

**VISUAL COMFORT OF PUBLIC BOARDING SECONDARY SCHOOL  
STUDENTS IN NAIROBI CITY COUNTY, KENYA**


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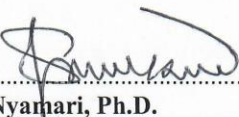
**DECLARATION**

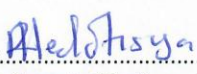
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**DEDICATION**

This work is dedicated to God for good health, ability, and patience. I also dedicate this paper to my parents: Eng. Benedict and Rev. Angela Magero, and the rest of my family: Paul, Wesley, and Daisy for their unconditional support and encouragement.

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**ABBREVIATIONS AND ACRONYMS**

<b>CFL</b>	:	Compact Fluorescent Lamp
<b>CIE</b>	:	International Commission on Illumination
<b>ISO</b>	:	International Organization for Standardization
<b>LED</b>	:	Light Emitting Diode
<b>MoE</b>	:	Ministry of Education
<b>SDG</b>	:	Sustainable Development Goals
<b>UNESCO</b>	:	United Nations Educational, Social and Cultural Organization

### **DEFINITION OF OPERATIONAL TERMS**

**Illuminance** or **illumination** (measured in **lux**) is the amount of luminous flux that falls on a specific surface area.

**Light** is the portion of the electromagnetic spectrum that the human eye can perceive.

**Luminous flux** is the quantity of light emitted by a light source.

**Luminance** is the brightness of a surface.

**Visual Comfort** refers to the satisfaction levels and well-being of occupants in relation to the visual aspects of their working environment such as the quantity and quality of light within a given space and time.

**Public Boarding** also referred to as Public Boarding High school

**Secondary School,** is a legally designated and government owned institution offering the 9<sup>th</sup> to 12<sup>th</sup> grade levels of the education cycle in Kenya's 8-4-4 school system and provide accommodation and meals for the students during the school term.

**ABSTRACT**

Indoor light quality refers to brightness and quantity of illumination in enclosed areas. Technological advancements have enabled artificial and natural light integration in schools. Light quality impacts students' visual comfort and health. Excessive or insufficient lighting may cause eye strain, light sensitivity, headaches, or musculoskeletal pain. Kenya lacks lighting standards for schools. International standards exist based on facility activities. This study assessed visual comfort among public boarding secondary school students in Nairobi City County, Kenya. Objectives included determining proportion of students reporting visual comfort or discomfort, examining associations between illumination levels and visual comfort, and establishing environmental factors associated with visual comfort. Cross-sectional analytical study design was used. 423 students were randomly sampled from 8 schools. Illumination was measured using a calibrated Benetech GM1010 light meter and compared to ISO/CIE standards. Students' perceptions were collected through self-administered semi-structured questionnaires and analysed using SPSS. Descriptive analysis involved frequency calculations. Inferential analysis used chi-squares. Findings showed 15% of respondents experienced visual comfort during the day, 13.5% at night, and 12.7% in both. 83.3% experienced at least one visual discomfort symptom. 14 of 38 classrooms achieved recommended illumination at 7:30, 20 at 13:00, and 10 at 18:00. Illumination ranged from 56.71 to 1289.93 lux. There were statistically significant associations between visual comfort and gender ( $X^2(1) = 11.805, p < .05$ ); eye problem ( $X^2(1) = 23.453, p < .05$ ); blinds on windows ( $X^2(1) = 3.982, p < .05$ ); window count ( $X^2(1) = 6.986, p < .05$ ); whiteboard ( $X^2(1) = 5.895, p < .05$ ); and classroom orientation ( $X^2(1) = 4.163, p < .05$ ) during the day; and blinds on windows ( $X^2(1) = 4.212, p < .05$ ); whiteboard ( $X^2(1) = 10.968, p < .05$ ); and seating positions ( $X^2(1) = 17.404, p < .05$ ) at night. The study recommends improving indoor illumination to promote visual comfort in schools.

