CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

# IMPACT OF DIVERSE LIGHTING IN A LABORATORY SETTING: A COMPARISON OF TWO LABORATORY SITES

A graduate project submitted in partial fulfillment of the requirements

For the degree of Master of Science in

Family and Consumer Sciences

by

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May 2015

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# DEDICATION

*"When you are inspired by some great purpose, some extraordinary project, all your thoughts break their bonds: Your mind transcends limitations, your consciousness expands in every direction, and you find yourself in a new, great and wonderful world. Dormant forces, faculties and talents become alive, and you discover yourself to be a greater person by far than you ever dreamed yourself to be."*

*-Patañjali, The Yoga Sutras of Patanjali-*

I would like to sincerely dedicate this project to my beloved family who has supported me in life.

To my father, Cesar, who gave me courage and have an optimistic view in life.

To my mother, Alice, for showing me how to be strong and never giving up in my dreams.

To my sister, Anabelle, for believing that I can accomplish anything in life.

To my brother, Christopher, for supporting me with my passion in interior design.

ACKNOWLEDGEMENT

I would like to send my appreciation to all my committee members who supported my efforts in writing this project.

Foremost, I would like to express my sincere gratitude to my advisor Dr. Anubhuti Thakur, for helping me refine my ideas. She has been very kind and encouraging throughout the process. Thank you so much for providing me with insight, expertise and wisdom in the field.

To my mentor Dr. Irma Gvilia, for supporting me in my work in the field of science. Her guidance and motivation had helped me in all the time in research. Thank you for believing in me and having my back every step of the way.

I am also immensely grateful to Dr. Sun-mee Kang and Prof. Judith Griffin for their valuable contribution with this project.

Thank you all! Shanti (Peace) & Mabuhay (Live great)!

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ABSTRACT

IMPACT OF DIVERSE LIGHTING IN A LABORATORY SETTING: A COMPARISON OF TWO LABORATORY SITES

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Integrating light in an interior setting is one of the most fundamental elements in design. Lighting can be categorized in two ways; one as natural light derived from the sunlight and the other as artificial light produced by an electronic device. These two types of lighting work in conjunction with other design factors when the proper lighting is achieved to transform a purposeful and aesthetically pleasing interior. In this project, two laboratories were visually examined to observe the impact of light on an interior setting. Extensive literature findings were implemented to generate a design proposal that would best fit for each laboratory site. The results obtained in this case study project suggest that the balance of natural and artificial light can impact various design elements in two interior environments with different functions.

CHAPTER I

# Introduction

## Study Background

Lighting plays a critical role in any type of interior settings. It is one of the most fundamental elements in a design. It helps to create the main ambiance in a space and promote the mood of an individual. Incorporating different types of lighting in an interior can also bring an illusion of the space to life. Further, lighting also works in conjunction with colors in a room, furnishing, and size of the room. These elements can be combined together as a whole when proper lighting transforms an interior space to become both functionally and aesthetically pleasing.

There have been prodigious amounts physiological studies done on lighting in work settings. Today, the majority of the research is pseudo-scientific assertions based on the overall performance of people in a work setting (Tofle, Schwarz, Yoon, & Royale, 2004). Nevertheless, there are minimal studies known that pertains to the major factors that contribute to the effectiveness (positive effects) of a good lighting design in a laboratory environment. The main aim of this project is to investigate the impact of light in a laboratory environment.

## Statement of the Problem

In today's laboratory interior settings, many design elements are incorporated to make a well functioning lab. Most laboratories are designed based on contemporary design that will meet the needs of the clients. Elements such as furnishings, equipment, colors and lighting are all part of the modern laboratory design. However, one of the most important

factors to consider when designing a laboratory would be lighting. Some studies have a general belief that a good lighting design can ultimately influence a work setting (Juslén, Wouters, &Tenner, 2005). In addition, many people do not realize that lighting plays a critical role in our daily life. Currently, the most commonly used lighting in laboratories is the fluorescent lamp. This type of lamp has the ability to balance the illumination of a room. However, can this type of artificial light have an impact on some of the design elements presented within interior space? Or would natural light be more preferred? These are some pertinent questions that need to be considered in order to see some major effects of light in a laboratory.

**Purpose of the Study**

The central goal of this project is to investigate light in a laboratory environment and its relationship within the interior space. Two laboratories will be closely examined based on the two types of lighting: natural and artificial that will play an integral part in a laboratory atmosphere. It can change the surroundings that may lead to increased productivity.

Furthermore, literature reviews will be incorporated to analyze some of the benefits of lighting within the interior setting. Laboratories will be examined visually based on other factors affecting light such as color and materials. Evaluations will also be made based on my own personal experience as a research associate in both facilities. Lastly, renderings of both spaces will be used to interpret the space with a design proposal as part of the recommendation.

## Definition of Terms

*Ambiance:* The mood or the feeling of a particular place (Mirriam-Webster, 2014).

*Biological*: Relating to biology or to life and living process (Mirriam-Webster, 2014).

*Circadian Rhythm:* A cycle of day and night that regulates and maintains our daily physiology (Anderson, Mardaljevic, & Lockley, 2012).

*Cognitive*: Relating and/or involving conscious mental activities such as thinking, reasoning or remembering (Mirriam-Webster, 2014).

