evidence in support of the use of natural day-lighting to illuminate spaces.

## **2.1 General effects of light on the human body**

Admitting daylight into the indoors improves mood, enhances morale, lowers fatigue, and reduces eyestrain. One additional and important psychological aspect from day-lighting is meeting a need for contact with the outside living environment (Robbins, 1986).

Various studies show that all people require daily doses of light and dark to be healthy. It appears that humans require more light exposure during the daytime and less at night than most people currently get. Dynamic light dosage refers to a high level in the morning to support wake-up, then a decrease to the standard level, a high level after lunch to

compensate the post-lunch-dip and after  $\pm 15$  hours the level will rise to decrease tiredness (van den Beld, 2003) (Fig. 1).



**Fig. 1: Dynamic light dosage (Van den Beld, 2003).**

Daylight exposure shows indirectly effective via work-related stress and job satisfaction levels. Exposure to daylight at least 3 hours a day was found to cause less stress and higher satisfaction at work. Suffering from sleep disorders, younger age, job-related health problems and educational level were found to have total or partial direct effects on occupants being exhausted (Alimoglu and Donmez, 2005).

Ott referred to the body uses of light as a nutrient for metabolic processes, and therefore it is similar to water or food. Natural light stimulates essential biological functions in the brain and is divided into colors that are vital to our health. On a cloudy day or under poor lighting conditions, the inability to perceive the colors from light can affect our mood and energy level (Ott Biolight Systems, Inc. 1997).

### **3. PHENOMENON OF GLARE**

Glare occurs when one part of the visual scene, much brighter than the general brightness of the rest of the scope. Source of high brightness, large area source, the light background and position close to the bottom line, all eyes will increase glare. There are two types of glare: disability glare and discomfort glare. Disability glare refers to the reduction in visual function, resulting in reduced contrast due to scattered light inside the eye. The light is scattered when a light source close to the direction of gaze. Light mainly, by the lens of the eye, also by the cornea, reducing the spread of retinal image contrast. Even without a reduction in visual function, sensitivity to light may also lead to discomfort (discomfort glare), with symptoms including eyestrain and headaches (Winterbottom and Wilkins, 2009).

Glare is an important issue. A study of teachers found that glare could lead to complaints of eye-strain, nausea, and headaches (Gifford, 2007; Ho et al., 2008). This is in addition to other studies that show glare can have a negative impact on learning.

Because of the problems associated with glare, a consensus amongst authors is that glare should be reduced and that school environments should have a light reflectance value between 50 and 60 percent. There is also agreement that the brightness ratios should be uniform throughout the room (Gates and Wilcox, 1984; Brubacker, 1997). As mentioned earlier, this will help achieve more uniform lighting and create equal opportunities for learning no matter where a student sits.

Glare, along with other factors, have at least one common problem, and that is the distraction of light. Colors and lighting patterns should always supplement learning; they should provide some stimulation, but not so much that it distracts. In general, materials and colors should be considered based on their light reflectance value. Floors should have a 20 to 30 percent reflectance (Brubacker, 1997; Hua et al.,2011). Carpet is one way of reducing reflectance but it can cause problems in air quality and is difficult to maintain. Natural wood has a reflectance of 20-30% and could be considered. Other materials such as stone and concrete have varying reflectance making some of them suitable to be considered as an alternative to high- reflectance linoleum.

#### **4. DAYLIGHTING STRATEGIES**

Given this evidence of the benefits, both physical and mental, of natural light, several strategies have been developed over time to help achieve effective daylight infiltration. One method is to have a one-storey building oriented along the east-west axis. This allows diffuse north light to enter and for easily controlled south light. Another method is to place clearstory, skylight, or tall side windows in the classrooms. It is also helpful to bring daylight in from multiple locations to help reduce the chances of glare. Classrooms should always use indirect lighting to reduce glare. Light shelves can also be used to bring light deeper into a room, and again, reduce glare (Ne'eman and Shrifteilig , 1982; Dudek, 2007).

The teaching walls, or the area where the teacher stands, should be the foreground, with remaining walls fading into the background. Teaching walls should have a slightly lower reflectance than the rest of the walls. Since color variation can be beneficial, this provides an opportunity to introduce a color in the form of an accent wall. Benefits of this accent wall include: relief of eye fatigue, focus of attention on the teacher, reduction in the overall glare reflected from white boards, and provide stimulation. It also reduces glare from natural light sources (Brubacker, 1997; Edmonds and Greenup ,2002). It should be noted that the focus of attention on the teacher by using an accent wall should work well in a traditional classroom using traditional teaching methods; however, classrooms with a focus on experimental learning may not require focus on the teacher, but instead encourage a group interaction.

Furniture, doors, and walls should have a reflectance value of 40 to 55 percent. The ceiling reflectance value should be 90 to 100 percent. Given these reflectance values, the reflective contrast ratio would be 2.5 to 1. The reflectance contrast ratio should never exceed 3 to 1. As a whole, the room average should be between 40 and 60 percent (Brubacker, 1997; Loutzenhiser et al.,2007). These values will help minimize distraction

while providing clear and focused contrast between the background and the fore-ground. These values can be used in the design process.

## **5. EFFECTS OF COLOR**

It is important to consider that when choosing color to understand that colors affect the body differently at different ages so the selection of color should be based on the age of students that will occupy the space. Secondary grades should have a cool-colored background, which has been correlated to lowering heart and breathing rates (Brubacker, 1997; Winterbottom and Wilkins, 2009). One study of child-care centers suggests that rooms with varied colors increase cooperative behavior as opposed to single colored rooms (Gifford, 2007).

The best approach to using color is to use a neutral color to allow the architecture to create the interest. Colors for accents should be chosen based on a scientific process and not taste and trends (Brubacker, 1997).

Warm colors are best in elementary schools as they have a diverting effect that draws visual and emotional interest outward (Brubacker, 1997). Cool colors have a passive effect that elicits better concentration. Libraries and study halls, as well as other spaces where individual tasks are of importance should be painted in cool colors (Brubaker, 1997).

It is important to note the correlation to light and air quality. Lights and computer monitors (particularly CRT displays), give off electromagnetic energy that attracts dust. Lights are often not cleaned because of their location. It is important to use compressed air to dust light fixtures when school is not in session, and prior to vacuuming (Rapp, 1996; Pattanasethanon et al., 2007).

## **Conclusions**

Numerous studies have linked learning behavior and performance in the classroom, as well as chemical and biological fluctuations, to light quality. Many schools consider fluorescent lighting because they are generally the most cost effective, but considering the results of some of the studies, an increase in test scores by even five percent and in some cases, many more, may cause a school to see the value in effective lighting. The balance between the need for daylight, the need for ventilation, and the desire for a more sustainable environment can help influence school districts to embrace day-lighting as necessary, rather than a frivolous detail. Even in existing schools, where day-lighting may be impossible to add, changes from cool-white to full-spectrum fluorescent can be markedly beneficial. Choosing new light fixtures that reduce glare, enhance reflectance, and distribute light evenly, will be of great benefit. These studies have shown the benefits of something as simple as choosing proper colors and finishes for the next repainting, can be a good start in the right direction.

This review provides sufficient evidence that light, in particular, natural light has a positive impact on performance and behavior in the classroom. Since light also corresponds to color, air quality, materials, and comfort, in addition to its sustainable benefits.

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