## CHAPTER ONE: INTRODUCTION

### 1.1 Background to the study

The propagation of electric lighting has provided widespread access to light virtually anywhere at any time of day. The ability of light to increase the visibility of critical details of a task implies that lighting directly affects visual performance (Mujeebu, 2019). Artificial illumination is one of the most significant human technological advances. The prevalent utilisation of artificial light has adverse effects on humans, animals, and plant populations (U.S. Department of Energy, 2014). The European Committee for Standardisation (2011) defines visual comfort as a “subjective condition of visual well-being induced by the visual environment.” Visual comfort refers to the conditions necessary for an ocular system to function optimally. Consequently, it is essential to evaluate how we light architectural spaces.

The quality of light depends on six different characteristics that will make the environment ideal for the occupants. These requirements are visual performance; post-visual performances such as reading, walking, and eating; communication and social interaction; mood and comfort; aesthetic judgements; and safety and health (Samani & Samani, 2012). School-going children need the correct balance of these aspects to enhance the learning process. The visual environment affects students’ performance since it influences their ability to perceive optical stimuli and affects their mental health (Tureková, Lukáčová, & Bánesz, 2018). Educators, administrators, designers, and maintenance teams in educational institutions need to pay more attention to the illumination of interior spaces in schools depending on the rooms’ functions.

Learners spend a better part of their days in school. The school environment should cater to the children's physical, mental, and social needs. Illumination is one of the environmental factors that have a significant role in students' academic performance. About 83% of the learning process depends on sight (Gilavand, Gilavand, & Gilavand, 2016). Therefore, inadequate or excessive lighting in learning institutions may influence the students' visual performance and psychological well-being. A study in elementary schools in Iran established that schools should ensure that visual perception is undertaken with minimum discomfort and effort (Gilavand, Gilavand, & Gilavand, 2016). Adequate illumination is vital in minimising the occurrence and prevalence of health issues associated with poor or excessive lighting; hence the staff and students can focus on education.

The Sustainable Development Goals aim at providing quality education for everyone. Unfortunately, this is yet to be achieved, particularly in developing countries. According to the United Nations Educational, Social, and Cultural Organization (UNESCO, 2013), educational institutions should be safe and intellectually stimulating. Kenya aims at fulfilling the SDGs through the provision of education for all. Vision 2030, through the social pillar, aims at providing internationally competitive education and training (Aloyo, 2015). The illumination of the learning environment influences students' attentiveness and performance of visual tasks such as reading and writing. The achievement of these objectives may be achieved by maintaining a good quality of light in all learning institutions, including secondary schools.

There are recommendations for best practices for illumination in schools. However, classroom lighting is continually changing due to technological advancements (Tureková, Lukáčová, & Bánesz, 2018). The development of LED bulbs and the introduction of data projectors and whiteboards to schools call for the assessment of their influence on the quality of indoor illumination in learning institutions. The quality and quantity of light in the interior spaces of secondary schools are essential in guaranteeing the visual comfort of the students.

### **1.2 Problem Statement**

Illumination has been found to directly affect the visual comfort, productivity, mood, and overall health of human beings (Ram & Bhardwaj, 2018). Environmental factors have a 15-2-% impact as a parameter influencing public health. This aspect is only secondary to population lifestyle that has a 50% impact on human health. Inadequate and excessive lighting can result in various physiological and psychological effects including lethargy, anxiety, headaches, eyestrain, nausea, backaches, neck aches, shoulder pain, lack of mental alertness, and daytime sleepiness. The quality of illumination in the learning environment is influenced by technological developments such as the invention of LED bulbs and the introduction of whiteboards in schools (Negiloni, Ramani, & Sudhir, 2019). Students in boarding schools spend all their time within the school environment whenever the school term is in session. Consequently, schools should ensure that every architectural space meets the appropriate lighting standards to guarantee the safety and health of both the students and staff (Tureková, Lukáčová, & Bánesz, 2018). While international standards provide guidelines on optimal lighting for different learning activities, there is minimal regard for the