*Color Rendering Index (CRI):* The ability of the light source to reveal the true colors of the objects (Brawley, 2009).

*Light- Emitting Diode (LED):* A semiconductor diode that emits light when voltage is applied to it (Miriam-Webster, 2014).

*Light Reflectance Value (LRV):* A part of light that is reflected from the surface (Brawley, 2009).

*Neurobehavioral*: The relationship between the action of the nervous system and behavior (Mirriam-Webster, 2014).

*Metabolism*: The chemical processes by which a plant or an animal uses food, water, etc., to grow and heal and to make energy (Mirriam-Webster, 2014).

*Visual Perception:* The way the surrounding is interpreted or seen (Logadottir, Christoffersen, & Fotios, 2012).

CHAPTER II

# Review of Literature

## Biological Effects of Light

The biological effect of light may be described as part of our well being. It has a great impact on our alertness and health (Van Bommel & Van Den Beld, 2004). In a work setting, artificial light play a key role in the productivity levels of employees. Task lighting such as LED can ultimately help illuminate a workplace that can promote a positive mood. More importantly, certain task lighting is designed to hit specific area that can increase our visual acuity as well as employee work performance (Sleegers et al., 2013).

In addition, natural light may also be preferred in a work setting. It can have a positive impact in an individual health. Exposure to light is essential for vitamin D metabolism in the human body (Joseph, 2006). In the healthcare industry, having natural light is more preferred than artificial ones. Studies suggest that incorporating natural light is a good way to combine nature in an interior setting (Joseph, 2006). Researchers have also verified that natural morning light has a biologically activating effect, whereas the red sky that we see more often in the early evening has a relaxing outcome (Canazei, Dehoff, Staggl, & Pohl, 2014). Furthermore, natural light can make people feel more alert and responsive within the interior space and is considered dynamic in intensity (Van Bommel & Van Den Beld, 2004).

## Circadian Rhythms in Humans

Circadian rhythm can be described as part of our cycle of day and night that regulates and maintains our daily physiology (Andersen, Mardaljevic & Lockley, 2012). It is considered as part of our internal rhythms based on the daily exposure to the light dark cycle. Circadian rhythm does not necessarily have a period of exactly 24 hours and cycles need to be adjusted according to the length of time exposure to day and night (light-dark cycle).

This type of cycle in humans can be determined based on the outdoor light, also referred to as *natural light*. The process is highly dependent on the exposure of light and dark cycle within 24-hours in length. In order for the cycle to be consistent, external factors such as light, play a key role. A research study by Duffy and Czeisler (2009) implied that timing and the intensity of the wavelength of light can change the human biological clock. For instance, increase in (natural) light level, can affect the spectral sensitivity of the circadian rhythm that may lead to the changes in an individual mood.

Likewise, early morning light exposures can advance the stages of circadian rhythms. All day light exposure is more preferred considering that it bear a resemblance to light and dark patterns within the space (White, Ancoli-Israel, & Wilson, 2013). High intensity of exposure to early light can also be beneficial to a person considering that it promotes early sleep and wake times. Sleepiness patterns can be improved by proper scheduling of light exposure during the day (Postnova, Robinson, & Postnov, 2013). Daylight contains the spectrum to which the biological clock is most sensitive and provides an increase of light (Brawley, 2009). Research has also determined that there is a great correlation between daylight exposure and productivity (Andersen et al., 2012)

On the contrary, delayed circadian rhythms or late light exposure will create more stress resulting in later sleep. This may also result in the decrease of work productivity and/or the neurobehavioral effects on the human body. Evening light can delay time of stages within the brain that would include the measurable effects of cognitive performance and brain activity (Anderson et al., 2012). Similarly, late light exposures can also be beneficial considering that it will help synchronize the external light –dark cycle within our brain.

**Visual Impact of Artificial Light**

Lighting creates the main visual impression within the physical environment. Studies in the field of architecture have touted that lighting can address the methodological issue that pertains to human behavior (Manav, 2013). In most interior settings, artificial light is preferred since it can illuminate with ease. This can also significantly affect reliability in which a visual task can be performed (Rossi & Lent, 2006). The purpose of having artificial light was to help enhance the visual of the room. Custers, Dehoff, Staggl, and Pohl (2010) mentioned that lighting sets the standards of an interior atmosphere. As such, having the ability to change the level or intensity of light can lead to the change of the ambiance of the interior space.

Furniture and objects in an interior setting can also be improved with the proper amount of artificial light. The visual perception of our surroundings can easily adapt to prevalent illumination (Logadóttir, Christoffersen & Fotios, 2011). Ambient lighting is utilized in most rooms that would help set the tone of the interior. It can also illuminate the colors of the space that may result in a dramatic impact to the overall visual element.

In essence, space captures light and renders the room (Howlett, 2003). This process can be seen within the spatial composition of the interior space.

**Visual Impact of Natural Light**

Healthcare design may be the most prominent field that incorporates natural lighting. According to Brawley (2009), vibrant daylight is a type of lighting system that creates a more inviting as well as a visually comfortable environment. Hospitals have different age demographics and would rely on natural daylight to create the visual of the space (Malone and Dellinger, 2011). More importantly, physical and mentally challenged individuals depend heavily on the type of lighting used in the space.

