Effects of Artificial Lighting in Dormitories on College Students' Physiology and Production

by

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ABSTRACT

The artificial lighting plays crucial role in the human life in the contemporary, globalized and highly complex world. Its influence on the physical and psychological health of the humans was studied by numerous reputable scholars from across the globe, however this study focuses on the impact of light on the college students living in the dormitories. The study seeks to find whether there is a correlation between light and health of the student, his/her performance, productivity, mood and feelings. The paper uses a relatively new housing near Arizona State University Tempe-campus as a case study as an attempt to substantiate the problem dimensions and suggest feasible solutions.

Basing on the available literature on the topic and the case study evaluation, the author determined the range of possible recommendations for the lighting professionals in the industry to maximally satisfy the needs of the students and make their stay and life in the dormitory comfortable and healthy experience. The relevant conclusions are made basing on the obtained results.

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CHAPTER 1

INTRODUCTION

1.1. Background of the Study and Statement of the Problem

The history and existence of humanity are inevitably connected with natural light. This natural resource has helped people to survive, being the key source of energy, the earth needed in forms of heat and illumination, to support live. As civilization advances, we have developed specific artificial light systems to be able to perform daily tasks at night or at places that lack natural light access. Artificial light has brought not only positive outcomes but also negative side effects (health-related psychological and physiological problems) for the people all over the world. The problem is particularly relevant to those who work or live in places that are designed to occupy tenants for a specific period (few years) especially in university settings and such as dormitories near universities campuses. The life quality of this kind of buildings is usually neglected. Students who live there may face some disorders because of the dependence on artificial light during the day due to the unawareness of the importance of light in the building. The improper orientations of the building, the wrongful placement of furniture, the irrelevant choice of lighting both in terms of quality and quantity, as well as numerous other related reasons may negatively affect one the students' lives. Among the key negative consequences for the students' health, it is important to mention the potential negative impacts on the students' state of mind, mood changes, disruption of the circadian cycle (problems with biological clock due to lack of synchronization of the internal body clock and solar day), and some other arguably negative impacts. It is believed that when people do not live according to the cycles of day and night, their biological clock functions at a different pace, causing a wide variety of problems, such as obesity, reduction in cognitive function,

and depression. Tackling the above-mentioned problems is costly and complicated. Thus, it is better to avoid these problems than to treat them.

Where people live defines the quality of their life and general well-being. Dormitories, being the home away from home for university students, need to be a comfortable and reliable place for living during the years of study, and the lighting solutions play a crucial part in it. It is important not only for the students, but also for the university authorities, as optimal choice of artificial light can significantly decrease the maintenance and operation costs (for instance, energy efficient and long-lasting LED fixtures and occupancy sensor technologies are perfect for the dormitories, as they help to reduce costs and increase efficiency). In other words, the lighting in the dormitories should be very versatile and serve multiple purposes (Acuity Brands Lighting, 2017). However, it is more important to have a lighting system that deliver the visual need while minimizing the non-visual effects of the light. For instance, light with different wavelength (different colors) may provide arguably equally visual outcomes, but the biological response for these lights are diverse.

Students are among the category that suffers the most from the improper use of artificial light, as they spend most of their spare and study time in their rooms. Students live in dormitories are among most vulnerable category of the population, as usually, they should adapt to the existing living and lighting conditions, instead of adapting the living and lighting conditions to their needs and requirements. To overcome such a situation, the lighting designers' role becomes especially important, as they define not only the quality of the building and its comfort but also the state of physical and psychological health of the future inhabitants (in this case, students). With more research of how we can benefit the most from artificial lighting while minimizing its negative

impacts as possible, it is necessary to pay attention to this problem, to re-evaluate it, and to develop the new approach and strategy to lighting in the communal buildings.

Several Universities are working to assure the best life quality of their students, and the businesses in the United States and all over the world are expected to adjust to the changing and rising needs of students. This approach would allow reaching more pleasant living and studying environment, helping the students to feel better and to increase the quality of life, by decreasing the key healthcare problem risks (Holophane, 2009). This thesis will examine best practices by looking at existing bibliography and built examples through the world. This research is aimed to shed the lights on the theoretical and practical implications of lighting in the students' health and well-being.

1.2. Theoretical and Practical Importance of the Research

The study of the effect of lighting on human beings and in biological systems in general is always associated with difficulties due to the extreme complexity these systems have. For example, Human beings skin absorbs solar ultraviolet B photons to produce Vitamin D precursors which is essential for bone health and prevention of autoimmune diseases (Holick, 2004). This effect of sunlight in this is initially correlated with the sunlight intensity until the intensity reaches a saturated level where the skin couldn't utilize the excessive energy. On the other hand, the circadian rhythm of people has been proven to be affected by the seasonality (light-dark daily cycle) where in Spring people usually have a delay at Dim light melatonin onset (DLMO) by an average of 20 minute compared to winter (Figueiro and Rea , 2010). The effect of the circadian rhythm is believed to be as a result light environmental signals that are captured by the eye and converted into a specific molecule that is ultimately regulate the expression of specific genes.

There is an agreement among scientists that the sunlight in the morning helps advancing the circadian clock which reduces the risk of delayed sleep phase disorder (DSPD) and the exposure of light during the night might have an impact on circadian rhythms disruption and delayed sleep patterns (Sharkey et al, 2011). While the focus of traditional architectural lighting design is to improve the visibility, safety, color rendering and, energy cost the appearance of the space (Figueiro et al, 2016), there is little attention is given to lighting characteristics that affect the circadian systems which affect our life physically and physiologically. In this study, we are only investigating the current practices in the universities dormitories and their effect magnitude on the students' physiology and production. Practices such as the size of windows, room's orientation, floor level, interior finishes, light sources, fixture type, race and gender will be evaluated to identify their level of influence on the students' health and well-beings.

The goal of this research is to create work with high theoretical applicability, serving as a good source of information for architectural and medical students, and professionals. The analysis of information presented in this study can be beneficial for the architects and lighting designers and archtictues when designing dormitories.

1.3. Goal and Objectives of the Research

The main goal of this research is to study the effects of lighting in dormitories on college students' physiology and productivity.

The main objectives of the research are the following:

- to analyze and improve the problems related to the visual comfort of the students that live in dormitories;

- to develop and investigate the possible lighting solutions for improving the quality of life of the students in the dormitories;
- to identify the source of variance

All in all, the above-mentioned objectives will help to realize the up-to-date and useful research that would have high theoretical and practical importance for the nowadays world.

1.4. Limitations of the Study

This study focuses only on how lighting effects student living on dormitories, not from architectural lighting design perspectives but as a tool that affects the human body in many ways. It is also important to mention that despite the general light standards and regulations, the perception and understanding of light are relatively subjective. While the physiological and physical needs vary among students, standards and regulations should be designed to fulfill people needs whenever it is feasible. The limitation of this study is based on the theoretical and practical subjectivity of the issue. The paper covers only the scholarly, objective and qualitative sources (peer-reviewed journal articles, academic websites, textbooks), written by professional and distinguished national and foreign scientists.

CHAPTER 2

LITERATURE REVIEW

Due to the fact that the topic of this research is large in scope, it was divided into three following sub-topics: (1) the effects of natural and artificial lights on people's health, physiology, and productivity; (2) an overview of the use of natural light and artificial light in the buildings; (3) the effect of artificial lighting in dormitories on students' physiology and productivity. Each of them will be further analyzed and evaluated in detail and with the range of relevant examples.

The main goal of this literature review is to demonstrate that the long-term exposure to artificial light can have the negative impact on the human in general and the students (as most of the dormitories have limited access to the sources of the natural light, and students often need to use artificial lighting even during the day), on the contrary to natural daylight that has a large positive effect on the person's performance, productivity, health and general well-being. Attention in this literature review is paid to the human circadian rhythm and the artificial light's impact on it. In fact, there are three major components in the human circadian system, an internal oscillator, external oscillators (for example, light-dark cycle between day and night), and melatonin hormone (Anjali, 2006). Overall, the researchers found out that people who study/work in the places with steady intensive lighting are more prone to the development of different psychological problems and have lower general productivity.

2.1. The Effects of Light on People's Health, Physiology, and Productivity

The issue of the harmful effect of artificial lighting was overviewed in detail by Chepesiuk (2009) in his research study. In particular, he stressed that significant over-illumination of the street causes the growth of light pollution (especially in the cities). In its turn, it negatively influences

both human and wild-life well-being and health. The author remarked that the large usage of artificial light became a health hazard in nowadays conditions, as it directly influences the life cycle and can disrupt humans' circadian rhythm (Chepesiuk, 2009). On the various examples from flora and fauna, the author overviewed the possible risks and threats from the artificial light. Moreover, the author also explained the possible effects of artificial lighting on human health, from the hormone production and cell regulation to the development of the breast cancer, due to the disruption of circadian and neuro-endocrine physiology, which stimulate the tumor growth in the long-term perspective (Chepesiuk, 2009). Furthermore, the number of reliable studies analyzed by Chepesiuk showed that artificial light at night can cause the development of insomnia, depression, obesity, and cardiovascular disease, due to the disruption of the circadian clock (Chepesiuk, 2009). The author stressed that most of the above-mentioned problems can be explained by the damage of the human' biological clocks and the insufficient secretion of the important hormone melatonin (that is mainly secreted at night). Thus, Chepesiuk stressed that it is very important to pay more attention to the issue of the artificial light and light pollution to minimize its negative impact on human health. The study by Stevens (2006) complements in many ways the research of Chepesiuk. The scholar evaluated the influence of the artificial light on the health of people. He found out that sun-free environment and active usage of artificial light can cause circadian disruption that in its turn, the damages in the melatonin production. The experiments on the animals showed that the lack of melatonin in the body can cause the development of various severe diseases, for instance, the breast cancer (Stevens, 2006). Moreover, the author stressed that the exogenous administration of melatonin will be harmful to the health and can cause even more serious circadian rhythm disruption. Thus, the researcher strongly

suggested maintaining a solar day-aligned circadian rhythm and following the rule of "a bright day and a dark night". This information was also proved by other research project conducted by Stevens, et al. (2007), where the scholars analyzed and overviewed the effect of the artificial light on the health of the people. The academics found out and concluded that the disruption of the circadian circle damages the physiologic and metabolic processes in the human body. To prove this statement Stevens et al. have made the laboratory experiments on mice, and tested the impact of the mutation of circadian clock on cancer cells growth. They found out that artificial light has a harmful effect on the circadian rhythms that are very important for maintaining the normal state of health. Furthermore, the authors stressed that even though the light is one of the most important reasons for the disruption of the circadian rhythms, there are several other reasons, as alcohol consumption, constant stresses, and irregular meals.

Bommel and Beld (2006) also analyzed the biological and visual effects of the artificial light. Their research is based on the analysis of the three photoreceptors in the human's eye. The scholars stressed that "the effects of good lighting extend much further than visual effects only: the biological effects mean that good lighting has a positive influence on health, well-being, alertness, and even on sleep quality (Bommel and Beld, 2006). Thus, the artificial light quality should be good enough to guarantee efficient visual performance. As well, lighting has a huge impact on the atmosphere and the visual impression of the surrounding space. Thus, it is very important to design properly the artificial lighting and to combine it with the daylight, as these lights will contribute to the person's mood and motivation to work. Also, the authors described in details the lighting requirements for the different types of work that students usually complete

(typing, reading, copying, technical drawing, etc.). Finally, the authors put significant attention to the connection between light and the human's biological clock and body rhythms.

Cho, et al. (2015) in their research study analyzed the possible harmful effects (for example, circadian phase disruption, breast cancer, and sleep disorders) of the artificial light at night (ALAN). They reviewed many reliable researches and articles (in total 85 articles) that covered the issue of the effect of ALAN on the human's well-being. They found out that outdoor ALAN increases the risk for the development of breast cancer. As well, they found out the confirmation to the fact that artificial light can provide a negative effect on the nighttime melatonin secretion, and to increase person's alertness and sleep onset latency (Cho, et al., 2015). Moreover, the author stressed that ALAN significantly influences the human's psychological, cardio-vascular and metabolic functions, due to the development of the circadian phase disruption. Overall, the authors stated that the artificial lighting is harmful to the human health and remarked that negative effect of the artificial light depends not only on its intensity but also on the type of the light and the wavelength.

Similar research was completed by Touitou and colleagues (2017), who also proved that ALAN caused a disruption of the circadian system. They found out that people with a disrupted circadian rhythm are more prone to the development of various illnesses (for example, obesity, mood disorders, diabetes, cardiovascular risks, and age-related macular degeneration, psychological stresses, depression, etc.). Furthermore, they found out that women, who regularly work at night, have up to 100% higher incidence of breast cancer (Touitou, Y., Reinberg, and Touitou, D, 2017). The researchers stressed that people, who have shift and/night work usually sleep less than people with the standard work schedule and have the disrupted circadian time

structure. The International Agency for Research on Cancer (IARC) even placed "shift work that involves circadian disruption" in special group 2A "probable carcinogens to humans", as the reasons that can cause the development of cancer (Touitou, Y., Reinberg, and Touitou, D, 2017). Moreover, similarly to Cho, et al., they overviewed the importance of melatonin for the human body and the influence of ALAN on melatonin secretion in the long-term run.

Küller (2002) in his review discussed and overviewed the influence of artificial light on humans' circadian rhythms. He stressed that disruption of the circadian rhythms is very harmful to the health and negatively influences a person's health and performance during the day. Thus, people, who have shift work or work in the buildings without access to the natural light can seriously damage their psychological health. The author stressed that in these environments, it is crucially important to design special very bright white light and to try to "develop artificial lighting systems, which stimulate the daytime variation of natural daylight" (Küller, 2002). Also, the author paid considerable attention to the seasonal affective disorder that is caused by the deviations from the person's normal circadian rhythm. In his study, Küller recommended applying special light therapy to remove the major symptoms of the disease and to use different levels of illumination in various seasons.

The important findings on the theme of the sleep and circadian disturbance on hormones and metabolism were analyzed in the research by Kim, Jeong, and Hong (2015). They analyzed and overviewed in their study the importance of sleep for the health of the people. They remarked that during sleep hours (especially during sunset), the growth of hormone levels significantly increased and humans' metabolic processes improved. The researchers remarked that hormones (melatonin, ghrelin, leptin, and cortisol) play an important role in glucose and lipid homeostasis,

and their efficiency is directly associated with sleep and circadian rhythmicity of the person. At the same time, the authors stressed that often sleep disturbances (deprivation) (due to the light, noise, alarm, etc.) have a negative effect on the person's well-being and health. Unfortunately, many people underestimate the negative impact of artificial light, circadian cycle disruptions and the health-related consequences related to it. People with low-quality sleep have significantly larger chances of the development of diabetes, obesity, lipid homeostasis, deregulation of leptin and ghrelin. Even more, people with the insufficient sleep can have clock gene rhythm loss and the develop the severe metabolic syndrome, as well as many other health-related problems.

Cajochen, et al. (2005), similarly to other above-mentioned authors analyzed in the research study the effect of the short wavelength light on the human's secretion of melatonin, development of alertness, the thermoregulation, and heart rate. They stressed that every person, regardless of age, gender, or race has his/her own "human phase-response curve to light" and thus "the effects of light depend on the circadian phase at which light is administered: light was given after the core body temperature (CBT) nadir advances the phase of circadian rhythms, whereas light given before the CBT nadir induces delays" (Cajochen, et al., 2015). Thus, accepting the time of the light exposure, the authors stressed that the light wavelength is very important. They stressed that the alerting response (reduced sleepiness in the evening) is more effective with the short wavelength light (460 nm) in contrast to the longer wavelength light (550 nm). They came to similar results in terms of the person's thermoregulation and heart rate too. Also, they proved the fact that suppression of melatonin is significantly better under the influence of the short wavelength light. Moreover, their results showed that short wavelength light's effect became visible in the significantly shorter time comparing to the white polychromatic light.