influence of light on visual comfort and ocular health in African countries, including Kenya. Currently, Kenya lacks lighting standards for schools. Schools, as part of the urban infrastructure, are influenced by local conditions such as geography, economic development, urban strategies, technological progress, and architectural models implemented in the region (Csobod, Eva; Annesi-Maesano, Isabella; Carrer, Paolo; Kephelopoulos, Stylianos; Madureira, Joana; Rudnai, Peter; Fernandes, Eduardo de Oliveira, 2014). Nairobi is Kenya's most populous and cosmopolitan city. Adequate infrastructure, including quality lighting of spaces, has not always accompanied the rapid expansion and urbanisation of the city. The growth of concrete slums and crowded environments may influence the schools' architectural designs, hindering the exposure of the students to natural light. Urban planning disregards the value of energy efficiency and quality illumination which is significant for visual comfort in buildings. The schools in Nairobi are located in regions with varying social classes. The disparities in lighting infrastructure can result in some regions benefiting from technological advancements such as while others languish in poor lighting conditions. Nairobi is a rapidly developing city with a higher exposure to technological advancements and urban light pollution than smaller towns. Boarders spend both day and night in the school environment hence experiencing consistent lighting conditions. These students are more likely to follow a consistent schedule with regard to study time, sleep patterns, and exposure to artificial illumination, hence creating a more homogenous population for the study. Conversely, illumination at the day scholars' homes would introduce variability that would confound the impact of illumination on visual comfort in schools. There is a paucity of studies on illumination and visual comfort in secondary schools,

hence the need to evaluate the visual comfort of the students of public boarding secondary schools. This study, therefore, assessed visual comfort in public boarding secondary schools in Nairobi City County, Kenya.

### **1.3 Justification**

The illumination of a room influences the ocular health and well-being of the people using it. Unfortunately, there is little documentation on the influence of illumination quality on health, especially in schools. The government of Kenya introduced the 100% transition from primary to secondary school policy increasing the number of students in secondary schools. Assessing the quality of light in schools is crucial due to the increasing student population that is exposed. The study sought to determine the levels of light to which students and staff in public boarding schools are exposed in Nairobi City County. The study focused on public schools since student enrolment is higher than private schools. Due to the standardised resource allocation by the government, public schools tend to have homogeneous infrastructure compared to private schools which may have broad variations in funding and facilities. Public schools accommodate students from diverse socio-economic backgrounds, providing a study population that has a broader demographic than that of private schools. Additionally, the study focused on boarding schools since these students spend most of the year within the learning facility both during the day and night whenever the school is in session. The study was conducted in Starehe and Westlands Sub-Counties in Nairobi City County since they have the highest concentration of public boarding secondary schools. The two sub-counties have a total of 16 public boarding secondary schools, which accounts for 39%

of such schools in the county. The remaining sub-counties have only four schools or less each.

#### **1.4 Research questions**

- (i). What is the proportion of students reporting visual comfort in selected buildings in public boarding secondary schools in Nairobi City County?
- (ii). What is the extent of conformity of the indoor illumination levels to the ISO/CIE standards in selected buildings in public boarding secondary schools in Nairobi City County?
- (iii). What environmental factors are associated with visual comfort in classrooms in Nairobi City County?

#### **1.5 Objectives of the study**

To assess the visual comfort of public boarding secondary school students in Nairobi City County, Kenya.

##### **1.5.1. Specific objectives**

- (i). To establish the proportion of students reporting visual comfort in the learning environment in public boarding secondary schools in Nairobi City County.
- (ii). To establish conformity of indoor illumination levels to the ISO/CIE standards in selected buildings in public boarding secondary schools in Nairobi City County.
- (iii). To establish the environmental factors associated with visual comfort in public boarding secondary schools in Nairobi City County.

### 1.6 Research Hypothesis

The study assumes that there is a significant association between the selected environmental factors and visual comfort in classrooms in schools. The following null hypotheses were tested.