The physical environment in healthcare focused more on the different factors of lighting design. The different types of lighting fixtures will serve not just for task purposes, but to create the atmosphere in the space. For instance, a surgical room utilizes light in order to perform a successful surgery (task lighting). Waiting room areas are concerned with ambient lighting, rather than task (lighting) as a way to create a peaceful environment.

Similarly, most healthcare buildings as well other types of buildings incorporate natural light as a form of design that would help create a spacious environment. Natural light provides the balanced colors of the spectrum within the interior space that can bring the interior setting to life (Joseph, 2006). Further, natural light in a hospital can make staff members feel more comfortable. Studies have shown that work environments in a hospital can be stressful. Inadequate natural light within the visual element of the hospital are likely lead to errors (Joseph, 2006).

## Factors of Good Lighting

Good interior lighting is primarily based on the quality of light. Most people have the perception that effective lighting relays on the quantity. Brawley (2009), stated that increasing the quantity of light levels does not necessarily guarantee the quality of the visual space. Some factors that contribute to positive lighting in an interior setting includes: light reflectance value (LRV) and coloring rendering index (CRI).

Light reflectance value can be described as the light reflected from the surface (Brawley, 2009). In interior design, paint samples indicate the LRV that will be used to determine the amount of light fixtures in interior space. Based on the LRV scale, Dark (Black) color is considered to be 0% and the lightest (white) is a 100%. This will allow designers to have the ability to manage the intensity of light in a controlled interior setting. Also, knowing the color's LRV can be utilized as a tool to coordinate colors.

On the other hand, the color rendering index works together with light source to reveal the true colors of objects in the interior space. The intensity of the light will determine how the color of an object appears. The higher intensity of light, the sharper the object will appear. This is an integral part in an interior environment since much of the light is reflected back off the surrounding objects or surfaces.

## Colors that Affect Light

Color can be described as a part of the visual element that can be measured based on the brightness of the reflected light. Interior color settings can change the mood in a room. The studies of color in a work setting demonstrated that light toned hues are more preferred than dark vibrant colors. Light colors tend to create a sense of spaciousness in

an interior space (Tofle et al., 2004). Similarly, most people would prefer lighter than dark considering that darker shades of colors create a sense of confinement. The main question that arises is *if there is a direct link between the colors used in a work environment that would increase productivity.*

In most interiors, the types of colors used are very intuitive based on an individual preference. The main role of colors in interiors is to contribute to the aesthetic of the space. Colors are shown based on the type of lighting in a room. Research had demonstrated that colors that most people prefer are earth toned color that contains a lighter hue (Tofle et al., 2004). Most people associate lighter colors with natural light. Darker colors are not preferred in a work facility considering that they create a somber mood. However, there is not much evidence to support that certain colors make a difference in how we perceive light. Research shows that colors are more associated with the mood of an individual. Red tones are associated with stimulating activities and blue tones with passivity and tranquility (Tofle et al., 2004).

Heerwagen and Hase (2010) mentioned that our emotional responses to different colors are also caused by our physical and psychological makeup. In a work environment, the use of color palettes are more challenging considering that it should make employees feel comfortable. The colors and light are also based on perception and/or physiology. According to Tofle, a co-author of *"Color in Healthcare Environments,"* there are no scientific explanations between the direct links of certain colors to the patients' healthcare outcomes.

CHAPTER III

# Methodology

## Scope of Study

This project examined two laboratory settings in order to assess how natural and artificial light affects their surroundings. This exploratory project also evaluated the advantage of having these types of lighting. Visual observation was highly utilized to study the space of each site. Specific areas such as the histology and the main workstation will be examined as part of the assessment. Moreover, an ample amount of literature review findings served as a foundation for the appropriate lighting for each individual space.

## General Description and Rendering

Laboratory A – Sleep Research (Area: Histology)

The histology room for Laboratory A served as room to conduct various experiments. The space consisted of two windows that can help increase the amount of natural light within the room (Figure 3.1). Likewise, fluorescent lamps are installed throughout the ceiling in order to help regulate the light intensity (Figure 3.2).

Figure 3.1 Rendering image of the histology room (Lab A)