Also, it is important to mention the study by Mariana Figueiro (2017). In her research, she stated that it is necessary to realize new studies or to make more investigations in the existing studies to find the clear connection between light at night and the insufficient secretion of melatonin, circadian disruption, and the possible risks of development of different diseases. The researcher proved that circadian rhythm can be significantly damaged due to the irregular light-dark patterns and light exposures at the wrong circadian phase (Figueiro, 2017). However, it is necessary to mention that the results received from the experiments on animals can be inaccurate due to the different perception and sensitivity to light of different species. In these conditions, Figueiro stated that it is necessary to conduct more studies to check these findings and to pay additional attention to the electrical response of the humans' retina to the influence of light.

2.2. The Use of Natural and Artificial Light in the Buildings

International Living Future Institute's team conducted a large 7-years research project with an active partnership of famous scientists, designers, architects, and medical experts to prepare a reliable book of the best practices in design and construction to maintain human well-being, comfort, and health. The authors divided the book into 7 major categories: air, water, nourishment, light, fitness, comfort and mind (International Living Future Institute, 2014). The researchers identified more than 100 different aspects to check the performance metrics of the building. The authors stressed that the buildings with "WELL Certified™" mark have interior spaces that improve the mood, sleep patterns, nutrition, fitness, and performance of people, who live or work there. Talking about the light, the authors remarked that it is important to give the priority to the natural light and to limit the usage of artificial lighting. As well, they recommended using special shading devices on the windows larger than 0.55 m^2 to minimize negative effects from the natural

light (International Living Future Institute, 2014). This automated shading and dimming controls aimed to control the sunlight and to reduce the possible glare at workstations. Furthermore, they prepared special guidance that helps to maximize the effect of the daylight. The authors stressed that access to the daylight will be very beneficial for humans' health and will improve the mood and general wellbeing of the people.

As well, researchers Danny Li and Joseph Lam (2001) investigated the importance of the lighting dimming control mechanisms to regulate the amount of light in the offices. They found out that proper day-lighting schemes can be a useful and efficient strategy to minimize energy consumption of the whole building. They conducted a large field measurement on day-lighting of the office building (fully air-conditioned) in Hong Kong. During their research project, they analyzed the energy consumption of the building and paid additional attention to the "fluorescent luminaires, indoor illuminance levels, and the room parameters affecting daylighting designs" (Li and Lam, 2001). Actually, the scholars proved the fact that it is possible to reduce the electrical demand of the building and to design more environmental friendly constructions, using more natural light instead of artificial light systems. According to the received data, it is possible to get almost 500 Lux to the office room, using only the natural light from both the northern and southern sides. In its turn, electricity consumption will be reduced up to 50% for artificial lighting, thanks to the proper design of the size and amount of the windows in the building, and thus, artificial light will produce less heat and the air condition system will consume less electricity too.

Hwang and Kim (2011) analyzed and evaluated the effects of artificial indoor lighting on the people's eye health and their visual comfort, basing on the example of the well-planned building (Samsung Corporation Headquarter in Korea). The study lasted for almost 1.5 years and

during that time, the researchers surveyed 2744 healthy employees at Samsung Corporation concerning the lighting environment in the offices. This building was built according to the latest technologies and it corresponds to the highest standards and requirements of Korea's Green Building Council. The building has well-planned screen-type shading devices that control automatically the amount of natural lighting depending on the season and time of the day. The researchers found out that well-organized screen-type shading devices help to minimize direct sunlight and to reduce glare. According to the survey data, the above-mentioned progressive and modern light systems and technologies impact positively employees' psychological health and productivity (Hwang and Kim, 2011). At the same time, most of the respondents remarked that the company should improve indoor lighting in the offices. Thus, the authors recommended paying more attention to the design of the indoor artificial lighting system and possible health hazards from it. Overall, this research study showed that amount of the daylight in the building directly depends on the location of the building and special devices that control it. These findings were also supported by Anjali (2006), who also overviewed the effect of windows in the workplace and the importance of daylight for employees and their satisfaction with the office environment. According to the survey data, there are following reasons of the daylight benefits compared to artificial light "psychological comfort, office appearance and pleasantness, general health, visual health, color appearance of people and furnishings, work performance, and jobs requiring fine observation (Anjali, 2006)". As well, Professor Anjali Joseph (2006) paid significant attention to the issue of the influence of daylight and artificial light on human health both in the short-term and in the long-term perspectives. In his research study, he identified the main ways by which artificial and natural light influence human health and performance. He supported his study with a large

scope of reliable and peer-reviewed articles and researches on the theme of the light influence on the healthcare settings. The author found out that light plays a very important role in the human's well-being and can affect the person's mood, perception, and circadian rhythms. The research results also showed that higher light levels helped to reduce depression and to improve the performance of the people in their daily tasks (Anjali, 2006). Furthermore, the light directly influences the human's circadian system and can influence it either positively or negatively, depending on the type and duration of the light. Overall, the researcher described the positive effect of the daylight during the treatment process in the hospitals. His and other researchers' findings stated that the daylight helps to ease the pain and to treat depression among the patients.

Sheikh and Ghalehnovi (2015) in their research work raised the importance of the utilization of daylight to reduce energy consumption and to reduce eye damages from artificial lighting. They overviewed the history of utilization of the natural light in Iranian architecture and described the major benefits of natural light for the people and the environment. The authors paid significant attention to the elements related to natural light in traditional architecture in Iran and provided several useful and thought-provoking examples of their active utilization. In addition, they analyzed and examined the effectiveness of sun pipes or solar channel system and special mirror conductors in the interior design of the building. They stressed that thanks to their effectiveness, they can successfully replace the artificial light in many public places (hospitals, universities, dormitories, etc.). Their utilization is especially relevant in the countries with a large amount of sunlight, like Iran.

Galasiu and Veitch (2006) also conducted a large and detailed peer-reviewed analysis on the theme of the use of sunlight in offices. In addition, the authors evaluated the occupants'

satisfaction of artificial electric lighting and window shading controls there. The researchers found out that most of the surveyed people prefer daylight, however, talking about the artificial lighting, the researchers found out the wide distribution between answers in the context of the most appropriate level of the artificial illuminance in the offices. In fact, the daylight was preferred by the people, due to its positive physiological and psychological impact on their general well-being and productivity. Among the important findings of this research, it is necessary to mention that project participants' preferences depended on several factors, such as visual comfort and glare, daylight availability, number of mullions and window size, windows' orientation, and, the room's lighting quality, but the person "acts only when the visual discomfort has reached an unacceptable level" (Galasiu and Veitch, 2016). Overall, the authors stressed that the most appropriate light levels for people who work on computers in the offices are between100 - 300 lux.

Iversen, Nielsen, and Svendsen (2008) investigated the satisfaction with the office's visual environment in a specially designed room, equipped with energy efficient artificial lighting and solar shading systems (rotated glass lamellas). In fact, the newly developed shading system consists of specially designed "transparent lamellas made of solar control glass with high reflectance coating" (Iversen, Nielsen, and Svendsen, 2008). These shading systems were aimed to reduce the sun glare and illuminance level in the front of the office on sunny days with clear sky and to increase the level of illuminance in the back of the office on days with cloudy sky. Also, the authors remarked that the lighting control systems such as daylight-linked dimming and occupancy sensors reduce the electricity consumption for lighting" (Iversen, Nielsen, and Svendsen, 2008). As well, the aim of this project was to analyze and evaluate the person's individual satisfaction with the visual environment by having individual control of light in the

room. For example, Newsham, et al. in their research study found out that “lighting control was associated with significant improvements in mood, satisfaction, self-assessed productivity and comfort” (Iversen, Nielsen, and Svendsen, 2008). At the same time, in this research project, most of the surveyed participants were bothered due to the restricted view from the window by the lamellas and did not have visible changes in the mood. However, it is necessary to mention that all the participants in the experiment were satisfied with the lighting conditions in their room.

Negrao (2013) in her work analyzed the major methods of the utilization of the artificial light in the design of the building. She analyzed the main principles of the utilization of artificial light in space and provided numerous examples of different types of lamps and their characteristics. She stressed that all the lamps have their own light intensity, color temperature, and magnitude. All these factors create their own patterns and different perception by the people. Thus, she overviewed several examples of different types of lighting of the space and made necessary conclusions. She stressed that depending on the source of light, its intensity, and number of luminaries the total expenditures for electricity, eyestrain (due to the shades and glare), and the general illumination of the room significantly vary. Moreover, she remarked that it is better to use colder temperatures (from 4000 º K) for working places, while warmer temperatures are better to use in place for the relaxation (Negrao, 2013). Overall, the author stated that light is a very important aspect of the design and it directly influences the person’s productivity, well-being, and the desire to visit a certain place.

Knez and Enmarker (1998) evaluated the importance of artificial light for the employees’ mood and cognitive skills in the office. They performed two laboratory lighting-exposure experiments with three main parameters of the artificial light: color temperature, illuminance, and

color rendering index. They divided 80 participants from the college of health sciences into two groups with the equal number of male and female participants. The received results showed that the artificial light does not have a significant influence on the performance of cognitive tasks by the people. At the same time, the researchers found out the connection between gender, color temperature (3000K and 4000K) and the mood of the person. The female participants showed other perception of the light compared to men, due to their more emotional psychology. Women felt the light "more glaring, more intense, less dim, and less soft" (Knez and Enmarker, 1998). Also, both genders have a different perception of the color temperature. The best positive mood for male and female audience was achieved with 4000K and 3000K light respectively.

Abbas (2006) in his research study analyzed the emotional effects of color and lighting on the physiological and psychological well-being of the people. He stressed that color and lighting conditions have a direct effect on the performance and emotions of people. He conducted his research study on the example of 15 people, who were exposed to different color and intensity lights conditions. The author found out that participants' heart rate and skin conductance were significantly influenced due to change in the intensity and color of lights (Abbas, 2006). The researcher also found out that natural light causes a pleasant effect for almost 73% of the participants, while the red color light caused mainly unpleasant emotions (for approximately 20-26% participants of the study) (Abbas, 2006). Overall, the researcher stressed that designers and architects should pay more attention to the lighting systems and give priority to the individual planning of the lights in the interior.

Also, the researchers Begemann, Van den Beld, and Tenner (1997) paid significant attention to the behavior of employees and the influence of daylight and artificial light on it. The

study clearly showed that people who work in standard window zone offices during daytime working hours prefer to use daylight instead of indoor lighting systems. Furthermore, Begeman and colleagues found out that the lack of daylight (during the night shifts or the work in the early-morning time) can be harmful to the employees' health. Also, the results of the study showed that it is very important for employees to follow their biological lighting needs comparing to their visual needs (Begemann, Van den Beld, and Tenner, 1997). In particular, the researchers remarked that indoor lighting is not sufficient source for the biological stimulation and can cause the lack of 'light vitamin' (Begemann, Van den Beld, and Tenner, 1997). Also, to support their point of view, the authors used statistical data that proved that access to the daylight helps to improve circadian rhythms, to reduce depression and to alleviate pain among the surveyed patients. At the same time, the use of artificial lighting led to the development of health and performance problems ('ill-lighting syndrome'). Thus, the researchers stated that it is very important to design healthy indoor lighting systems to improve the general well-being of the building occupants.

Oh, Yang, and Do (2014) put their attention to the optimization of artificial lighting. In particular, they analyzed the impact utilization of the white light-emitting diodes for healthy and smart lighting of the room. They analyzed four types of white LEDs (long-wavelength pass dichroic filter (LPDF)-capped, phosphor-converted red, amber and green LEDs (pc-LEDs) and a blue LED) and their effect on the circadian rhythm and the production of melatonin hormone (Oh, Yang, and Do, 2014). They found out that the standard LED artificial lighting that is the most appropriate for vision, actually is not good for the circadian system. Thus, they overviewed the possible variations of the multi-chip white LEDs combination. After the series of the experiments, the authors remarked that "the distinct color control of LEDs combined with a narrow InGaN blue

LED and three wide-band LPDF-capped green, amber, red pc-LEDs" can provide the most effective combination of visual performance, high color qualities, and the positive influence on the circadian rhythms (Oh, Yang, and Do, 2014).

Patania, Gagliano, Nocera, Galesi, and Caserta (2011) also overviewed the usage of dynamic artificial light in indoor design and its biological effect on the people in the long-term perspective. They stressed the importance of light for the humans' health and well-being (body temperature, alertness, etc.). As well, the authors paid attention to the important hormones (melatonin and cortisol) and the "biological clock" of people. Through the study, they paid attention to the "dynamic lighting" – the "advanced technique that tries to bring the dynamic of daylight in indoor environments with the aim of creating a stimulating "natural" light that may enhance people's sense of well-being" (Patania, et al., 2011). Using all the advantages of the dynamic artificial light, people can organize their own space and atmosphere, according to their current mood, needs, and tasks. The authors stressed that the creation of the appropriate light will help to improve a person's performance and motivation. For example, the authors remarked that the higher illuminance with the colder light will be helpful in the morning and after the post-lunch dip, while low illuminance with a warm color temperature will be helpful in the evening. Overall, the author stressed that it is recommended to follow the daylight circle, "It changes throughout the day, affecting our emotions, moods, perception and performance" (Patania, et al., 2011).

Similar findings were also supported by Clark and Brennan (2016), who analyzed six major principles in design to support the circadian health of the people. They stressed that daylight is essential for humans, as "we woke to a reddish sunrise, spent the day in the blueish light, with the peak intensity at midday, and fell asleep to the reddish sunset or the warm red glow of firelight"

(Clark and Brennan, 2016). They stressed that circadian rhythms are individual for every person but have a tendency to be repeated daily at the same time. Thus, the light is one of the most important ways to follow and regulate it. Thus, they recommended following the next principles in the design, (1) to use a blue light and warm light at strategic times, as humans' eyes' ganglion cells have the best sensitivity to the blueish light. In its turn, the blueish light has an alerting effect and it helps to manage a person's body clock; (2) to use artificial light to follow day/night circle, as the correct light stimulus received in morning time will provide more energy during the day, while the wrong light exposure in the evening can postpone the person's bedtime. As a result, the person will sleep less and will feel fatigue and less productivity during the day; (3) to learn the habits and needs of the person (for example, working schedule); (4) to maximize daylight exposure, as the natural light has all the necessary features to impact positively person's circadian rhythm; (5) to utilize the spectral content of the light, as it will help to develop various lighting solutions to provide the most appropriate light in the room; (6) to pay attention to the materials, as the materials and their design can change the intensity and the color of the light.

Handley (2009) investigated the influence of the artificial light in the offices at BAE Systems in New Malden. He conducted a survey of 50 people, who work in different parts of the offices. The main aim of the survey was to check the lighting efficiency of the office light system and its impact on the psychological well-being of the colleagues (visual acuity, mood, alertness, fatigue, eye strain, headaches, performance, productivity, etc.). As well, he compared the two main types of artificial light standard halophosphate 18W lamps and new "Daylight Deluxe" lamps. Most of the test participants indicated that the new white lighting has a positive influence on the mood, eye strain, and visual acuity. As well, most of the surveyed people felt less fatigue

and their alertness at work was improved. Furthermore, responders noticed in their feedbacks that "everything is sharper and crisper" and "it's brighter inside compared to the yellow gloomy lights" (Handley, 2009). The new white light was especially helpful for the people who worked away from the windows, and thus, without the natural light access. Overall, the author stressed that the new "Daylight Deluxe" lamps received only positive feedbacks and he recommended using them in other offices as well.

Gabel, et al. (2013) in their research analyzed the effect of light exposure on human physiology, mood, and performance. They stressed that artificial light's wavelength, its intensity, and duration directly influences a person's psychology and performance. For example, they remarked that bright white light sources are very effective in the therapeutic countermeasure against the disruption of the circadian rhythm and helps to improve person's mood stability, well-being, and vitality (Gabel, et al., 2013). At the same time, blue-enriched moderate intensity light can help to increase visual comfort and improve person's alertness, sleepiness, and psychological well-being in the working environment. Moreover, the researchers made the main accent on the role of morning light exposure on the person's mood, and behavior during the day. After the analysis of the laboratory results, which they received from 17 participants, the researchers found out that "a dawn-simulating light starting 30 min before and ending 20 min after scheduled wake-up time" is the most effective light option for strengthening cognitive performance and improvement of the well-being of the person.