*H<sub>01</sub>: Sociodemographic factor ( $S_i$ ) has no significant association with visual comfort in classrooms in public boarding schools.*

Where  $S_i$  include:

- i. Gender
- ii. Sub-County
- iii. School category
- iv. Form/ grade level

*H<sub>02</sub>: Environmental factor ( $E_i$ ) has no significant association with visual comfort in classrooms in public boarding schools.*

Where  $E_i$  include:

- v. Blinds or curtains on windows
- vi. Number of windows and doors
- vii. Number of luminaries in the room
- viii. Every lighting equipment functioning
- ix. Reflective surfaces (e.g. whiteboards and paint on wall)
- x. Orientation of the school facilities
- xi. Sitting position of the respondent

### 1.7 Significance and Anticipated Output

The purpose of the study was to assess and document the levels of indoor light exposure and its effect on visual comfort among public boarding secondary schools in Nairobi City County. It is envisaged that this study will increase the awareness of the staff and students on the levels of light they are exposed to and the consequent health effects. Additionally, the Ministry of Education and the public will have supplementary

information that will enable them to formulate policies that will ensure the health and safety of the school environment. Relevant authorities will use the information gathered to assist in the formulation of local lighting standards for schools in Kenya. The expected long-term outcome is the reduction of health risks related to inadequate or excessive light.

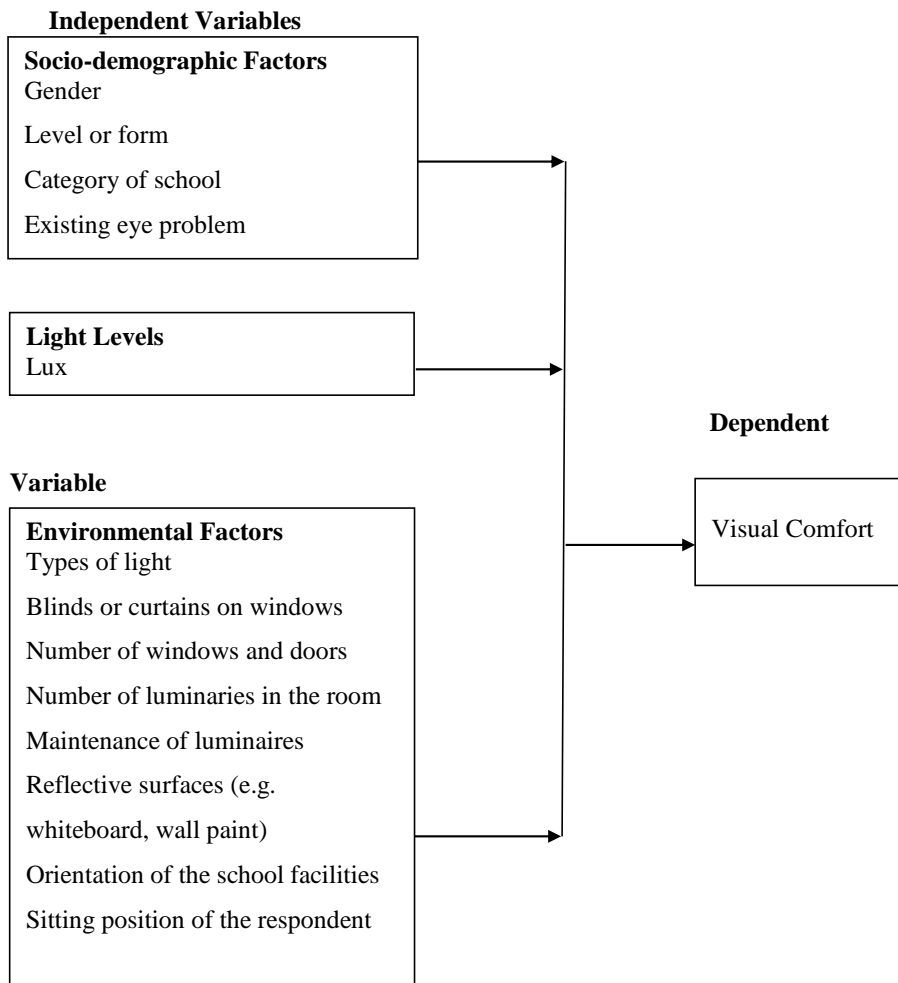
### **1.8 Limitation and delimitation**

The outbreak of the Corona Virus 19 Disease was a limitation of the study. COVID-19 control measures on social contacts and interactions led to methodological limitations. To minimise the respondents' exposure, only one person who had taken the necessary measures came into contact with the data collection materials. Measurement of the illumination levels in the selected buildings was done when the students were out of the classrooms.