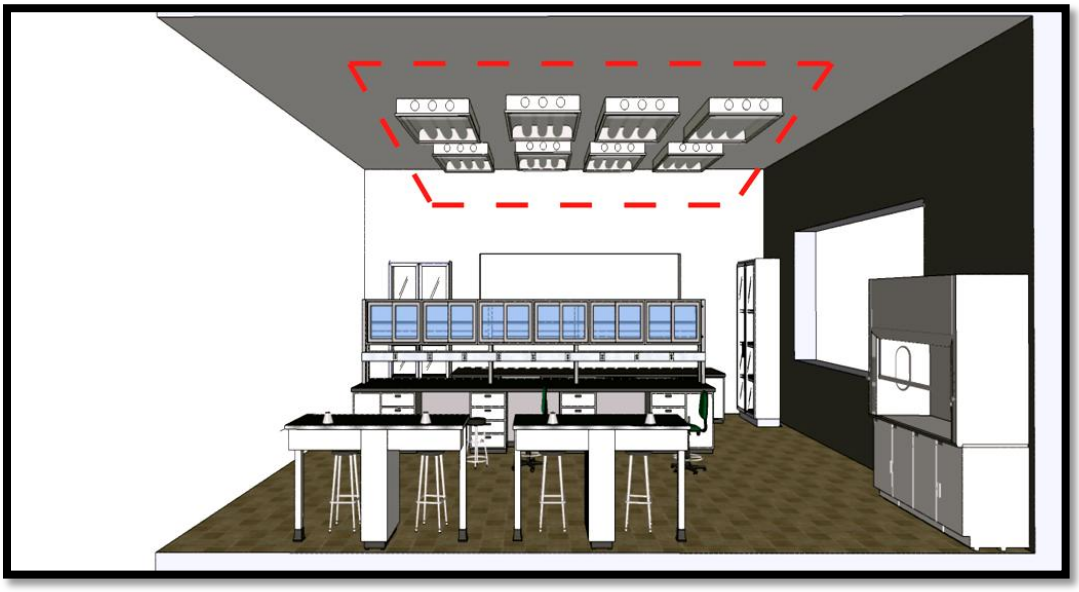

Figure 3.2 Full size fluorescent lamp (Lab A)

Laboratory B – Cancer Research (Area: Main workstation)

The main workstation for Laboratory B is a functional space for scientists to conduct their own experiments. The room does not present any windows throughout the area

(Figure 3.3) but compact and full size fluorescent lamps are installed as the only type of lighting in the space (Figure 3.4).

Figure 3.3 Rendering image of the main work station (Lab B)

Figure 3.4 Various types of lamps are installed throughout the room (Lab B)

## Guideline Assessment

### Part I: Site Background Information

**Laboratory A – sleep research (area: histology).** The sleep research lab is used to study sleep disorders such as sleep apnea, insomnia, REM, behavior disorder, circadian rhythm, narcolepsy etc. Researchers utilize the facility to create pilot studies pertaining to their topic of choice. In this regard, different experiments are conducted in order to find answers that will contribute to the academia.

**Laboratory B – cancer research (area: main workstation).** The department of cancer research focuses on the interactions of cancer development. The main laboratory operates as a facility to conduct experiments relating to cancer progression. Additionally, the facility provides a space for scientists to develop pilot studies that would help answer their own hypotheses. The work station serves as the main office as well as a space to carry out different types of scientific experiments.

### Part II: Checklist from the existing design

**Colors (lab A).** The main color of the interior wall was white with a light reflectance value of 100% and the grey accent wall with an LRV value of 20% (Figure 3.5). The white walls created a sense of pristine environment that can be very critical in a lab setting. Through this, the interior space becomes more spacious. Since laboratory A is a sleep research facility, the white colored walls helped scientist to conduct experiments with ease. On the contrary, the grey accent wall was utilized to create a sense of interior dimension.

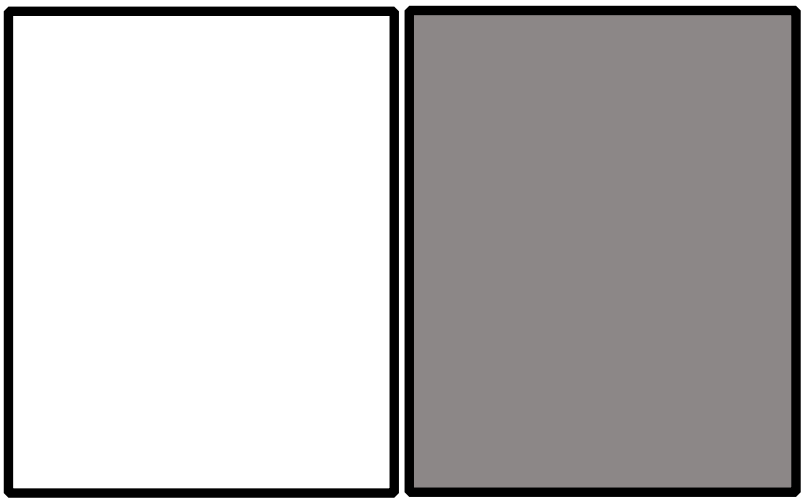

Figure 3.5 White paint; LRV100 and Grey paint; LRV20

**Materials –textiles (lab A).** The histology room had multiple types of chairs such as high back chairs, stools and office seating. All of the seating consisted of a textile back and seat made from cotton blend, poly fabric (Figure 3.6). This type of material can be problematic taking into account that cotton can easily absorb bacteria in a laboratory interior. Also, cotton cannot be easily cleaned due to the nature of the work space. The histology room was highly used area and chairs are utilized throughout the working hours.

Figure 3.6 Inspirational image of a lab chair with (ESD) poly fabric based seat/back.

JHA TECHSPACE (2015). E200SF1F CHAIR, Retrieved from http://jhateschspace.com /lab-and-task-seating/

**Natural light (lab A).** There are two windows in the histology room that allowed natural light to enter the room. This enabled researchers to work without relying on the artificial light. Having the natural light can also increase the temperature in the room and that may help regulate the room temperature. More importantly, daylight exposure can be beneficial to the workers as well. This will help promote vitamin D as part of their well being. Moreover, increases in daylight exposure to dayshift workers may even promote positive circadian rhythm (Canazai et al., 2014).This may result to a better amount of sleep that can lead a better quality of work.

**Artificial light (lab A).** Full size fluorescent lamps are utilized throughout the room (Figure 3.7). Perhaps one of the advantages of having artificial light was the ability to manipulate the amount of light incorporated in the room. Bearing in mind that Laboratory A is a sleep research facility, it was pertinent to have a controlled light setting. Although this type of lamp may be preferred, the cost may increase and can ultimately be economical in the long run.