2.3. Overview of the effect of artificial lighting in dormitories on students' physiology and productivity

Najafabadi (2015) managed to prove through her research that daylight has a positive influence on the students' performance on the example of the three students' dormitories of Eastern Mediterranean University, located in Cyprus. The scholar stressed that daylight was the major source of light up to 1940s, while in the short span artificial lighting supplemented the natural light in the buildings. She mentioned that in hot countries a lot of windows in the dormitories cause several negative problems, as solar glare, higher temperatures inside the buildings, and harmful luminance reflections. Thus, she stressed that it is very important to pay significant attention to the dormitories location and their exterior and interior design. The largest part of the surveyed students from the Eastern Mediterranean University campus was dissatisfied with the influence of natural light, as it significantly decreases their performance during the day and increases tiredness due to the not well-planned building orientation, and absence of the necessary shading devices (Najafabadi, 2015). At the same time, the research results demonstrated that more than 70% of the total number of students prefers daylight rather than artificial lighting.

Chen (2017) in the research paper analyzed and overviewed the thermal and humid conditions, acoustic and luminous environments in Baoding's College dormitories (China). She stressed that dormitories indoor environment directly influences the academic achievements and the rest of the students. She surveyed 41 students from the seven dormitories to check their satisfaction with the indoor environment. Talking about the artificial light, the author found out that most of the students think the brightness in the dormitory is acceptable and that it corresponds to their personal needs. At the same time, almost 36% of students answered that it is too dark in

their rooms (Chen, 2017). The author explained this result with the fact that the rooms of these students are located on the shady side of the building and thus, they receive less sunlight compared to the rooms on the sunny side. Also, the author found out that most of the students prefer to use natural light, rather than artificial light, mainly due to the energy-saving policy.

Deroisy and Deneyer (2017) in their recent study analyzed the importance of daylight for human health and paid special attention to the new European standard for daylight in buildings. This new standard was aimed to create comfortable daylight areas and to set important requirements for the architects and designers. According to this standard, architects should take into consideration four important daylight indicators, from the daylight provision to protect against glare and exposure to direct sunlight to visibility level in the room. The minimum requirement for daylight for the working space is 300 lux, while for other parts of the room is 100 Lux for at minimum 50% of the daylight hours (Deroisy and Deneyer, 2017). The authors stressed that it is crucially important to create daylight conditions that are very similar to outdoor conditions, as people spend more and more time in the buildings. As well, the authors remarked that access to daylight is very important for the dormitories, patient rooms in the hospitals, flats, and others similar places, where the people are staying for a long period of time.

Mehrdad et al. (2013) in their research study examined the intensity of the artificial light in study halls of dormitories of Isfahan University of Medical Sciences (Iran). They stressed that most of the students spend a lot of time in study saloons, thus the design of appropriate artificial light is very important in these places. The authors remarked that with well-planned light, the students' eye fatigue will be reduced, and hence, performance and productivity will grow. During this research project, they analyzed 24 study saloons and measured the illumination intensity there

with appropriate equipment. They found out that the average intensity of daylight was more than 300 Lux only in 9 study halls, while, the intensity of artificial light was more than 300 Lux only in two study areas, and the intensity of both daylight and artificial illumination was achieved in 21 study halls (Mehrdad, et al., 2013). Furthermore, they stressed that the average ratio of windows in male and female dormitories is not equal and is 0.14 and 0.12 respectively. Overall, they stressed that it is necessary to improve the artificial light intensity in study halls and to design new sources of natural light there.

Moradi at al. (2016) in their research paper also paid their attention to the luminance intensity and sound volume in students' dormitories of Kermanshah University of Medical Sciences in Iran. They stressed that well-developed artificial light is very important for the students' health and productivity, especially in the long-term perspective. They stressed that in case of poor light, even the students with healthy eyes in a short time can feel diverse problems, from the eyestrain and impaired vision to a headache and considerable physical fatigue. As well, it was proved that the poor artificial light contributes to the development of the various serious psychological diseases. They performed their project in two male dormitories of Kermanshah University of Medical Science (Moradi, et al., 2016). They investigated almost 120 light stations and 105 sound stations in students' rooms and 2 stations in study saloons. They found out that the illuminance is not equal in every room and in the majority of cases, it does not correspondent to the Iranian norms and standards. In addition, the research results showed that 31 light stations were in the standard range between 150 to 300 lux, while 15 stations were lower than 150 lux, and 563 stations were higher than 300 Lux (Moradi, et al., 2016). The researchers stressed that due to the inappropriate illuminance the students' physiology and productivity are negatively affected.

Overall, they recommended paying more attention to the illuminance design in dormitories rooms, regular cleaning of lamps and switching off the burned lamps in the dormitories.

Wilson (2013) analyzed the carbon footprint from the usage of artificial light on the example of two Cornell University (United States) undergraduate student dormitories. She stressed that it is necessary to develop pro-environmental behavior from the early beginning and to design the dormitories that would motivate students to reduce their carbon footprint and implement green initiatives. Through the project, she analyzed 10 students (5 males and 5 females) from two dormitories. One of the dormitories was built according to the Leadership in Energy Environmental Design Green Building Rating System (LEED), while another dormitory was non-LEED certified building. In fact, LEED buildings should consume on average 10-39% less energy compared to the non-LEED buildings. The LEED dormitory has well-planned artificial lighting, as it was designed according to the LEED energy prerequisite guidelines, and the numerous signatures on the theme of pro-environmental behavior and its importance. Overall, the author found out that the students in the LEED-certified dormitories consumed less energy comparing to the students, who lived in non-LEED certified dormitories. However, the author remarked that the effectiveness of the green building design of the dormitories can be achieved only with the environmentally conscious students and their proper behavior.

Morgan (2012) analyzed how the design of dormitories influences the behavior of the students, who lived there. As an example, for his project, he took two recently built dormitories of the Pomona College in California (United States). These dormitories were built according to the LEED-Gold-standards to influence residents' behavior and reduce the harmful effect on the surrounding environment. The architects paid significant attention to the importance of sunlight

and thus these two dormitories were planned with the large windows on the outside walls. The research showed that “for many occupants one or two windows allow sufficient light to prevent the need to turn on their overhead light at least part of the time” (Morgan, 2012). Furthermore, to reduce the energy consumption, all the artificial lighting in the public lounges, kitchens, and study rooms have automatic day-lighting controls. These controls help to regulate brightness in the room, based on the amount of sunlight. This prevents students’ from switching on unnecessary artificial lighting when the amount of the natural light is sufficient. Overall, the research project clearly showed that daylight is strongly preferred to artificial light by students, thus it is necessary to pay more attention to it with the planning of new dormitories, as well as during the renovation of the old buildings.

Hathaway and colleagues (1992) in the report overviewed a large 2-year study of the effects of artificial lighting systems on elementary school students' performance, vision, and health. As well, they described the possible psychological and physiological effects of light and color on the students. They analyzed four major light types used in the educational institution, cool white fluorescent, high-pressure sodium vapor, full spectrum fluorescent and full spectrum fluorescent with ultraviolet light supplements. They discovered that type of the artificial light has a direct impact on the health and performance of the students, as students who studied under the ultraviolet light supplements had fewer cases of dental caries and better academic attendance and performance. As well, these students had greater gains in weight and height, compared to students from the other school. At the same time, students, who studied under the high-pressure sodium vapor lighting, had less visible results in personal growth in height. As well, their educational achievements were not so significant. Finally, the researchers overviewed major direct and indirect

biological, medical physiologic, pathologic, and therapeutic effects of light on the people in general and on the students in particular.

Song (2016) analyzed and overviewed the major ways to improve students' living conditions and to turn the dormitories into joyful and livable places. The author paid particular attention to the architecture of the dormitories and their interior. The scholar stressed that dormitories are practically a "second home" for the students, as they spend there a great part of their lives. The author analyzed in detail Unitec Student Village dormitories, their design, materials, color, textures, lighting, courtyard, and trees. He stressed that for the comfortable life, the dormitories should be spacious and have the sufficient amount of the natural light, as it is crucially sufficient for the good mood and feelings of the students. Also, he provided an extensive overview of Roger Walker's houses, as practically all his houses are aimed to bring happiness to the people who live there. Walker paid significant attention to the light and it became "another major element of his projects which show a striking contrast in lighting design. He uses light to express and represent the building's characteristics such as materials, textures, windows, walls and colors" (Song, 2016). Overall, the author stressed that the building of the students' dormitories under the new standards and requirements "will enhance the quality of student living, increase the happiness of their campus life, and change the existing negative impressions of student housing" (Song, 2016). The scholar also paid attention to numerous other important issues related to lighting in the buildings.

Jovanovic at al. (2014) in their study analyzed and measured the level of daylight in students' dormitories in Serbia. They stressed that the use of daylight is the most appropriate method to reduce energy consumption and dependence from the artificial light. Also, as the

majority of universities are state-funded institutions, the rational use of electricity is truly crucial for the university budget. Furthermore, the researchers remarked that daylight increases visual comfort and improves the mental and physical health of the students. These findings were also supported by the students, who shared their experiences and completed a survey in the frame of this project. The research results demonstrated that the students did not have the necessary access to the natural light, both in the south oriented rooms and in the north oriented rooms. Overall, the researchers found out that daylight is the most appropriate and preferable source of the light among the surveyed students. However, the amount of illuminance should be regulated also with the help of artificial light, as the rooms from the different sides of the building do not receive an equal amount of sunlight during the year.

"*College and university lighting guide*" (2009) prepared by the Holophane Company analyzed the different types of the artificial light for both indoor and outdoor usage, with particular attention to the needs of the students. In fact, Holophane is one of the leaders on the U.S. lighting marked that provides a wide range of lamps that correspond to the highest standards and requirements. Holophane's lamps provide superior visibility and great visual comfort for the people. Furthermore, Holophane lighting systems were developed and designed according to the highest and latest requirements developed by "The Illuminating Engineering Society of North America (IESNA). IESNA directly develops and controls lighting standards of various environments within the educational institutions and the students' campuses. The company works with the well-known American colleges and universities, like Georgetown University, Mississippi State University, University of Notre Dame, North Carolina State University, Southwest Texas State University, the College of William and Mary, and many others. For example, Holophane

series of the PrismGlo® luminaries are up to 40% more effective comparing to the standard incandescent and fluorescent lamps (Holophane, 2009). In particular, replacement of the 160 standard lamps in Lake Michigan College to 41 PrismGlo® luminaries allowed to reduce significantly the energy expenditures and to improve visibility (Holophane, 2009). All in all, it is necessary to mention that the use of high-quality artificial light can not only help to reduce the total energy cost, but also to improve the comfort and the general well-being of the students.

To conclude, it is important to state that this literature review demonstrated that the problem of artificial lighting of student's dormitory rooms really exists and really influences their health and productivity both in the short-term and in the long-term perspectives. After the careful analysis of the wide range of the reliable scholarly sources, it is possible to remark that artificial light, emitted by different types of lamps directly impacts human circadian rhythm, alertness, performance, and productivity during the day. Moreover, in certain cases, it can even lead to the development of breast cancer, obesity, and diabetes. Also, several recent studies proved that bright artificial light can be used both as ordinary light and for the therapeutic applications, such as depression, sleep disorders, treatment of the seasonal affective disorder, chronic fatigue, and many others. Moreover, as it is visible from the research studies provided above the artificial lighting can change natural processes, and cause the disruption of the melatonin production and damage the human's biological clock. In these conditions, it is important to remember that even though some consequences of such negative impact are reversible, many of them are irreversible. Thus, it is necessary not to underestimate the problem. Also, it is possible to make a conclusion basing on this literature review that almost all the people prefer the daylight compared to the artificial light.

Thus, it is very important to apply only high-quality lamps in the dormitories and to provide the proper access to the daylight in the students' dormitories rooms.

2.4. Overview of Current Dormitories Implementing Creative Lighting Solutions

2.4.1. The Lighting Solutions of the Likins Hall of the University of Arizona

The architecture of Likins Hall dormitory looks very functional and modern. The four to six-story dormitory was built in 2011. The designers made a significant effort to improve students' lives and they focused on the importance of sustainability and community. In particular, NAC Architecture remarked: "The architecture of Likins Hall represents a departure from the 'walled city' paradigm of earlier residences. It is a progressive live-learn community which outperforms all other campus buildings in energy-efficient design". Thus, there is a lot of public and recreational places, modern laundry and kitchen facilities, study rooms, etc. The designers paid particular attention to the important issue of the lighting design process. It is clearly visible, that the designers focused in detail on the natural light, as it has a lot of benefits for the students' health, productivity, and general well-being. The projects combined both well-planned and efficient sources of the natural light and the sources of the artificial light. The designers constructed a very well-planned building with the maximum possible sustainability within the budget of the project (Monrad Engineering, 2012). Monrad Engineering (2012) rightly remarked: "The project emphasizes daylighting as the principal daytime light source for nearly all spaces, and layered, high-performance lighting creates a warm, residential-like atmosphere for evening study and social activities". Talking about the artificial lighting, the designers decided to use both lighting power density of average 0.63 Watt/Square Feet and intelligent switching. Thanks to the

motion sensing systems and automatic controls in public and private areas, the dormitory has high standards of energy efficiency and less energy consumption rates.

Talking about the natural sources of the light it is necessary to remark the following aspects. First of all, it is important to note that Likins Hall was built with the close orientation on the principles of natural light sources domination in the architecture. As, it is visible from Figure 1, there are plenty of both large and small windows that directly cover the need in the daylight. Secondly, it is necessary to notice that the main lobby of Likins Hall has west-facing glass, which was shaded with a specially designed asymmetric metal trellis (see Figure 2). As well, there are several large windows that serve as a significant source of the natural light. Thus, thanks to the combination of the modern technologies and glass, the main lobby received an appropriate amount of the natural light during the day. Moreover, there is an amazing stained glass artwork that backlighted with LED (see Figure 3). It is not only a beautiful piece of art but also a perfect source of the light in the main lobby. Furthermore, the main lobby is decorated with large pendant luminaires (GE T8 Starcoat 3000K fluorescent lamps) and several small fluorescent downlights (GE CMH 39 watt) (see Figure 4) (Monrad Engineering, 2012).

Talking about the public and recreational area, it is important to state that they also have a very well-planned lighting scheme. There is a wisely-organized combination of the natural and artificial lights that absolutely satisfied the students' daily activities and needs. The application of casual furniture, wood decoration, and the warm light (in lounge area) significantly improve the level of comfort in the room (see Figure 5, Figure 6, and Figure 7). The researcher Ana Teresa Luís Negrão (2013) rightly remarked that light with a warm temperature is the best for the places for the relaxation. In addition, large windows allow students to have the possibility to relax, play,

and communicate in a very pleasant atmosphere. As it was stated above, the natural light significantly contributes to the general well-being and positive mood of the people. Finally, it is important to note the large windows in the bedrooms (see Figure 8). The designers used the large windows, as they provide the sufficient amount of light and prevent the need to turn the artificial light (that was proved by the data from the numerous studies conducted by famous and reliable researchers (for example, Morgan, 2012, Moradi, et al., 2016, Mehrdad, et al., 2013, and many others)). Chepesiuk (2009) and other researchers mentioned within this study found out a close relationship between the application of artificial light and lack of the natural light in the disruption of circadian and neuro-endocrine physiology that in their turn influence the development of the tumor growth in the future. Thus, the design of such large windows serves not only like an effective way to reduce energy consumption, but also to improve dormitory residence health and general well-being. As well, there are special shading devices on the windows to prevent possible negative effects from the sunlight (see Figure 8). This shading system helps to control the sunlight and to minimize the possible glare in the room. Furthermore, talking about the artificial light, it is necessary to mention that there are long motion light lamps that provide the necessary amount of light at evening and night (see Figure 9). As well, motion sensors help to develop pro-environmental behavior in the students' minds and to motivate them to reduce their carbon footprint. Thus, the effective following of the LEED requirements helped to reduce the total consumption of the energy and at the same time, not to make a negative footprint on the students' lives. Moreover, the designers applied special angular perforated shapes on the windows to increase interior light levels during the day (see Figure 10). As well, John Minnella, who led the construction of Likins Hall dormitory, remarked: "These metal grates are designed to shade the

windows when the sunlight intensity is at its greatest. These shade structures help keep the building cool while minimizing the use of extra electricity for air conditioning" (Wagner, 2011). In addition, to motivate students to reduce energy and water consumption, it was decided to put special 32-inch touchscreen monitor in the dining area that shows the entire current data on the amount of electricity and water consumed by the residents each day. The students can view the information in a clear graph that shows the daily consumption of energy and water in the dormitory (see Figure 11).