### **1.9 Conceptual Framework**

The schematic diagram illustrates the various aspects that determine the levels of visual comfort of students in public boarding secondary schools. The independent variables were the socio-demographic factors, including the age, gender, form, and the category of the school of the respondents; type of light source; the illumination levels in the room; and environmental factors that may influence the quality of light such as the orientation of the school facilities, number of luminaries in the room, presence or absence of reflective surfaces such as whiteboards and the colour of paint on the walls, number of windows and doors, functioning of illumination sources, presence of blinds or curtains on windows, and sitting position of the respondent. The dependent variable in the study was visual comfort among students in public boarding secondary schools.

Visual comfort was measured by assessing the amount of light, perceived comfort of the respondent, the uniformity of light, and the existence of symptoms of visual discomfort such as eyestrain, blurred vision, red eyes, burning sensation in eyes, and headaches.



**Figure 1.1: Conceptual Framework** (Giarma, Tsikaloudaki, & Aravantinos, 2017)

## **CHAPTER TWO: LITERATURE REVIEW**

### **2.1 Introduction**

This chapter has details of the existing global and local studies on light and human health. Literature related to indoor environmental quality and its effect on the learning process and the health of the staff and students is reviewed. This chapter incorporates the various studies to identify the missing knowledge gaps that, in turn, guide the specific objectives of this research.

### **2.2 Indices for Assessing Visual Comfort**

The visual well-being of a human being depends on the physiology of the person's eye, the quantity and distribution of light in space, and the spectral emission of the illumination source. Visual comfort is evaluated through the use of aspects that characterise the relationship between the occupant's needs and the visual environment (Carlucci, Causone, De Rosa, & Pagliano, 2015). Indices for assessing visual comfort are presented below.

#### **2.2.1. Level of illumination**

An occupant requires an adequate amount of light to complete visual tasks effectively. Illumination levels that are too high or too low can result in visual discomfort (Carlucci, Causone, De Rosa, & Pagliano, 2015). Additionally, light exposure is an environmental risk factor for myopia (Zhang & Zhu, 2022). Illumination levels influence the occurrence and progression of myopia. Higher ambivalent illumination level offers protection against myopia onset for non-myopic students and slows down axial growth for both myopic and non-myopic students (Hua, et al., 2015). The light in school

facilities should be adequate for reading and performing academic tasks according to the activities in the given room.

### **2.2.2. Uniformity of light**

Proper lighting should be spread evenly over a task area to enhance visual comfort. Uneven distribution of light will increase visual stress as the eye will have to adapt to the under-lit and over-lit regions frequently (Carlucci, Causone, De Rosa, & Pagliano, 2015). The distribution of luminaries in school facilities should be uniform to ensure the even distribution of light and improve the visual comfort of the students.

### **2.2.3. Flicker**

Flicker refers to the fast and repetitive change of the brightness of a light. Flickers can result in visual discomfort, fatigue, reduced visual performance, and the triggering of some forms of epileptic seizures. The critical flicker frequency is usually at 60Hz. Flicker that is below this frequency can lead to headaches, eyestrain, and photosensitive epileptic seizures (Ticleanu & Littlefair, 2017). The human eye cannot perceive flicker that is above the critical flicker frequency. However, long-term exposure to the flickering of frequencies of over 60Hz can cause headaches, eyestrain, and visual fatigue.

### **2.2.4. Glare**

Glare is the sensation that a luminance creates that is of a higher intensity than the luminance to which the eyes are adjusted to within a given visual field (ISO & CIE, 2002). Human eyes can adjust to a broad range of illumination levels. However, a position that is too near to the line of sight and extreme light levels and luminance

contrasts can result in glare. Glare occurs when one section of the visual scene is significantly brighter than the general brightness of the rest of the field of view (Negiloni, Ramani, & Sudhir, 2019). Glare is of two types, namely disability glare and discomfort glare.