Figure 3.7 Image of a full size fluorescent lamp.Trade press (2014).
Philips Alto II Fluorescent Lamp, Retrieved from http://www.facilitiesnet.com
/buildingproducts/details/Fluorescent-Lamp-Philips—1574

**Color (Lab B).** The wall color of the main work station was white with a light reflectance value of 100% (Figure 3.8). This wall color makes the room feel more spacious and atmospheric. The white also contributed to the separation of furniture elements presented in the room. Although, this type of color was common in a laboratory, it can also be visually tiring to workers. Having white walls throughout the interior space with no contrast or alteration was monotonous. This may lead to fatigue considering that our eyes may need variety of colors while looking around.

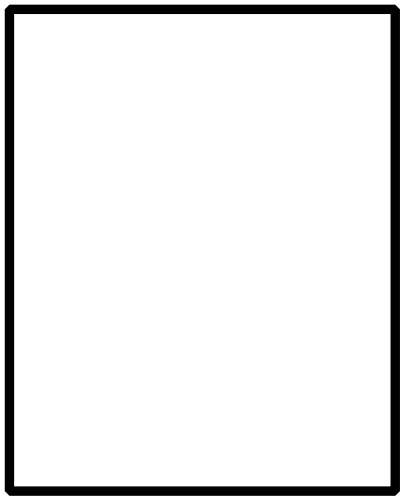

Figure 3.8 White paint; LRV 100

***Materials-textiles(lab B)*** The different types of seating in the room are upholstered in vinyl (Figure 3.9). Since Laboratory B is a multi functional space (office and experiment room), vinyl may be the best material to incorporate. Vinyl may be beneficial in a healthcare and laboratory setting considering that this textile does not absorb or transfer

bacteria. Furthermore, vinyl does not promote microbial growth and is considered breathable, acclimating to the room temperature.

Figure 3.9 Inspirational image of a laboratory chairs with vinyl seating and back. VWR LLC (2015), Contour Deluxe Lab Chairs, Retrieved from https://pr.vwr.com/store/catalog/product.jsp?product_id=7410939

**Natural light (lab B).** The main laboratory station does not have any windows throughout the interior space. Therefore, the room does not incorporate natural light during the daytime. The ambiance in the room felt a little somber due to the lack of natural light. In this regard, the lack of windows and natural light can be a negative factor. Since most scientists are dayshift workers, it was also critical to have some

daylight exposure within interior space. The atmosphere felt more claustrophobic since there are no windows as a way to connect with nature.

**Artificial light (lab B).** The interior space had full size and compact fluorescent lamps installed throughout the room (Figure 3.10). This is the only type of lighting that helped scientists to work with ease. However, the light can be overwhelming to workers especially because it was the only type of lighting. Additionally, this lamp cannot be controlled and would result in the increase of the temperature of the room.


Figure 3.10 Image of different types of compact fluorescent lamps. Panasonic Corporation (2015), LED Lamps, Retrieved from http://news.panasonic.com /global/topics/2013/22964.html

## Part III: Recommendations and Proposal

### Colors

#### Laboratory A.

- Since laboratory A is a facility dedicated to sleep research, light toned colors are more appropriate to the space. Having a white wall finish can be too monochromatic.
- Having the grey accent wall can help bring out the dimension to the interior space. Neutral blue colors may also be suitable considering that some studies suggested that blue is a tranquil color (Tofle et al., 2004).

#### Laboratory B.

- The interior space should implement other colors to blend with the white wall finish. Since Laboratory B is highly used facility, it may be fitting to combine other neutral colors (Figure 3.11).
- Perhaps adding art work throughout the space can help minimize the monochromatic wall finish.

Figure 3.11 Inspirational image of multi colored wall finish in a laboratory. RMW Architecture & Interiors (2015), Lawrence Berkeley National Laboratory, Retrieved from http://rmw.com/projects/lawrence-berkeley-national-laboratory-building-74-modernization/

**Materials—textiles**

**Laboratory A.**

- Vinyl textiles should be use throughout the room. This type of textile is more convenient in a healthcare and/or laboratory setting.
- Vinyl textiles offer more performance benefits such as: chemical resistant, highly cleanable, fire resistant, UV resistant and less maintenance.

**Laboratory B.**

- Incorporating other types of textile like Crypton brand fabric may also help the room look more aesthetically pleasing.
- Crypton brand fabric, like vinyl, can produce more variations in patterns and prints. It is also engineered to last a long period of time (Figure 3.12).

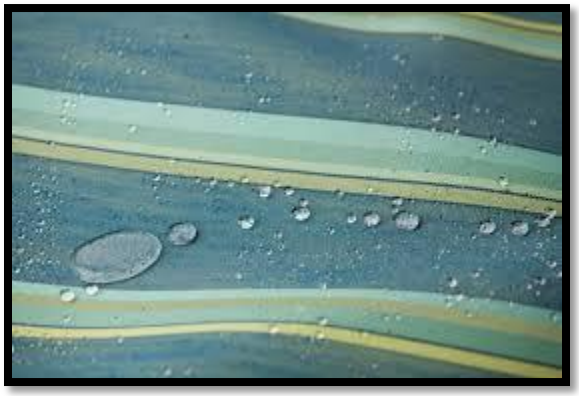

Figure 3.12 Image of a Cryton fabric with water resistant properties. Hi-Tex, Inc (2014), Crypton, Retrieved from http://crypton.com/

**Natural light**

**Laboratory A.**

- Windows should have blinds to protect from daylight. The histology room may be used to conduct sleep experiments and requires control from the natural light.
- Blinds can also help regulate the room temperature.