The lighting specialists created the favorable environment for the students, where they can study comfortably without the unnecessary distractions. When the student tries to work on a certain educational project, there is nothing worse than annoying distractions related to fluorescent lamps flickering or disturbance of the personnel that changes the burnt-out bulbs. To decrease the distractions, Likins Hall switched to LED light, as its longevity is 50 times more than the standard incandescent bulb.

As well, as a lot of the students spend their time in study saloons, it is very important to have a well-planned lighting system there. Talking about the Likins Hall dormitory, it is possible to state that the designers used appropriate artificial light and daylight sources in that area (see Figure 12). Also, the designers used light with the colder temperatures, as it is better for the working places and improve students' productivity (Negrao, 2013). The well-planned lighting source enhances the performance and productivity of students and reduces eye fatigue. Finally, hallways in the dormitory do not have natural light sources (see Figure 13). At the same, time the designers used bright white light that simulates the natural daylight. Thus, the artificial light in the hallways absolutely satisfy the needs of the students and do not harm their performance and health.

Overall, thanks to the well-planned lighting system the dormitory received prestigious LEED Platinum award, as the designers managed to create an effective day-lighting and building envelope scheme (Monrad Engineering, 2012). Also, the dormitory received Edison Award for Environmental Design (GE Lighting) in 2002 as a result of the utilization of modern technologies, sustainable lighting design, and the environment protection initiatives (Monrad Engineering, 2012).

To sum up, Likins Hall dormitory is a perfect example of the well-planned living place with the appropriate conditions for studying, lounge, rest, communication, and other activities. The entire building is a perfect source of the natural light that contributes to the sufficient amount of the sunlight inside the building. Because of the active utilization of modern technologies and large windows in both private and public spaces, all the residents have the opportunity to improve their performance, health, and well-being.

Figure 1 Likins Hall Building

Figure 2: The Likins Hall Main Lobby

Figure 3: The Stained-Glass Artwork

Figure 4: Likins Hall Main Lobby Artificial Light

Figure 5: Likins Hall Lounge Area (a)

Figure 6: Likins Hall Lounge Area (b)

Figure 7: Likins Hall Recreational Area

Figure 8:. Window in the Dormitory Rooms of Likins Hall

Figure 9: Artificial Light in the Dormitory Rooms of Likins Hall

Figure 10: The Outside View of Likins Hall Building

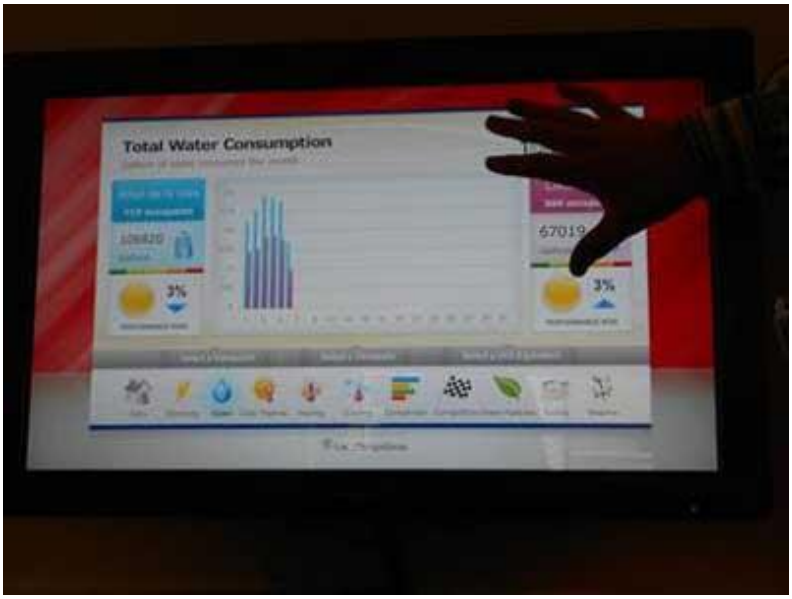

Figure 11: 32-inch Touch Screen Water& Electricity Monitor in Likins Hall

Figure 12: Study Saloon of Likins Hall

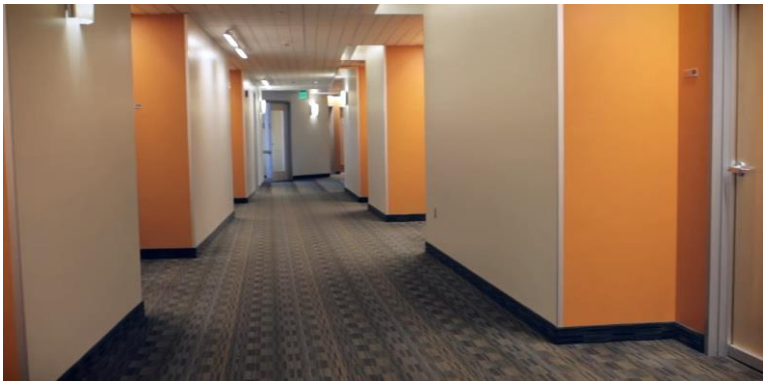

Figure 13: Artificial Light in Hallways of Likins Hall

2.4.2. The Lighting at Simmons Hall of the Massachusetts Institute of Technology

Simmons Hall of the Massachusetts Institute of Technology is considered by many the architectural masterpiece both in terms of comfort and design: “Simmons is already an incredible dorm, with thousands of windows, several terraces, a two-story movie theater, a giant ball pit, and dozens of lounges scattered throughout the building (Steven Holl Architects, 2002)”. This 10-story dormitory was designed by Steven Holl in close cooperation with Perry Dean Rogers. They made the building look like a sponge that has a porous structure and that soaks the light. The lighting solutions are very well-designed, making the construction both intuitive and rational. For

instance, the windows welcome plenty of natural light and provide good ventilation for all the rooms. Overall, there are almost 6,000 operable windows, which is more than enough for such type of construction. All the windows can be opened to make better ventilation and air circulation in the room. In addition, all the windows are connected "by a grid of anodized aluminum" ("Simmons Hall", 2007). Thus, the entire construction reflects sunlight during the day and glows with interior light in the dark.

While completing the Simmons Hall, the architect was in many ways inspired by the Pantheon, as the latter changed a lot together with the environment, depending on climate, time of the day or other characteristics. During one of the interviews, Holl was asked about the main focus of all his buildings, and he answered that it is actually light: "I really believe in a certain sense you can sculpt with light. I think architecture should connect, like the Pantheon does, to the atmosphere, to the seasons, to the sunlight, to the air, to the wind. That, to me, is essential (PRI, 2015)". The following figure clearly demonstrates that light was the key concept of Holl's work (see Figure 14). As well, like in the Pantheon, the architects designed a large hole at the top to provide natural light to the public area (see Figure 15 and Figure 16). The large window on the top serves as a giant source of the light and thus, the area has only some examples of the artificial light in the room. Even more, the warm sunlight gives the entire concrete structure more attractive look and contributes to more relaxation and communication. As well, the natural light is the main source of light in hallways and other public areas. For example, in Figure 17, it is clearly visible that the entire public area (concert or lecture hall) is full of the sunlight. Thus, there is no significant need in the additional sources of the light that directly contributes to the less energy consumption and reduced carbon footprint.

Also, it is important to remark that the designers paid significant attention to the natural light in the hallways (see Figure 18). It is possible to see that the main accent is made on the natural light, while the sources of the artificial light are not so significant there. The numerous net of the windows creates not only the extraordinary design but also absolutely functional space that fulfills the need in the light during the day. Also, the width of the corridors is almost 11 feet that contribute to the better ventilation and lighting of the space (see Figure 19) (Perez, 2010). Similarly, the architects paid a lot of attention to the lighting of the gym (see Figure 20). Thus, despite the low ceiling, the entire room does not look small or uncomfortable. The windows provide a sufficient amount of light that have positive outcomes for the students' physical performance. For example, these findings were supported by the research study conducted by Jovanovic, et al. (2014), who found out that daylight increases visual comfort and improves the mental and physical health of the students.

In addition, the dining hall is a very attractive place too. The wide utilization of the large windows generously provided the students the opportunity to eat in a pleasant and healthy atmosphere. It is significantly better to have the view on the street rather stay in a closed space from every side. In addition, it improves the mood, encourages socialization, reduces the level of psychological fatigue. Talking about the theatre, the designers did not use sources of the natural light and placed it at the basement level (see Figure 21). It is common practice for the theatres to use only artificial light and the choice of artificial light allowed making the place comfortable and relevant for its purpose.

Figure 14: The Exterior View of Simmons Hall

Figure 15: The Light Hall at the Top of Simmons Hall

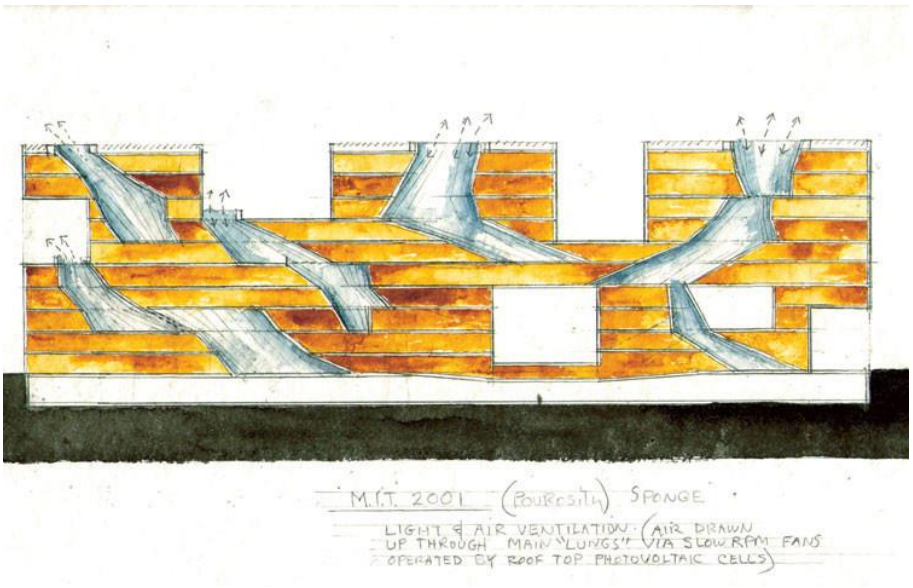

Figure 16: Light and Air Ventilation of Simmons Hall

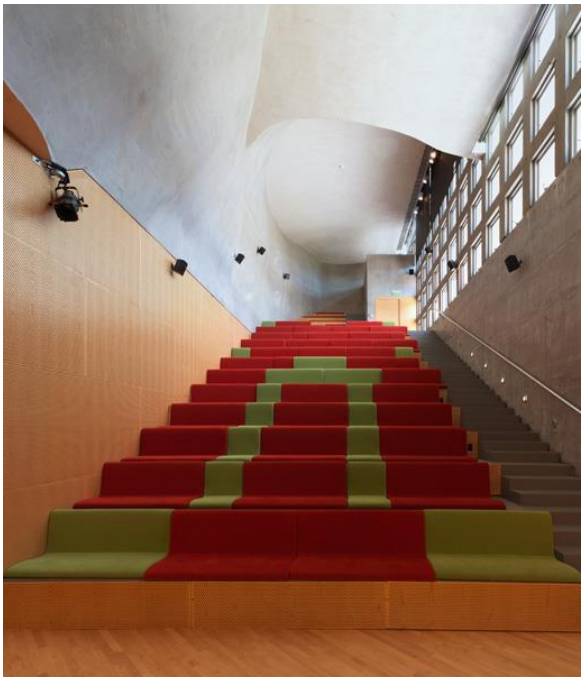

Figure 17: Lecture Hall at Simmons Hall

Figure 18: Hallways at Simmons Hall

Figure 19: Corridor at Simmons Hall

It is important to mention that Simmons Hall is designed in a way when in each hallway ends with daylight. Such an approach allows decreasing the amount of artificial light within the building.

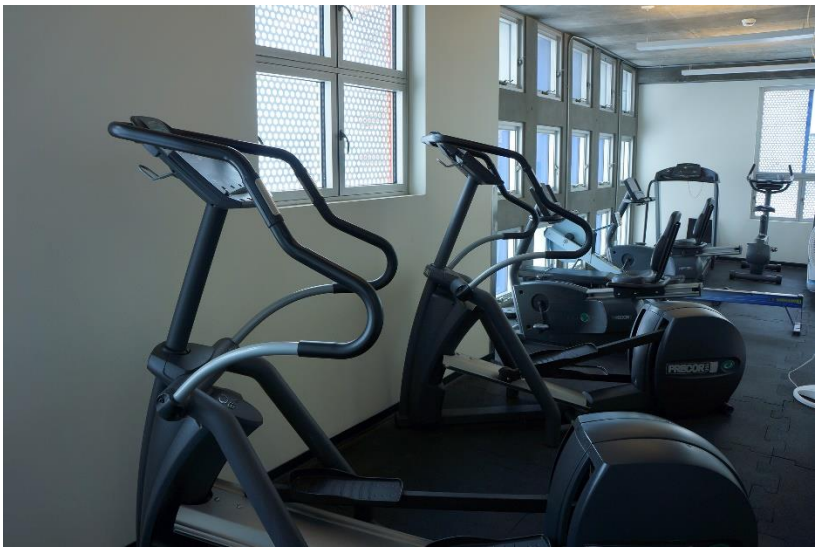

Figure 20: The Gym at Simmons Hall

Figure 21: The Theater at Simmons Hall

Also, it is important to analyze within this case study the opinion of the students, as they are the primary users of the building. According to the interviews of the students and the available photos, one may see that generally speaking, the construction is relatively well-designed in terms of utilization of light. For instance, every dormitory room at Simmons has nine functioning windows and each of them provides a fractured view of the city. Adelyn Perez (2010) rightly remarked: “The abundance of windows creates a constant flicker of changing lights as the different

rooms are occupied, resembling a city skyline at night. These windows also welcome plenty of sunlight and natural ventilation for each room (Perez, 2010)". Thus, thanks to the combination of the 9 operable windows 2' x 2' in size and walls with the depth in almost 18-inch, the architects managed to use low-angled winter sun to warm the place and to make it colder during the summer months. In addition, every window has a curtain, which is a good idea, because the student may regulate the amount of natural light that he or she wants to have within the room. However, there is a negative side of the issue, as according to the students' feedback, they spend on average 5 minutes every evening to shut all the curtains (Nasr, 2007). In addition, the students complain that the screens of the windows create the so-called Faraday cage, meaning that the cell-phone signals are often blocked from entering the room. For instance, according to statistics around 116 freshmen, who started living at Simmons, had to open the windows and to put out the screens to talk to their families and friends (Nasr, 2007). At the same time, the entire construction received numerous prestigious awards, as Build Massachusetts Merit Award (2003), Honor Award for Outstanding Architecture (2003), Charles Harleston Parker Award (2004), and others ("Simmons Hall", 2007).

Figure 22: Multi-Purpose Room of Simmons Hall

The following figure shows the proper location of the furniture in general and working (studying) table in particular. Location near the windows provides enough natural light for reading, writing, drawing or completing any other related activity. At the same time, the picture does not show the overhead light, which is a bad sign, because it most likely means that the student does not have enough artificial light to study during the evenings and nights if it is necessary.

Figure 23: Students' Room at Simmons Hall (a)

The lighting and furniture in the dormitory rooms contribute greatly to the better posture of the students. In particular, the students can forget about uncomfortable and weird positions to be closer to the screen of the computer, or to the page of the book, as it is no longer necessary. The students can sit comfortably in the chair and work at the table with the necessary amount of light. Such lighting also has a positive impact on the concentration.

The university also does not provide the desk lamps. From one side, it may be good, as each person can buy the lamp that he likes and put it how he/she wants. However, from the other side, if the student does not buy the desk lamp, he/she will study in very bad lighting conditions for the body in general and for the eyes in particular. It has been proved that reading or writing in darkness (or in the conditions with not enough light) has a negative impact on the sight, mood and other health-related characteristics. The light bulbs for the desk lamps are also not provided by the dormitory ("What to Bring", 2018). Again, such an approach has two sides. From the one side, the dormitory saves the money, as it does not need to invest the financial resources on the light bulbs. However, from the other side, it means that the students can use any light-bulb they want. It could be not energy saving or harmful for the environment. Utilization of not energy-friendly and not energy saving light bulbs leads to the unnecessary waste of energy and additional expenses.

Figure 24: Students' Room at Simmons Hall (b)

This student's room is rather similar to the previous one, both in terms of design and location of the furniture (see Figure 23). However, here the working table is located not near the windows, but near the wall. On practice, it means that even during the day, the natural light will not be enough for studying purposes and it will be necessary to use the artificial light. It is bad for the students' health and their educational routine. Due to bad location of furniture, the students may refuse to utilize the table for studying and instead may use the bed for this purpose. Due to the fact that the bed is not equipped with a light for studying, it may bring harmful impact for the health and productivity of the student. Also, on this photo, one may see that the overhead light is aesthetically beautiful in terms of design, but not good in terms of functionality (it is mainly the problem during the evenings). This lighting solution is not proper for any studying activity. In the short-term period (one day - one week) it may be normal, but in the long-term one (two weeks – year and more), it may bring plenty of negative consequences.

The following figure shows the different location of the furniture. The bed is located directly near the windows, while the lamp is near the wall. Such an approach is good for the student, as in the morning the student gets the natural sunlight, that is very beneficial for the health (of course if the curtains are open). At the same time, the study table would require more artificial light. The desk lamp that is located on the table is also not a perfect lighting solution for the student. It is not adaptable and does not provide the necessary lighting coverage, especially for reading and writing activities, especially compared to the other alternatives available on the market.

Figure 25: The Bedroom at Simmons Hall

According to Gunnar (2018), LED light can cause the irreparable damage to the cells of the eyes' retina. In particular, the in vitro study found that the radiation from LED can bring considerable damage to the epithelial cells of human's retinal pigment. The statistics demonstrate that every human on average has the eyes open for around 6000 hours every year. They are exposed to artificial light for the great majority of that time. Thus, it is necessary to choose the safe sources of light. The experts recommend using the specific filters to cut the blue glare (Gunnar, 2018).

The figures presented below demonstrate that the windows are lungs of this building that allow the light and air to enter and interact with the inhabitants. Steven Holl Architects (2002) remarked: "Large, dynamic openings are the lungs, bringing natural light down and moving air up". The architect used the natural light very wisely. As a result, it became possible to save the financial resources, as there was no need to implement a lot of artificial light.

Figure 26: Main Entrance and Common Area of Simmons Hall

Figure 27: Library and Gallery Space at Simmons Hall

To sum up, Simmons Hall dormitory is a perfect example of the dormitory that was build according to the latest trends of the natural light utilization. Practically, all the public and private areas have the sufficient level of the natural light. It has positive outcomes for the students'

health, performance, and well-being. As well, the carbon footprint of such kind of buildings is significantly lower, which has positive outcomes for the environment.

2.4.3. The Lighting at Morgens Hall of the University of Cincinnati

In the past, Morgens Hall of the University of Cincinnati was a depressive and tired tower, where students did not want to live, as it was very conservative brick and concrete exterior building with a poorly designed exterior. In 2014, Richard Fleischman together with Partners Architects totally renovated this building to make it more attractive, comfortable, and healthy place for living. Today, it is a well-designed and functional dormitory for the students. It is visible that in the process of construction of the building, the architect valued greatly the natural light. The architects used 2,000 high-quality glass panels to construct this outstanding building (Robinette, 2013). From the one side, they are a reflection of high-tech design, while from the other side, they provide better building insulation thanks to the low emissive characteristics of the glass. Thomas Robinette (2013) remarked: “Each panel is made of two quarter-inch thick windows with a half inch of air space separating each window. The glass has low-emissive properties, making it better than standard glass by preventing heat loss or heat gain”. Figure 26 demonstrates the beautiful glass exterior of the Morgens Hall. There are windows from all the sides of the building to catch the as much natural light as it is possible. Also, almost all panels have fritting (a special white linear pattern) that is aimed to improve insulation and to decrease the solar heat of the room up to 20%. As well, white linear pattern helps to warn birds about the glass obstacle on their way. In addition, from the inside, this white pattern provides a window a unique appearance similar to the chair rail (see Figure 27).

Thus, it is clearly visible that a lot of attention during the design of that building was paid to the importance of sunlight for the residents of the dormitory (see Figure 28). The panoramic windows give enough natural light for studying purposes during the day. In practice, it means that the artificial lights are almost not used during the day, which allows energy saving and provides numerous other health-related benefits. The daylight is particularly important during the dark and short winter days, as a lot of people are influenced by the so-called Seasonal Affective Disorder. The natural light can help to fight this problem or even to avoid it, through improving the mood, boosting the energy, general better feelings, regulation of the natural circadian rhythm, and better sleeping at night.

Moreover, the big windows help to bring the outdoors inside. Today, at the time when people are more and more disrupted from nature, it is particularly important to connect to nature, as it contributes greatly to the well-being and health of the person through boosting the mood and making people happy. Richard Fleischman + Partners Architects (2013) stressed: "With the complete replacement of the building façade, floor-to-ceiling glass now creates the sense of sitting within a park on the lower floors and presents beautiful vistas of the campus green from the upper floors". Finally, the big windows of Morgens Hall help to create the illusion of a relatively big space (or at least bigger space than it really is). The perception of space thanks to the big windows and the light that goes through it is known to influence the general perception of habitation, satisfaction with it and its final comfort and functionality. The proof of it is the fact that the 464 residence places within the building were sold out in the first three days after completion of renovation ("Richard Fleischman and Partner Architects", 2017). The important factor of the protection of privacy was successfully realized in the dormitory too. Despite the large windows,

all of them have “adjustable privacy screens that are 98 percent opaque and thermal weaved for energy conservation” (Robinette, 2013). Morgens university architect and associate vice president of Planning, Design, and Construction Mary Beth McGrew justly underlined: “Morgens small but elegant spaces combined with the insulation advantages of the windows and privacy screens will reduce the energy used for lighting, heating and cooling” (Robinette, 2013). As well, all the hallways in the dormitory have the motion sensing systems that contribute to the less energy consumption. Thus, the entire building was renovated according to the highest standards of environmental protection, seeking to reduce its carbon footprint and to improve the students’ living conditions.

Moreover, talking about the kitchen area, it is important to mention that it was designed in white colors and during the day it looks very attractive and sunny (see Figure 29). There is no need to switch the artificial light, as thanks to the large window the amount of light is very significant. Thus, even the routine cooking process can be transformed in the positive process thanks to the well-planned sources of the light. Similarly, the study area has large windows-walls that absolutely fulfill the need in the light during the day (see Figure 30). Similarly, to the dormitories analyzed above, thanks to the professionally designed access to the natural light, the students have the great opportunity to study in healthy, comfortable, and well-illuminated conditions. Furthermore, the students have free access to a full rooftop terrace (see Figure 31 and Figure 32). Thus, they have the possibility to be on the fresh air even in the frames of their residence.

The lighting in the dormitory is designed in the way that it provides the building with the contemporary feeling and long-lasting durability. The project is a very good example of sustainable and ecological design. The focus of the university is on adaptive re-utilization, which

shows the commitment of this university to the environment. For example, due to the fact that all the lighting within the building is LED, the university and the residents of the dormitory are able to save almost 50% in the building's operating costs (KLH Engineers, 2012). Thanks to the utilization of energy saving technologies and beautiful design, the dormitory recently received American Institute of Architects of Ohio Award, the AIA Cincinnati and AIA Cleveland awards. In addition, it is important to mention that in 2015 Morgens Hall achieved LEED silver certification (Schefft, 2016).

It is important to mention that the transformation in terms of light of Morgens Hall was immense. In the past, the walkways and the corridors were dimly and inadequately lit. The public in general and the students, in particular, felt unsafe and insecure at this place. The bad lighting was one of the reasons for the failure of the previous dormitory and the fact that students preferred other places of residence. The new project of the Morgens Hall demonstrated the high attention to details. It became the role model of the proper lighting not only in the classroom and in the dormitory room, but everywhere – around the dormitory, in the parking lot, and at other places in the campus. The lighting specialists managed to demonstrate the benefits of LED light, compared to the alternatives through better coverage, eco-friendliness, and energy-saving characteristics. The better lighting also improved the security cameras performance and therefore improved the safety of the students and their comfort in the campus. At the same time, there is also another side of the situation. According to the recent studies by Gunnar (2018), LED light can cause the irreparable damage to the cells of the eyes' retina. In particular, the in vitro study found that the radiation from LED can bring the considerable damage to the epithelial cells of human's retinal pigment (Gunar, 2018). The statistics demonstrate that every human on average has the eyes open for around 6000

hours every year (Gunar, 2018). They are exposed to artificial light for the great majority of that time. Thus, it is necessary to choose the safe sources of light. The experts recommend using the specific filters to cut the blue glare (Gunnar, 2018). Thus, the artificial lights used at Morgens Hall should be further investigated to ensure that they do not influence negatively the health of the inhabitants of the building.

The design of this building clearly demonstrates that the occupants have enough access to daylight. Considering the fact that the day-lighting impacts greatly the quality of sleep, it is possible to state confidently that the quality of sleep of the inhabitants should be relatively good. Morning light plays a critical role in the synchronization of metabolic rhythms and balancing the biological clock of the student. The designers of the analyzed dormitory knew this and through the proper fenestration, façade orientation and location of the furniture achieved the situation when the morning sunlight falls directly on the bed (Mariamma, 1967).

To sum up, the importance of the natural light was one of the most important tasks of the architects. Thus, practically all the places have floor to ceiling windows that provide the necessary amount of the light during the day. Therefore, the residents of the dormitory can work or relax with the little consumption of the artificial light and their health and mood would be improved. The following table demonstrates the achievements of the lighting specialists in the Morgens Hall in relation to the students.

Table 1: The Impact of Light on the Physical and Psychological State of the Students at Morgens Hall

Physically		Psychologically	
Improve	Decrease	Improve	Decrease
Vitamin D	Cancer Possibility	Mood	Depression
Visual System	Abnormal Bone Formation	Mental Performance	Stress

Circadian Rhythms	-	Alertness	Sadness
Sleep Quality	-	Brain activity	Violent Behavior

Figure 28: The Exterior of Morgens Hall

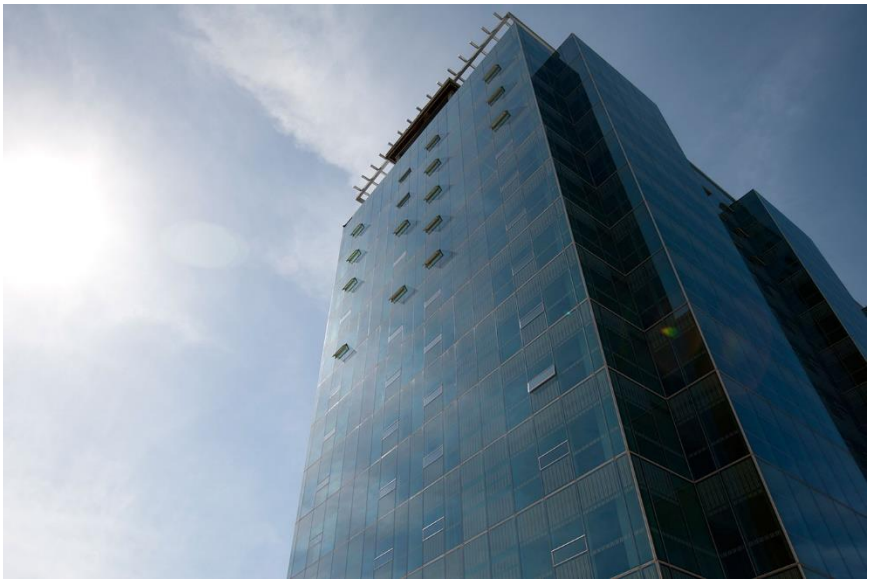

Figure 29: The White Linear Pattern on the Windows

Figure 30: Students' Rooms at Morgens Hall

Figure 31: Kitchen area at Morgens Hall

Figure 32: Study Room at Morgens Hall

Figure 33: Terrace at Morgens Hall from Outside

Figure 34: Terrace at Morgens Hall from Inside

2.4.4 The characteristics of future housings

The analysis and evaluation of the lighting solutions of the three case study dormitories Likins Hall of the University of Arizona, Simmons Hall of the Massachusetts Institute of Technology and Morgens Hall of the University of Cincinnati have demonstrated that the architects of contemporary dormitories pay a lot of attention to the economic, ecological, ergonomic, health, comfort and design features of the light in the students' residencies. Compared to the past, today much more progressive technologies are available. Such situation is caused by the technological progress and the processes of globalization all around the world.

The evidence presented within the case studies have demonstrated that LED lighting is the optimal and rational solution for the contemporary dormitories (as well as many other residence spaces), as they have a relatively long lifespan (2-4 times longer compared to the alternatives), produce high-quality light and provide high efficiency. The analysis demonstrates that the developers of the modern dormitories understand that vision cannot operate without light. They

also consider the fact that light has the stimulating effect on the individual's social, psychological and physiological reactions. This effect is manifested through heart rate, learning efficiency, productivity, concentration, toxin build-up, longevity, cognitive and mental processes, as well as numerous other characteristics. The study by Mariama (1967) demonstrates that the biggest percentage of impressions that reach the brain of the human comes from the process of seeing. Moreover, this research demonstrates that visual work, similarly to physical work, requires high energy consumption: "There is a consumption of a quarter of the bodily energy in the processes of seeing when vision is normal and illumination is sufficient. That is, 25% of our calorie intake is used to power our eyes under optimum conditions (Mariama, 1967)". At the same time, when the lighting conditions are not favorable enough, even more, energy is used. The above-mentioned facts determine largely the importance of work of lighting specialists within the buildings in general and within the dormitories. From one side, it is an element of design, while from the other side, it is a necessity that defines comfort and efficiency of the human. Thus, it is visible that the lighting specialists of the analyzed dormitories try to use the space ergonomically, to satisfy the educational and health needs of the users. In the great majority of cases, their efforts were successful.

The analysis of the available literature together with the examination of the dormitories has shown that there are certain factors that differ from person to person and thus cannot be fully addressed by the lighting specialists. Among such factors, it is important to mention the psychological factors (mental fatigue, alertness, annoyance, distraction, impression, and attention) and physiological factors (blinking, heart rate, tenseness, headache, body fatigue, and eye fatigue). The fact that these characteristics vary from person to person does not mean that they should not

be considered. It is necessary to determine the average indicators and then to implement them on practice.

The study by Mariama (1967) demonstrates that if the table of the student does not have the proper lighting, it is very likely that the student will study sitting at the divan or lying in the bed. The interviews with the students from the analyzed dormitories proved this statement. Such an approach has a negative impact on posture, as bed and sofa were not developed for the prolonged period of studying and working. This furniture was developed more for relaxation purposes and usually does not provide adequate lighting for studying, which has a considerable negative impact on the users. When the student studies in the improper place, he/she often places the books or other studying materials too close to the eyes, or strain the eyes too much to see something. Such an approach has a negative impact on the vision of the person. The analysis of the dormitories has demonstrated that there are certain flaws with the location of the furniture and they should be addressed promptly to avoid the negative impact on the students in the future.

All in all, it is important to state that the lighting specialists of the analyzed dormitories try to minimize the risks and negative impacts of lighting solutions and to maximize the opportunities and the positive influence of lighting choices. Making the healthy student have problems with health due to the inappropriate lighting in the dormitories is something that all the universities try to avoid at all means.