**Laboratory B.**

- Laboratory B should have windows installed throughout the space (Figure 3.13).

- Some exposure to natural light is critical especially in a lab setting. According to one research study (Canzai et al., 2014), dynamic lighting has an acute physiological effects on dayshifts workers.
- Alternatively, installing artwork with a landscape photograph can help bring a sense of nature indoors.

Figure 3.13 Inspirational image of a laboratory with windows. Rudolph and Sletten, Inc. (2015), The Warren and Katharine Schlinger Laboratory, Retrieved from http://www.rsconstruction.com/visit-our-projects/10-education/112-caltech-schlinger-laboratory-for-chemistry

## Artificial Light

### Laboratory A.

- LED lighting helps to control the light setting of room. It can easily change the room ambiance.
- LED is more durable than other types of lamps (Figure 3.14).
- LED lighting has the ability to control scatter lighting in a laboratory (Berger and Kratt, 2008).

- The number LED fixtures installed should adhere with all building codes and Title 24 based on applicable lighting density calculations.

**Laboratory B.**

- LED lighting should also be considered for Laboratory B. This type of lighting can help create a more inviting atmosphere (Figure 3.14).
- LED has a higher initial cost, but will lead to reduced maintenance that can last for up to 20 years.
- Title 24 and other building codes regulations should be adhered to in determining the number of LED fixtures incorporated.


Figure 3.14 Inspirational image of various LED bulbs. Koninklijke Philips (2014), LED Lamps, Retrieved from http://www.usa.lighting.philips.com/

CHAPTER IV

# Results

The proposed design for each laboratory will be depicted using design renderings. Evidence from the literature was used to identify optimal lighting solutions for the two labs. Design elements such as colors, materials, natural and artificial lighting will be represented through renderings as an integral part of the existing design.

## Colors

**Laboratory A.** The original wall color in laboratory A was white and had a grey accent wall (Figure 4.1). This color combination may be appropriate in a sleep research facility. However, combining neutral colors to the interior space can make the room appear more subtle (Figure 4.2). Colors such as blue or green is restful to the eye and does not promote stress. This is extremely beneficial since laboratory A is utilized to conduct sleep research. Having variety of neutral colors in work space will help instill a harmonious and a peaceful environment.

Figure 4.1 Existing wall color

Figure 4.2 Proposed design

**Laboratory B.** The wall color for laboratory B consisted of only white wall paint throughout the space (Figure 4.3). This can promote a monotonous tone in a workplace and would create a sense of confinement to employees. As part of the recommendations, changing one side of the existing wall color to neutral tones will make the work environment feel inviting (Figure 4.4). This will represent the impact wall in the room allowing the break on the white wall paint throughout.

Figure 4.3 Existing wall color

Figure 4.4 Proposed design

**Materials/Textiles**

**Laboratory A.** The upholstered textiles in laboratory A consisted of different types of work chairs with seat and back made from cotton (Figure 4.5). This type of textile can cause health issue since cotton can easily attract germs and bacteria. Re-upholstering the

seating in a different type of material can help resolve the issue. Vinyl can be beneficial in laboratory settings since this type of fabric is engineered to last longer and does not absorb bacteria (Figure 4.6).

Figure 4.5 Existing furniture

Figure 4.6 Lab stools made from vinyl seat and back

**Laboratory B.** Although vinyl seats are throughout the room, some of the vinyl textiles lacked colors and/or patterns that can make the room more aesthetically pleasing (Figure 4.7). Incorporating Crypton brand fabrics (with patterns) will compliment other design elements in the room (Figure 4.8).

Figure 4.7 Existing chairs

Figure 4.8 Crypton brand fabrics with patterns

**Natural Light**

**Laboratory A.** There are two windows in laboratory A that allowed natural light to enter the room (Figure 4.9). However, natural light can increase the room temperature that could affect the ambiance in the room. Installing blinds will easily resolve the problem (Figure 4.10). In doing so, the room will have protection from daylight that would permit employees to conduct sleep experiments.

Figure 4.9 Existing structure with two windows

Figure 4.10 Proposed design with installed blinds

**Laboratory B.** There are no windows in the existing site for laboratory B creating a somber mood in the room (Figure 4.11). Having a space without windows will lead to disconnect from the natural light. One way to resolve the issue is to install landscape artwork to emulate nature within the interior setting (Figure 4.12).

Figure 4.11 Existing design without artwork

Figure 4.12 Proposed design with installed artwork of nature

**Artificial Light**

**Laboratory A.** Laboratory A has existing full size fluorescent lamps installed throughout the room (Figure 4.13). As proposed, it would be beneficial to have installed LED lamps considering that this are cost efficient and will allow employees to control the light setting during diverse sleep experiments (Figure 4.14). Applicable lighting density calculations should be implemented to satisfy all building codes regulations and Title 24.