The following figure demonstrates the conceptual map of lighting and its impact on the psychological and physiological state of the human. One may easily see that all the factors on the

figure are very interrelated. Due to such a situation, it is difficult to realize the qualitative and quantitative analysis of the information and make the objective conclusions.

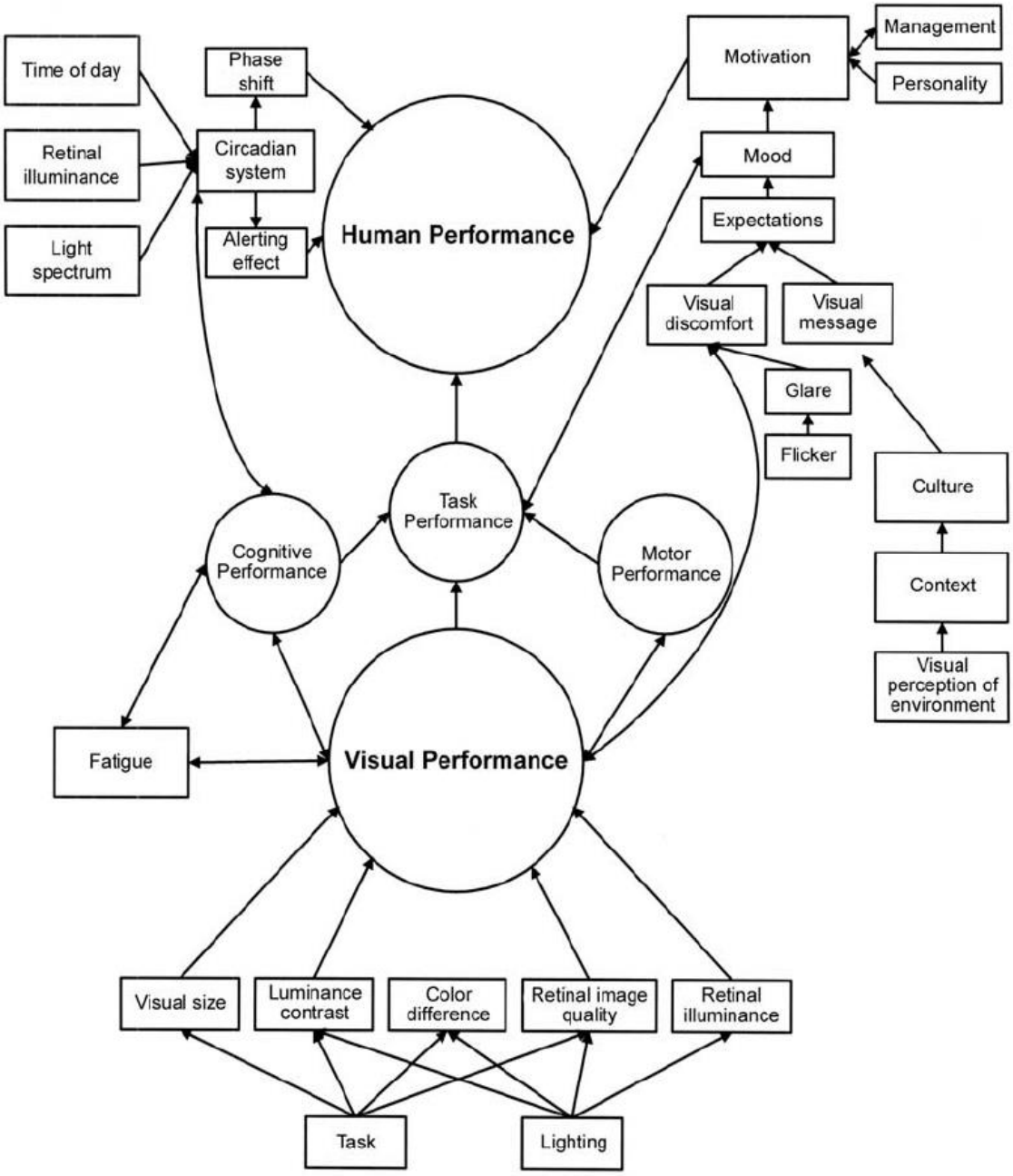

Figure 35: The Conceptual Map of Lighting Impact on the Human

The analysis of the interviews of three people (presented in the appendix) from the three universities confirm the above-mentioned results of the case study. Generally, the students are satisfied with the lighting conditions in their dormitories, however, they offered several improvements that could make the quality of lighting even better and more comfortable for future users. For example, Samuel Hoam that lives in Simmons Hall of the Massachusetts Institute of Technology offered to allow the students painting the room, as "paint could bring the different perception of place and different perception of light (both artificial and natural) (Appendix)". Also, all the students agreed that the light influences the human. For instance, Pamela Stevens that lives in the Morgens Hall of the University of Cincinnati stated that light in the dormitory impacts greatly her physical and psychological state: "Yes, the light definitely impacts my mood, the quality of my sleep and even my productivity. The studying conditions matter a lot to me. If they are not good, I can't study well (Appendix)". Eric Thompson from the Likins Hall of the University of Arizona has a similar opinion. He stated that light in the dormitory room impacts him positively: "For example, I like when I wake up from the sunlight. It improves my mood and makes me feel better (Appendix)". All in all, it is important to state that the answers provided in the interviews showed that light matters a lot to the students and confirmed the relevance of this work.

CHAPTER 3

METHODOLOGY

In the light designing field, researchers use the range of academic qualitative methods that contribute considerably to the achievement of the goals mentioned earlier. The quantitative data are usually obtained from the existing scholarly literature on the topic, while qualitative data are obtained from practical methods of information gathering (interviews of dormitory students, observation, case studies, assessment of the personal experience in the dormitory). The analysis of each method in details will be presented below.

- The method of correlation analysis allows finding out the social, psychological, behavioral and emotional relationships between the lighting in the dormitories and students' well-being, productivity, and state of health.
- The method of descriptive qualitative analysis gives the possibility to examine the information about light in the dormitories, taken from different academic articles, books, business reports, reviews, as well as other appropriate sources.
- The case study method. The examples of different dormitory rooms with different quality and amount of light will be studied out through the case study method to determine the advantages and disadvantages of each and to develop the set of appropriate recommendations for the relevant lighting that will both satisfy the legal standards of the country (or state) and the needs and requirements of the students, making their stay in the dormitory room the pleasant and comfortable experience.
- The survey method allows getting the practical and up-to-date information on the problem of light in the students' dormitories and its impact on the performance of the students'

health, performance and productivity basing on the personal experience of students and professional opinion on the problem of the architects and lighting specialists. Twenty-four students are participated in taking survey about their life in dormitory room and its impact on their health and productivity (see Appendix for the interviews with the students).

To sum up, it is important to state that all the above-mentioned methods work in synergy which will enhance the preciseness of the study increasing the possibility to solve the existing problem of light in the dormitories and reaching a practical relevant conclusion. However, this study will be only limited to the qualitative analysis methods such as interviews of dormitory students, observation, case studies and finally an assessment of the personal experience in the dormitory.

3.1. Applicants and Material Used for Data Collection

The twenty-four students who lives on the University House at Arizona State University-Tempe campus were asked to kindly participate on the on-line survey. Multi-choice questions are answered by the participants which could determine the different variables of the volunteered students such as floor, windows direction, sleeping pattern, and lighting system. See Appendix A for more information about the survey. Students are also asked about their knowledge about the circadian rhythm and if they think they got enough sunlight exposure or not. The survey is an attempt to understand the impact magnitude of these variables, and the importance they play in the students' lives. Along with the survey, the building, where the students live, will be studied to identify some of the lighting technical aspects. illuminance measurements are taken every 30 minutes during the day (from 7:00 AM to 7 PM) from two rooms one facing East and one facing South. All measurements are taken from 1.2-meter (4 feet) distance from the window's center,

and 4 different measures are taken to calculate the light intensity of different scenarios during the day. The four measurements are as follow: 1- Closed Light and Window Shades 2- Closed Windows Shade only 3-Horizintal Light Intensity with open Shades 4-Vertical Light Intensity with open Shades. The lightning systems specifications such as lamps types, manufactures, and correlated color temperatures (CCTs) will be identified along with the illuminances which will be measured using photometer (URCERI Digital Illuminance Meter) for the rooms with different scenarios. The goal is to determine Circadian Stimulate (CS) of the dormitory rooms and investigate if there is a correlation between students' comfort and their interaction with light. The CS is calculated using CS Calculator developed by Light Research Center at Rensselaer Polytechnical Institute (https://www.lrc.rpi.edu/cscalculator/).

3.2. Data Collection Strategy

The collection of data from survey and lighting system measurements should enable us to evaluate the outcomes of the systems and the importance of different variables' role. From the data, the hypothesis of the light effects on the students' performance and well-being will be evaluated based on the qualitative data gathered from the survey and quantitative data measured in the field. The gathered information will assist us knowing the students live quality in the dormitories and how it may unintentionally affect their academic outcomes. Information such as the availability of additional lights, hours spent in the dormitory, the need of blackout to sleep, area of study (in-room, designated Study room, on-campus or other), before-sleep smartphone usage, overall academic outcomes, and the satisfaction degree for the overall living experience could be gathered from the students' survey answers. The quantitative data is calculated by a photometer to determine the illuminance in the room (the visibility) and then to calculate CS of

each light source assuming that CCT daylight ranges from 5000K to 6500K. Different scenarios will be applied for the dormitory rooms to determine the minimum and maximum obtained CS values of common lifestyle practices of the students. For instance, students' economic situation and the awareness of electricity rationalization push the students to minimize lights which could be a good or bad practice from circadian rhythm perspectives.

3.3 Data Analysis

The data will be analyzed to find if there is a correlation between the lighting system and the students' physiology and production. It is an effort to support the existing academic findings that relates the circadian disruption to some physiological and health problems. Sensitivity analysis for the variables will be examined to determine the magnitude of their effects on the students. For example, it is common that rooms facing east have better chance to help residents to calibrate their biological clock with nature, but the effect could be minimal if the students tend to blackout windows to get a better sleep. Also, it might be possible that using smartphones before the sleep could suppress Melatonin causing a shift in the circadian rhythm. The questionnaire will provide qualitative data about the students' comforts, and from the lightning measurements we find if the comfort of the students correlate with their light exposure.

CHAPTER 4

RESULTS AND DISCUSSION

The students' housing used in this study is 19th floor housing near Arizona State Tempe-campus. Twenty-four students living in the housing who are above the age of 18 participated in the online survey between March 2nd and March 12th, 2019. The students participated in the study were from different floor levels and windows directions which gives us a diverse sample that can help for better understanding about the effect of the windows direction and the floor level on the student comfort. Forty-one-point seven percent of the participants live on the floors from Five to Ten while 37.5% live between the Eleventh and Fifteenth floor, and the rest live on the Sixteenth floor and above. 25% of the participants have windows that face West while 20.8% have East facing windows, and 10 out of 24 students participated in the study have room windows that face South.

Most students, 17 out of 24, spend from 8 to 12 hours in their rooms including sleeping time and 13 out of 24 say their foremost act in the room is sleeping which indicates that students in housing spend most of their time outside their room. Ten out of the 24 students study in their rooms, and 7 of the 10 students use a purchased additional lighting source, and only 1 of them believe his/her academic outcomes have improved after moving in. All the Eight students who said they are totally aware of the effect of lighting level on the circadian rhythm sleep 7 to 8 hours on average. Seven of them their main use of the room is to sleep. Also, seven of the eight students who are totally aware of the circadian rhythm do not use blackout system on their windows.

Five students believe they do not get enough daily sunlight out of whom 80% spend more than 12 hours in their rooms while 13 out of the 16 who believe they get enough sunlight exposure spend between 8 to 12 hours on their place. All the three students who said their academic outcomes got better since they moved in spend less than 12 hours on the housing.

This a clear indication that students believe their sunlight exposure is associated with their outside activities. The number of students who study in their rooms and the number of students who study on campus is 10 each, however, two out of the three of the students whom academic outcomes improved study more on campus. On the other hand, 5 out of 8 who said their academic outcomes have worsened do their studying in their rooms.

The number of students who purchased additional lighting is 13 out of 24, and all the 7 students whose main activity is gaming or watching TV have purchased additional lighting and use it as the main lighting source. Two thirds of the students believe they get enough sunlight exposure. Most of the students live in East (80%) and West (83.3%) oriented rooms believe they get enough sunlight while only 50% of students who have South rooms believe they get enough sunlight. All students who study on campus believe they get enough sunlight exposure while 4 of the 5 students who believe they don't get enough sunlight study in their rooms.

Most students (95.8%) uses alarm clock to have a fixed wake up times which means they usually get up before their natural waking time. Only one student relies on her/his biological clock to wake up. However, all the students participated in the study do not depend on the surrounding environment's signals such as sun rise on their sleeping habits.

Along with the survey, illuminance measurements from an East oriented room from the 6th floor were taken every 30 minutes from 7 AM to 7 PM as described above. The lightning measurements was taken on the 7th March 2019 on a clear sky day. The intensity of the horizontal and vertical daylights were measured during the day time. Daylight illumination measurement are taken horizontally and vertically as shown on the following graph.

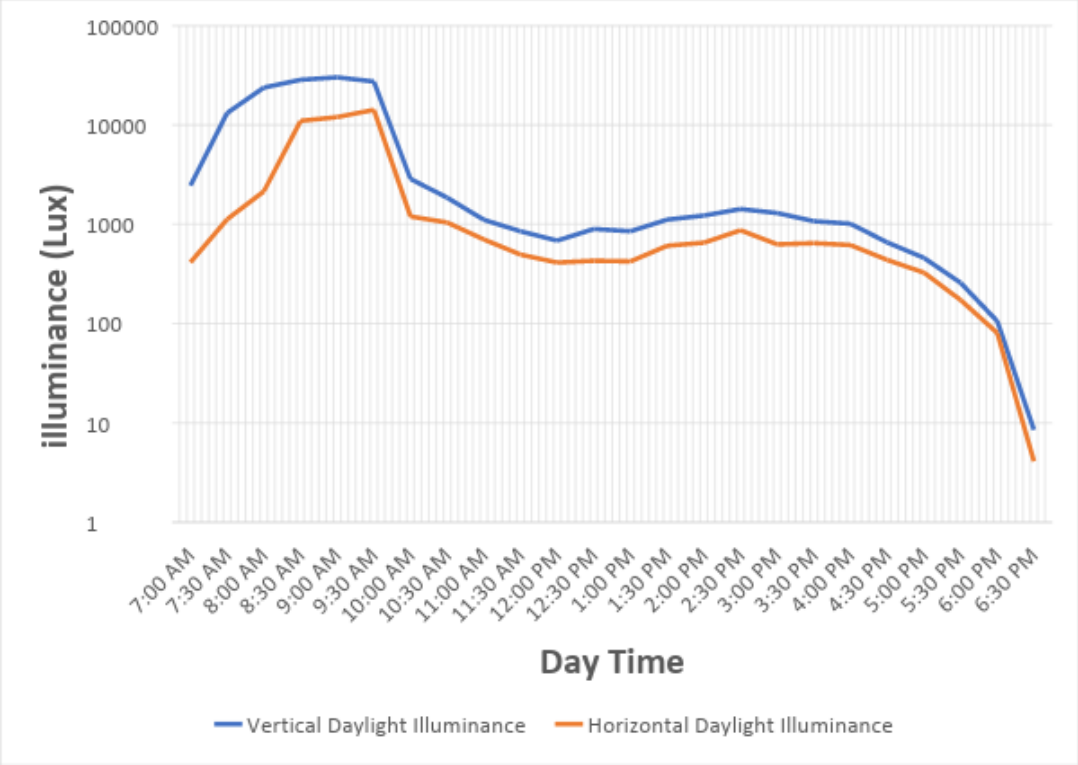

Figure 36: The Horizontal and Vertical illuminance intensity during the day when windows shades opened

The vertical daylight illuminance is almost double the horizontal illuminance. Despite the surface orientation, the illuminance is 1000 or higher during most of the day. The spike in light intensity from 7:30 to 10:00 am is because the illumination measurements was taken from an East facing room and is a result of a direct sunlight. After 10:00 am, the light intensity sharply

decreases as the sun moves into the middle of the sky. From 12:00, the light intensity starts to increase again as the sun moves toward the west. Most illuminance after 12:00 is as a result of sunlight diffusion. The direct sunlight illuminance exceeds 25 k Lux in the early hours which would not only cause discomfort but also would cause high heat influx.