Figure 4.13 Existing ceiling design with full size fluorescent lamps

Figure 4.14 Proposed design with combined fluorescent and LED lamps (numbers of fixtures will be determined based on appropriate load and lighting density calculations)

**Laboratory B.** Laboratory B had a combination of full and compact size fluorescent lamps (Figure 4.15). Based on the proposal, installing various types of LED lamps would be more feasible for the space (Figure 4.16). LED has a higher initial cost but will result in reduced maintenance as well as energy efficiency. The amount and placement of LED

lamps will be regulated based on the proper lighting density calculations to comply with building codes and Title 24.

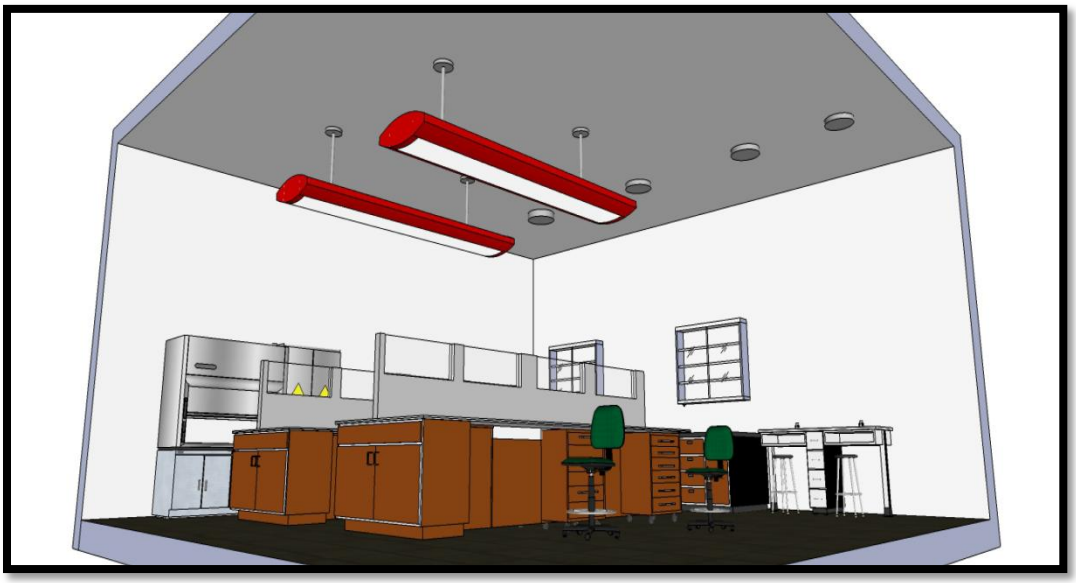

Figure 4.15 Existing ceiling design

Figure 4.16 Proposed design with variations of LED lamps (numbers of fixtures will be determined based on appropriate load and lighting density calculations)

CHAPTER V

# Discussion

The purpose of this project was to examine how natural and artificial light impacted various design elements in a laboratory setting. It is believed that lighting plays a critical role in our daily lives. In particular, laboratories would need adequate balance of light to achieve an optimally functional space and promote a positive atmosphere.

Two types of laboratories were examined based on various design elements that may affect the types of lighting in each facility. Some of these design elements included: colors, materials, and types of lighting implemented therein. This project had demonstrated that different types of lighting will have an impact on design elements in a room. One study, in particular mentioned that dynamic daylight can create a comfortable and relaxing environment (Brawley, 2009). On the contrary, another stated that artificial light can significantly bolster the overall image of the interior (Kocabey & Ekren, 2013).These findings were utilized for each site recommendations and renderings were created as a way to communicate the overall visual design.

## Discussion of Findings

The findings of this project verified how the different elements of design affect the visual impact of light. Lighting can ultimately change the mood in an interior setting by combining the balance of various types of light. It plays an integral role in a laboratory interior and set the standard for the environment (Custers et al., 2010). Through this, certain types lighting including natural and artificial light can hit specific areas in a room that may help bolster the visual perception of employees.

Natural light is considered dynamic in nature and makes people feel more receptive to the environment (Van Bommel & Van Den Beld, 2004).This type of lighting can lead to more inviting surroundings. Similarly, artificial light allows people to have the control of its intensity emitted within the interior space that may result in the change of the overall mood (Custers et al., 2010).

Furthermore, colors contribute to the effect of lighting. This concept was shown based on the color rendering index (CRI) to help reveal the true colors within the interior. According to Tofle et al. (2004), lighter hues are more preferred than vibrant ones. This was prevalent in the two laboratories examined where the grey and white walls are revealed in both labs. Additionally, these colors signify lighter tones in each room. More importantly, people associate lighter or neutral tones as a type of color that can affect our psychological and physical behavior (Heerwagen & Hase, 2001).

**Implications and Suggestions**

A design proposal was developed based on evidence from existing literature. Although this method may be practical, some shortcomings were encountered during the proposal design phase. The major concerns were the budget for renovation and the time it would take to finish the project.

In most cases, laboratories rely greatly on funding to conduct research experiments. In this regard, funding may not include a budget for any kind of interior renovations. This can be problematic considering that all types of renovations and constructions would require some financial plan. One issue raised was the budget limitations for each lab. Even though renovation may be economical, some laboratories may or may not have the

allocated budget to revamp the facility. One suggestion for future laboratory design might include utilizing the existing materials presented within the space in order to reduce cost of renovations. For instance, furniture may be re-upholstered as way to save funds and promote sustainable practice.