The daylight illuminance level was taken when windows shades are applied. Two scenarios were tested one with and the other without using the room light (lumen CFL / LUGU24S13-27K) which has a light output of 900. However, the actual average illuminance level in the room at night is 23.9±11 Lux which is way less than 150 Lux the recommended light level of houses (DiLaura et. al, 2011). The light intensity of the room during the day when the windows shades is applied is illustrated in figure 37.

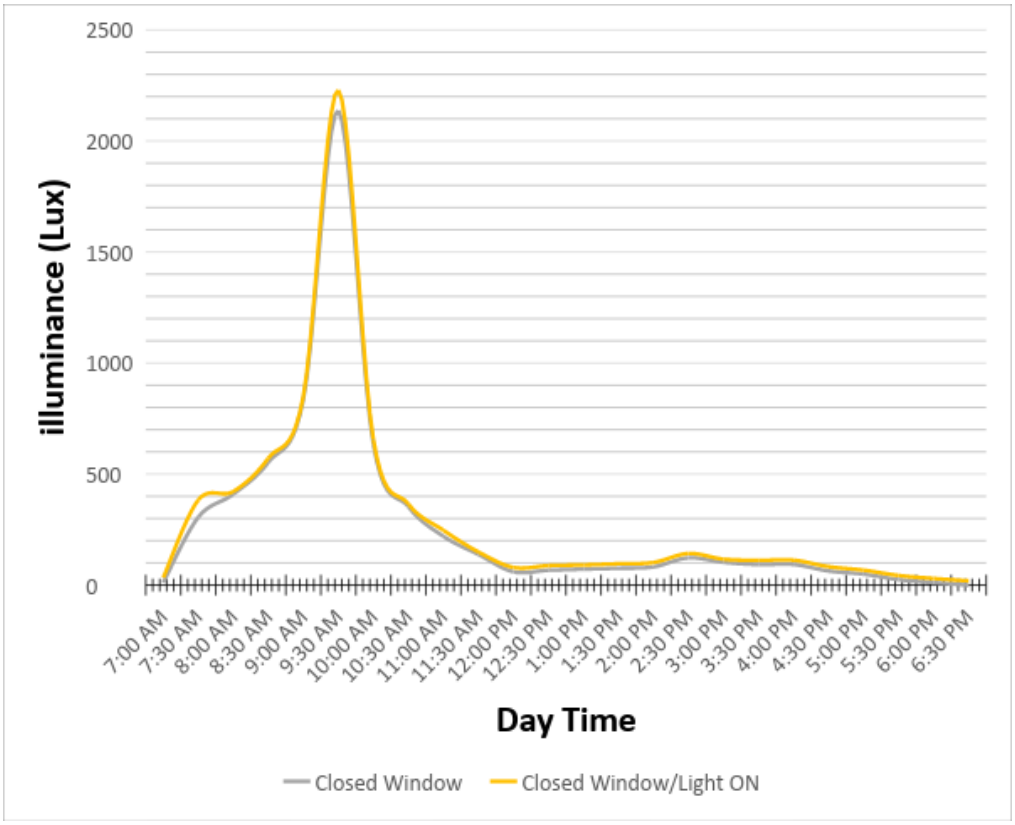

Figure 37: Illuminance intensity during the day when windows shades applied

The increase in illuminance level from 7:30 to 10:30 am is because of the sun glare on the shades. This is believed to be exclusive to the East oriented rooms and other directions might have similar illuminance level spikes on different time frames during the year. However, only the early day illuminance level spikes could be helpful for synchronizing our biological clock. After 11:30 am, the illumination falls below 150 Lux which is the minimum recommended illuminance level. With these conditions and during the night, the vision is partially compromised unless additional lighting system is likely introduced.

The circadian stimulus metrics is a calculator that can be used to evaluate the non-vision effects of light on the internal body clock. The goal of such measurements is to identify whether the room can provide enough natural and artificial light access for students to satisfy their vision and non-vision needs. The following graph is a representation of the CS values that have been calculated for the 4 different scenarios during the day.

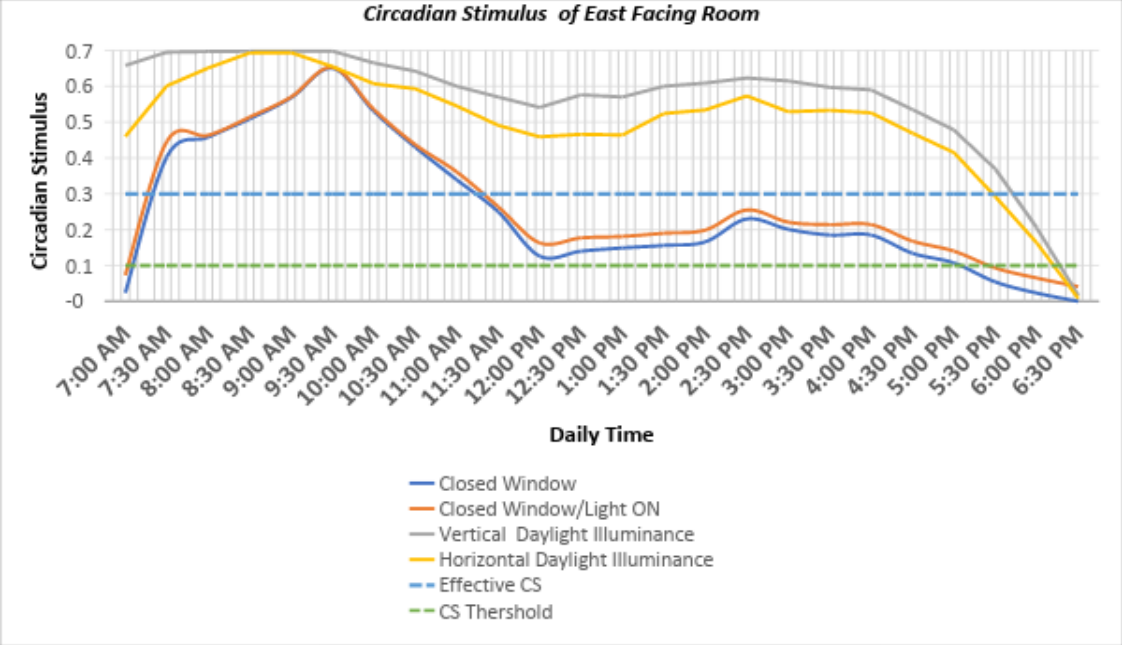

Figure 38: The Circadian Stimulus during the day for different lighting scenarios

The CS values range from 0 to 0.7 which correspond to the maximum suppression level of melatonin. For our calculation, CIE D65: Average Daylight as the main lighting source since it accounts to both direct sunlight and diffused light from a clear sky. The threshold CS is believed to be 0.1 where the melatonin level is not affected by the light (dim light) and CS of 0.3 is believed to be effective to sustain enough light to synchronize the circadian rhythm. As the result in figure 34 shows, students can get enough sunlight if they set near the window for half an hour between 7:30AM and 11:00 AM which is stuffiest to suppress the melatonin level and harmonize the internal clock with the surrounding environments.

4.1 Findings and Discussion:

The housing chosen in this study is a relatively new building and is considered one of the best housing near campus when it comes to the windows size and natural light integration. However, based on the survey data, the majority of the students purchase additional light source and more than 40% of them do their studying in their rooms. Even though the day lighting might be sufficient to sustain a healthy environment, students seem to be unable to integrate the use of daylight for different reasons. Sunlight integration might be avoided because of the excessive photons that carry which will, if not reflected, introduce heat to the space and increases the air conditioning power consumption. Another issue students are not able to integrate sunlight is that open windows might jeopardize their privacy. Designing students' housings should have different perspectives than designing an office or school for instance. Offices and schools are

considered as public spaces where students and workers are less concerned about the privacy and the energy cost of the system.

All the three students who spend 16 hours or more in their rooms believe they don't get enough daily sunlight. Also, 13 out of the 16 students who believe they got enough sunlight spend most of the day outside their rooms. Students tend to link their interaction with daylight with their outside activities, and this is not necessarily true, but at least it can be seen as a dissatisfaction. Even though more than 70% of the students spend most of their time outside, the housing design should be at higher standards to satisfy the need of the vulnerable. The other issue students' housings in general have is the lack of adequate built-in lighting. The average illuminance during the night is about 23 Lux which is far less that the recommended for schools, homes and offices. Even though the artificial lighting is extremely affordable, the choice of the lighting type could be risky since students are not expected to differentiate between the non-visual effects of timing, intensity, spectrum, and other light characteristics from different sources. For example, it is unlikely for someone to buy a cool white light lamp with CCT value of >4000K which could deliver CS value of 0.1 to 0.3 and cause melatonin suppression and consequently circadian rhythm distribution if used for a few hours.

Almost all students (23 out of 24) depend on the alarm clock to wake up which is usually set up in accordance with classes schedule rather than the body needs. It is believed that more than 50% of the college students are chronically sleep deprived (Hershner et. al, 2014). There are many physiologic and behavioral reasons that have been suggested to cause sleep deprivation in college students, however, the living practices and students' interaction with the built environment should be further investigated to determine the order of magnitude of the effect. In

this study, only one of each six students sleep 6 hours less on average and the average sleep duration of the 24 participants is 7.33 hours. However, further research is needed to evaluate the universities' policies and class schedules that may have an impact on students' sleep, health and education.

More than 70% of the students are aware that daylight have an impact on our internal body clock, however, their understanding of the sunlight exposure is linked with being outside, and it seems that students don't rely on the daylight as the main light source during the day as offices' employees for example. Fortunately, being outside for more than half an hour is enough to synchronize your circadian rhythm with the solar day (Figueiro, 2017). However, students would have a sleep deprivation because of melatonin suppression during the night from the room light or self-luminous displays devices which has been proven to intervene with melatonin concentration (Figueiro et. al, 2018). There is a need to alert students about the importance of sleep in their health and performance.

4.2 The Study limitations

One of the study limitations is that the study does not identify the relationship between their academic performance with their class schedule timing and sleeping habits. Also, the study focuses on sleep duration and how sleeping is ceased, but it does not investigate the sleeping pattern and timing. It is possible that college students have a healthy sleeping duration, 7-8 hours, and they still experience a delayed circadian system. Although the number of the students participated in the study is 24, we believe that, as the study has many variables to examine, some of the results could not be as conclusive as desired.

Another limitation worth noting is that the CS measurements is limited to one place due to some technical and regulatory difficulties. Nevertheless, the day measurements could vary from one direction to another based on the time of the year and the sole objective of the day measurements is to inspect whether it is possible to stimulate the circadian rhythm on early morning by simply opening the windows shades for half an hour. The night time measurements are apparently believed to be the same if only essential built-in lights used. Also, the illuminance/light meter used is not a professional laboratory grade, however, the accuracy of the device is considerably accurate as it is mainly used to measure natural light for CS calculation.

Also, the type of additional lights purchased by students have not been studied to determine whether they could effectively affect the CS value or not. This is essential because light plays a potent role as it has been proven to promote prosperity and comfort but its effect on human health have also been investigated. We believe it is important to study if there is a correlation between the type of lighting system independently added to the room and the academic performance and the well-being of the students.

CHAPTER 5

EVALUATION OF RESULTS FINDINGS AND DEVELOPMENT OF THE POSSIBLE SOLUTIONS

5.1. Artificial Lights Recommendations for Dormitories

After the evaluation of the literature on the topic and the available case studies, it was found out that due to differences in terms of architecture, construction materials, the orientation of the building, the geographical characteristics of the area, climate, as well as numerous other factors, there is no universal recipe of lighting. In other words, one solution is not able to fit all the needs and requirements. However, basing on the examination of many available sources on the topic, the range of recommendations were developed by the author to help the architects to meet the health-related and education-related needs of the students.

1. Each dormitory room should have the access to the natural light and should have at least the minimum lighting requirements assuming that students may not be able to differentiate between the non-visual effects of different lighting devices.
2. Ideally, the table for studying should be located near the window (it will allow the student to study with the sunlight instead of artificial light, such an approach has numerous positive consequences for the health).
3. Motion sensors should also be used to ensure the energy efficiency, whenever and wherever it is possible. For instance, it is possible to put the sensor mechanism on every door in the hall that would activate the lights for 5 minutes and then would be automatically turned off. Also, it is possible to install the hand-wave sensor with timer in the strategically important locations to turn the lights on and off.

4. The windows should be cleaned regularly to ensure the satisfactory level of incoming light;
5. All the spaces within dormitories should correspond to the following lighting standards (see Table 2).

Table 2: Illuminance Categories and Illuminance Values for Generic Types of Activities in Interiors

Type of Activity	Category	Ranges of Illuminances		Reference Work Plane
		Lux	Foot-candles	
Public spaces with dark surroundings	A	20-30-50	2-3-5	General lighting through spaces
Simple orientation for short temporary visits	B	50-75-100	5 -7.5.-10	
Working spaces where visual tasks are only occasionally performed	C	100-150-200	10-15-20	
Performance of visual tasks of high contrast or large size	D	200-300-500	20-30-50	
Performance of visual tasks of medium contrast or small size	E	500-750-1000	50-75-100	Illuminance on task
Performance of visual tasks of low contrast and very small size	F	1000-1500-2000	100-150-200	
Performance of visual tasks of low contrast and very small size over a prolonged period	G	2000-3000-5000	200-300-500	Illuminance on task, obtained by a combination of (general and local supplementary lighting).
Performance of very prolonged and exacting visual tasks	H	5000-7500-10000	500-750-1000	

Performance of very special visual tasks of extremely low contrast and small size	I	10000-15000- 20000	1000-1500-2000	

Source: (Lighting Design, 2018).

6. It is important to remember that too much glare or light is as bad as too little light (Louie, 2018). Thus, the lighting specialists should take this factor into account to provide safe solutions to the end users.
7. It is also necessary to ensure that there is no high contrast between the end of the room and the studying area, as in this case the eye moves from the brightly illuminated area to the shadowy one all the time (such high contrast scenario repeats multiple times, fatiguing the eye of the person and making the individual sleepy).
8. It is necessary to implement the shaded lamps into every dormitory room. Such lamps would allow adapting the light to the needs of the student and allow to achieve the difference in production, accuracy, and focus. The example of such lamp is presented below (see figure 36). As it is possible to see, the lamp gives the user the possibility to perform different types of activities (reading, writing, working with the laptop, tablet, relaxing etc.) with the relevantly adapted forms of light. In fact, the eyes will "show what they want". If the choice of light is not comfortable enough, they will demonstrate the characteristics of fatigue, redness, burning, brow ache and squinting (Louie, 2018). Currently, the case studies demonstrated that the dormitories do not have the shaded lamp lighting solution. Thus, such recommendation can serve as a good idea for the dormitories to implement.

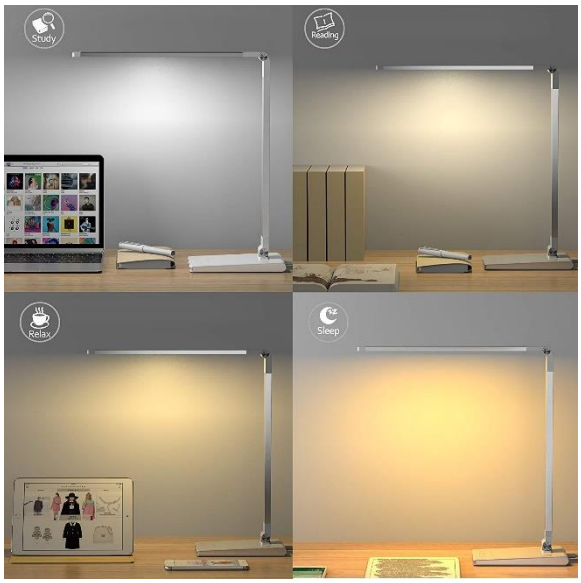

Figure 39: Different Types of Lighting of Shaded Lamp

9. Different light CCT and intensity during the day could be used to synchronize the internal body clock with the solar day. According to Park and Tokura (1999), in the morning the light should be cooler and with the flow of the day, it should change gradually to warmer yellow colors. The recent study by Giang (2017) confirms this idea, stating that the light should be programmable. It will adapt to the needs and state of the user. The adaptation of light should be made based on the following figure. It shows the circadian rhythm and the release of cortisol and their influence on the human.

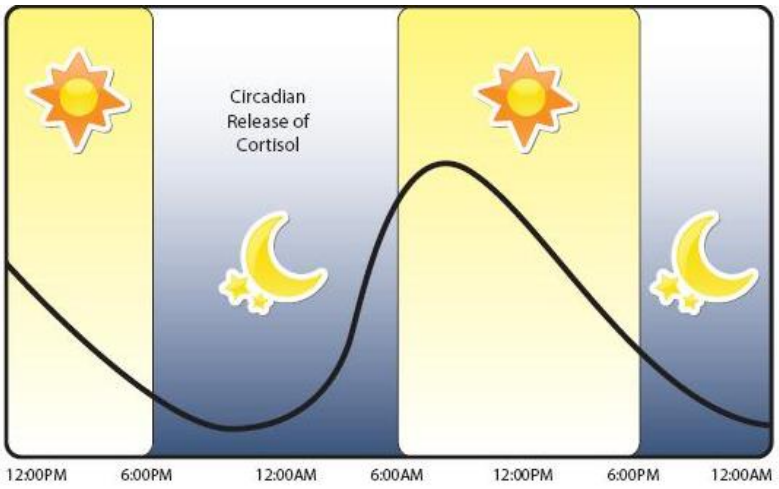

Figure 40:. The Circadian Release of Cortisol

10. It is also important to remember that the level of cortisol decreases significantly under the poor or artificial light, bringing more stress and sleepiness to the human and not giving the possibility to stabilize the energy level of the organism both in the short-term and in the long-term run (Widrich, 2016).
11. It is necessary to provide the info-sheets to the students concerning the light. From the one side, the development and spread of the info-sheets may seem the useless expenditure of money. At the same time, from the other side, it reflects responsibility that may help the students in terms of their state of health and help the universities to decrease the consumption of energy. The sample of such info-sheet can be seen in the appendix.
12. The lighting designers should consider the fenestration, façade orientation and location of the furniture to make the sunlight enter the room and fall on the bed and study area.

Of course, there are many ways to light the room, however it is important to keep in mind that the goal of the lighting specialist in the dormitory is to have a well-lit room (with ambient

comfortable lighting), with the special accent on studying area with the focused and generous pool of light.

CHAPTER 6

CONCLUSIONS

6.1. General Conclusions

The main goal of this research is to study the effects of traditional artificial lighting in dormitories on college students' physiology and productivity. The evaluation of literature and the analysis of the case studies demonstrated that universities try to focus their attention more and more on the creation of the comfortable living and studying conditions in the campus in general and in the dormitories. The examination of lighting solutions of Likins Hall of the University of Arizona, Simmons Hall of the Massachusetts Institute of Technology, and Morgens Hall of the University of Cincinnati showed that the choice of light is an integral part of comfort creation both in terms of functionality and design. The comfortable studying conditions in the dormitory within the campus serve as a foundation and favorable condition for obtaining a good education. The lighting specialists of all three dormitories focus firstly on satisfying the need of the human in natural light, as the latter has plenty of positive effects on the health. Secondly, the lighting specialists try to choose and implement the safe, efficient, and eco-friendly artificial light with minimum negative impact on the health of the inhabitants. All the analyzed universities try to ensure that the students remain healthy after obtaining the degree.

Despite the high scientific activity in the field of lighting, this science remains under-researched. Due to the novelty of different new types of lighting solutions, their impact on the health of the human is still unknown or partially known and requires additional attention. For instance, as it was previously mentioned, there are many recent studies that demonstrate the

potential dangers and threats of LED lighting for the physical and psychological health of the human in the short-term and long-term run.

6.2. Implications for Future Studies

The current study can be further expanded in the future both in terms of depth and scope. This research studies only a few examples of light in the dormitories in the United States, however, the examples of dormitories of other countries can also be considered. The good examples of some dormitories and their lighting systems are of interest, as their positive experience can be borrowed and utilized in the future. The correlation between light and energy utilization in the dormitory can also be studied in more details in the future. The progressive light systems and new kinds of lamps are also an interesting and beneficial complementation to this research.

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APPENDIX A

INTERVIEWS OF STUDENTS LIVING IN THE STUDIED DORMITORIES

(DATA COLLECTED APRIL 2018)

A. The Interview with the Inhabitant of the Likins Hall of the University of Arizona (E. T.)

How would you rate the quality of the light in your dormitory on 10 points scale? Why?

I live in the dormitory, however, I never thought about the quality of light within it. You know, there is a point of view that the person does not notice the comfort. He/she starts to pay attention to the certain issue when there is something wrong with it. For example, if the light does not work on the regular basis or if the quality of light is poor, you start to notice it. For now, I am totally satisfied with the quality of light and would rate it 10 out of 10.

What would you change in your dormitory in general and in your room in particular in terms of light? Would you improve it somehow or would you leave everything as it is?

I would leave everything as it is. I have no proposals for improvement, as everything was well-thought by the architects and the lighting professionals.

Please evaluate the access to natural and artificial light in your dormitory room.

I have a medium size window in my room. The amount of sunlight that goes through it is enough for my studying and reading purposes. I rarely study at my room in the evening, as I prefer working in the study halls. The quality of artificial light is ok for relaxation and short periods of study.

Do you think that light in your dormitory impacts your physical and psychological state?

Yes. I think it impacts me positively. For example, I like when I wake up from the sunlight. It improves my mood and makes me feel better.

B. The Interview with the Inhabitant of Simmons Hall of the Massachusetts Institute of Technology (S. H.)

How would you rate the quality of the light in your dormitory on 10 points scale? Why?

My mark would be 6 out of 10. I guess you will be surprised by such evaluation, as this dormitory is considered the architectural masterpiece. I do not like to have 9 small windows, I would prefer one large instead of 9 small, as they provide too fragmented light. Sometimes, I even associate my room with a prison cell due to these windows. I agree that from outside the building looks perfect and modern, however, from the inside, I do not like it at all, especially in terms of light.

What would you change in your dormitory in general and in your room in particular in terms of light? Would you improve it somehow or would you leave everything as it is?

I would allow decorating the room. Now, it is forbidden to paint the room, however, the paint could bring the different perception of place and different perception of light (both artificial and natural). It would be also good if the dorm provided the high-quality desk lamp for the students.

Please evaluate the access to natural and artificial light in your dormitory room.

There is access to both natural and artificial light, however, I do not consider it good, as I do not like the general approach to the architecture of the building.

Do you think that light in your dormitory impacts your physical and psychological state?

Yes. It impacts me both positively and negatively. When the weather is good, I enjoy spending the time in my room, as there is enough sunlight, it is bright and comfortable. At the same time, when the weather is bad, everything in my room is grey, sad and depressive. I try to leave the place and not to spend time there.

C. The Interview with the Inhabitant of Morgens Hall of the University of Cincinnati (P. S.)

How would you rate the quality of the light in your dormitory on 10 points scale? Why?

I would give 9 points out of 10 in terms of lighting. We have big windows with natural light practically everywhere. In my room, I switch on the artificial light only in the evening. The amount and quality of artificial light are enough for any activity. Still, I do not give 10 out of 10, because the university provides only overhead light, while the desk lamp should be bought by the student. The rooms lack the focused and regulated light.

What would you change in your dormitory in general and in your room in particular in terms of light? Would you improve it somehow or would you leave everything as it is?

I would like to have the possibility to change the intensity and brightness of the artificial light in my room. It would allow adapting the light to my activities.

Please evaluate the access to natural and artificial light in your dormitory room.

I am 100% satisfied with the access to the natural light in my dormitory room. It is even much better than at home. However, artificial light needs additional attention. However, I think that it is impossible to satisfy everyone, as people have different personal tastes and needs in terms of light. For example, my friend who comes to visit me from time to time enjoys a little bit dim atmosphere in the evening instead of bright light.

Do you think that light in your dormitory impacts your physical and psychological state?

Yes, the light definitely impacts my mood, the quality of my sleep and even my productivity. The studying conditions matter a lot to me. If they are not good, I can’t study well.

D. The Sample of the Info-sheet for the Students about Utilization of Light

Dear Students,

Our university specialists have developed for you the range of recommendations about the utilization of light in the dormitories. This simple advice is beneficial for your health, comfort, and productivity. It is in your best interest to follow them responsibly.

1) Use the natural light as much as it is possible, as it is the best natural solution for your eyes. Try to study near the window to catch the sunlight directly. The natural light is known to have a positive impact on the psychological and physical health of the person both in the short-term and in the long-term perspectives.
2) Always try to have the lights in the room on, while studying in the evening/at night. It will allow minimizing the headaches and eye strain caused by improper lighting.
3) Be careful and attentive when using the additional artificial sources of light for your dormitory rooms. Choose the color temperature depending on the performed task. If it is possible, buy the smart lighting solutions that give the possibility to regulate and adapt the light depending on the time of the day or type of the performed task.
4) Chose the energy efficient lighting solutions, as it helps to save energy.
5) Use the light responsibly. Turn off the light, when you do not use it. Switch off the devices after charging them. It will allow reducing your carbon footprint.
6) If you use the bright cold LED light, try to use the shading devices, as such an approach may help to avoid cancer, fight depression and improve mood. Please, be aware that there

are many contemporary studies that prove the negative impact of bright cold LED light on the health of the human.

7) Try to use the light with glare reducing features, as it creates unnecessary stress for the eyes. Remember that too much light is as bad as not enough light.
8) If you are left-handed, put the desk lamp to the right. If you are right handed – to the left. Such an approach will help you to decrease the shadows from the hand that may cover the studying/working surface.
9) Try not to use the too bright light (especially short-waved), as it has a negative impact on the physiology of the human. It decreases and blocks the production of melatonin, the hormone that the person needs a lot for the healthy life. Without this hormone, the risk of depression, obesity and diabetes increases. As well, the absence of this hormone increases the risk of cancer development. For instance, according to American Medical Association (2016), the women who live in the neighborhoods with higher levels of outdoor light during the night are more prone to the development of cancer, compared to those who live in the neighborhoods with lower levels of outdoor light. Basing on this statement, the American Medical Association encourages people to minimize the utilization and emission of blue light (Brienan, 2018). In the dormitories, the experts recommend using the special dimming devices in the evening.
10) Encourage and motivate your colleagues to follow the above-mentioned rules.

APPENDIX B

SURVEY RESULTS (MARCH 2019)

Is the main light source on your room provided or purchased?	Are you aware of the effect of lighting in your internal body clock (Circadian Rhythm)?
Purchased	I am totally aware of its effects
Provided	I haven't heard about something like that
Purchased	I know it exists
Provided	I haven't heard about something like that
Provided	I know it exists
Purchased	I know it exists
Purchased	I haven't heard about something like that
Provided	I am totally aware of its effects
Provided	I am totally aware of its effects
Provided	I know it exists
Purchased	I haven't heard about something like that
Purchased	I know it exists
Purchased	I know it exists
Provided	I haven't heard about something like that
Provided	I haven't heard about something like that
Provided	I am totally aware of its effects
Purchased	I haven't heard about something like that
Purchased	I know it exists
Provided	I am totally aware of its effects
Purchased	I am totally aware of its effects
Purchased	I know it exists
Purchased	I know it exists
Provided	I am totally aware of its effects
Purchased	I know it exists

What is your floor Level?	How many hours in average you spent on your room?	What does your window face?
11-15	8 to 12 hours	West
11-15	8 to 12 hours	West
5-10	8 to 12 hours	South
>15	More than 20 hours	West
>15	8 to 12 hours	South
5-10	8 to 12 hours	East
>15	8 to 12 hours	South
5-10	8 to 12 hours	South
5-10	8 to 12 hours	South
5-10	8 to 12 hours	West
>15	16 to 20 hours	East
5-10	8 to 12 hours	North
11-15	12 to 16 hours	West
11-15	8 to 12 hours	East
11-15	8 to 12 hours	West
11-15	8 to 12 hours	North
5-10	8 to 12 hours	South
11-15	12 to 16 hours	East
5-10	8 to 12 hours	South
11-15	16 to 20 hours	North
5-10	12 to 16 hours	East
>15	12 to 16 hours	South
5-10	8 to 12 hours	South
11-15	8 to 12 hours	South

How many hours do you sleep (in average)?	What is your main activity when you are home?	What is your second main activity?
7	Sleeping	Studying
6	Communicating	Studying
5	Gaming/watching TV	Sleeping
9	Communicating	Studying
8	Sleeping	Communicating
8	Sleeping	Communicating
9	Gaming/watching TV	Communicating
7	Sleeping	Gaming/watching TV
7	Sleeping	Gaming/watching TV
7	Sleeping	Gaming/watching TV
9	Gaming/watching TV	Communicating
7	Gaming/watching TV	Sleeping
6	Gaming/watching TV	Communicating
7	Sleeping	Communicating
8	Communicating	Sleeping
8	Sleeping	Communicating
8	Sleeping	Gaming/watching TV
7	Gaming/watching TV	Sleeping
8	Sleeping	Communicating
7	Studying	Gaming/watching TV
7	Sleeping	Gaming/watching TV
8	Sleeping	Studying
8	Sleeping	Studying
5	Gaming/watching TV	Gaming/watching TV

What is your third main activity?	How do you wake up?	Do you use blackout in your window so you can sleep better?
Communicating	Alarm Clock	No
Sleeping	Alarm Clock	No
Communicating	Alarm Clock	Yes
Sleeping	Alarm Clock	Maybe
Gaming/watching TV	Alarm Clock	Yes
Gaming/watching TV	Alarm Clock	No
Sleeping	By yourself	No
Studying	Alarm Clock	No
Communicating	Alarm Clock	No
Studying	Alarm Clock	No
Studying	Alarm Clock	Yes
Studying	Alarm Clock	No
Sleeping	Alarm Clock	Yes
Gaming/watching TV	Alarm Clock	Yes
Studying	Alarm Clock	Yes
Gaming/watching TV	Alarm Clock	No
Communicating	Alarm Clock	No
Studying	Alarm Clock	No
Gaming/watching TV	Alarm Clock	No
Sleeping	Alarm Clock	No
Communicating	Alarm Clock	No
Gaming/watching TV	Alarm Clock	No
Communicating	Alarm Clock	Yes
Studying	Alarm Clock	No

Are you able to bring your room into complete darkness?	Do you believe you get enough daily sunlight exposure?	Where do you usually study?
No	Yes	At Campus
No	Yes	At Campus
Yes	Maybe	In your room
Yes	No	In your room
Yes	Maybe	In the designated study ro
Yes	Yes	At Campus
No	Yes	In your room
Yes	Yes	In your room
Yes	Yes	In the designated study ro
Maybe	Yes	At Campus
No	No	In your room
No	Yes	At Campus
No	Yes	In your room
Yes	Yes	At Campus
Yes	Yes	At Campus
No	Yes	At Campus
No	Yes	At Campus
Yes	Yes	In your room
Maybe	Maybe	In the designated study ro
No	No	In your room
No	Yes	In your room
Yes	No	In the designated study ro
No	No	In your room
No	Yes	At Campus

Do you believe your academic level has changed since you moved in?
No, it is the same
No, it is the same
Yes, it has worsened
Yes, it has worsened
Yes, it has worsened
Yes, it has worsened
No, it is the same
Yes, it has improved
No, it is the same
Yes, it has improved
Yes, it has worsened
No, it is the same
Not Applicable
Yes, it has improved
No, it is the same
Not Applicable
No, it is the same
Yes, it has worsened
No, it is the same
Yes, it has worsened
Not Applicable
No, it is the same
No, it is the same
Yes, it has worsened