In addition, bearing in mind that all laboratories are dedicated for research, facilities function on a daily basis. Evaluating the interiors by themselves is time consuming because it involves informed decision making between personnel and design professionals. Any type of remodeling may cause problems since it can interfere with current ongoing experimental research. Perhaps a good way to resolve this issue is to work only on certain parts of the laboratory during renovation that would enable employees to conduct experiments as well.

**Conclusion**

In summary, evidence from literature and the design proposal may be a potential avenue to improve upon future laboratory designs. Above all, having the balance of natural and artificial light in a lab setting can help regulate the room temperature. Also, installing art work may be more feasible for a room without windows. Neutral colors are more preferred in laboratory work setting. All these factors attribute to the change of the interior ambiance to one that is more favorable for occupants.

On a personal note, working as a research associate in both laboratories discussed in this project made me realize there may not be a pre-determined standard for designing a lab. All laboratories should be built according to its' mission and/or goals. The type of work in research will help determine how the facility will be designed. Therefore, it is

critical to identify the needs of employees within their work surroundings before building and/or developing the space.

## REFERENCES


Andersen, M., Mardaljevic, J., & Lockley, S. (2012). A framework for predicting the non-visual effects of daylight – Part I: photobiology- based model. *Lighting Research & Technology, 44*(1), 37-53. doi:10.1177/1477153511435961

Berger, G., Kratt, C. (2008). LED laboratory lighting. *Ancient TL, 26* (1), 11-14.

Brawley, E. C. (2009). Enriching lighting design. *Neurorehabilitation, 25*(3), 189-199. doi:10.3233/NRE-2009-0515

Canazei, M., Dehoff, P., Staggl, S., & Pohl, W. (2014). Effects of dynamic ambient lighting on female permanent morning shift workers. *Lighting Research & Technology*, *46*(2), 140-156. doi:10.1177/1477153513475914

Custers, P. M., de Kort, Y. W., IJsselsteijn, W. A., & de Kruiff, M. E. (2010). Lighting in retail environments: Atmosphere perception in the real world. *Lighting Research & Technology, 42*(3), 331-343. doi:10.1177/1477153510377836

Duffy, J., Czeisler, C. (2009). Effect of light on human circadian physiology. *Sleep Medical Clinic.4*(2), 165-167. doi:10.1016/j.jsmc.2009.01.004.

Howlett, O. A. (2003). Reflectance characteristics of display screen equipment: application to workplace lighting design. *Lighting Research & Technology, 35*(4), 285-296.

Heerwagen, J., Hase, B. (2001). Building biophilia: Connecting people to nature in building design, 1-6.

Joseph, A. (2006). The impact of light on outcomes in healthcare settings. *The center for Health design.* 2. 1-12.

Juslén, H. T., Wouters, M. M., & Tenner, A. D. (2005). Preferred task-lighting levels in an industrial work area without daylight. *Lighting Research & Technology, 37*(3), 219-233. doi:10.1191/1365782805li138oa

Kocabey, S., & Ekren, N. (2014). A new approach for examination of performance of interior lighting systems. *Energy & Buildings, 74*1-7. doi:10.1016/j.enbuild.2014.01.014

Logadóttir, Á., Christoffersen, J., & Fotios, S. (2011). Investigating the use of an adjustment task to set the preferred illuminance in a workplace environment. *Lighting Research & Technology*, *43*(4), 403-422. doi:10.1177/1477153511400971

Malone, E., Dellinger, B. (2011). Furniture design features and healthcare outcomes. *The Center Health Design,* 1-73.

Manav,B. (2013). A Research on Light-Color Perception: Can Visual Images Be Used Instead of 1/1 model study for space perception?. *Scientific Research,4*(9). 711-716.

Merriam-Webster. (2014). Retrieved October 22, 2014 from http://www.merriam-webster.com/

Rossi, M., Lent, T. (2006). Creating safe and healthy spaces: selecting materials that

support healing. *The Center of Health Design,* 1-27.

Sleegers, P., Moolenaar, N., Galetzka, M., Pruyn, A., Sarroukh, B., & van der Zande, B. (2013). Lighting affects students' concentration positively: Findings from three Dutch studies. *Lighting Research & Technology, 45*(2), 159-175. doi:10.1177/1477153512446099

Tofle, R., Schwarz, B., Yoon, S-Y., Royale, A. (2004). Color in healthcare environments. *Coalition for Health Environments Research,* 1-4.

Van Bommel, W. M., & Van Den Beld, G. J. (2004). Lighting for work: a review of visual and biological effects. *Lighting Research & Technology, 36*(4), 255-269. doi:10.1191/1365782804li122oa

White, M. D., Ancoli-Israel, S., & Wilson, R. R. (2013). Senior Living Environments: Evidence-Based Lighting Design Strategies. *Health Environments Research & Design Journal (HERD) (Vendome Group LLC), 7*(1), 60-78.

Postnova, S., Robinson, P. A., & Postnov, D. D. (2013). Adaptation to Shift Work: Physiologically Based Modeling of the Effects of Lighting and Shifts' Start Time. *Plos ONE, 8*(1), 1-13. doi:10.1371/journal.pone.0053379