Disability glare, also known as physiological glare, occurs when there is a high luminance, especially by point light sources, in a low-luminance scene (Khademagha, Aries, Rosemann, & Jan van Loenen, 2016). Although disability glare does not directly pose any health risks, it can reduce vision or the ability to recognise objects. The observer may immediately react by squinting, blinking, or looking away. Discomfort or psychological glare occurs when there is excessive contrast between illuminated and dark regions of an observer's visual field. Discomfort glare is the most common type of glare and has adverse effects on the mood and well-being of humans (Mujeebu, 2019). It results in symptoms of visual fatigue such as ocular discomfort, annoyance, irritability, or distraction that doesn't affect the ability to see. Discomfort glare can lead to eyestrain, headaches, fatigue, neckache, backache, irritation and inflammation of the eyes and lids, itchiness, dry or watery eyes, tense muscles, and blurry or double vision.

#### **2.2.5. Quality of light in rendering colours**

Colour rendering refers to how an illumination source makes the colour of an object and the slight distinctions in the colour shades appear to human eyes. According to previous studies, human beings tend to prefer natural light over artificial light (Ma'bdeh & Al-Khatatbeh, 2019); and (Van Duijnhoven, Aarts, Aries, Rosemann, & Kort, 2019). Natural light offers great colour rendering characteristics. Natural light boosts worker satisfaction, increases productivity, and promotes energy efficiency due to the decrease

in the amount of artificial lighting utilised (Carlucci, Causone, De Rosa, & Pagliano, 2015). However, excessive daylight may result in greater luminance than the occupant requires or lead to a non-uniform distribution of light in a given visual field.

### **2.3 Criteria for the Assessment of Visual Comfort in Buildings**

Environmental performance assessment tools evaluate buildings by assessing whether there was consideration of visual comfort in the structure. Sustainable Building Tool (SBTool) is an assessment tool that rates the environmental performance of buildings. The tool includes the examination of parameters for visual comfort under the 'Indoor Environmental Quality' section, which is one of the seven topics that the tool assesses (Giarna, Tsikaloudaki, & Aravantinos, 2017). SBTool assesses daylight, glare control, appropriate illumination levels and quality of lighting, lighting controllability, and quality views. Table 2-1 highlights the specific parameters examined.

**Table 2.1: Criteria for the Assessment of Visual Comfort in SBTool (International Initiative for a Sustainable Built Environment, 2015)**

<b>Issue examined</b>	<b>Main axes of the compliance criteria</b>	<b>Type of criteria</b>
Control of glare from daylighting	Ensuring that glare conditions are minimized during periods of maximum exterior brightness (interior shading)	Quantitative (ratio of contrast in illuminance between windows and adjacent wall areas)
Appropriate illumination levels and quality of lighting	Ensuring the provision of adequate illumination levels and lighting quality and task lighting support capability	Descriptive (ambient illumination, provision for task lighting, etc.)
Controllability	Ensuring the effectiveness of facility management control system	Descriptive (existence & capabilities of management control systems)
	Confirming the ability of relative building systems to provide partial lighting services, according to design documentation	Descriptive (capability of partial or off-hours service of the system for separate areas of varying extent)
	Ensuring a satisfactory level of occupants' control over lighting conditions	Quantitative (size of lighting system control zones)
	Ensuring a maximum degree of personal control over illumination systems	Descriptive (possibility of personal control over illumination levels)
Access to exterior views from the interior	Ensuring the provision of quality views	Quantitative and descriptive (visual quality, distance of exterior objects)

#### **2.4 Indoor Lighting in Schools**

Artificial lighting is essential in secondary schools since the majority of the schools have early morning and evening classes. The number of luminaires in the room will determine the light intensity in the interior space. The positioning of the luminaires should be proportional to ensure uniform illumination on every side of the room

(Gilavand, Gilavand, & Gilavand, 2016). Additionally, the maintenance of the illumination sources may affect the quality of light. Timely replacement of light bulbs that are no longer functioning and cleaning of windows ensures the school facilities have uniform lighting and prevent the occurrence of shadows. The interior spaces of buildings in the educational institution may have reflective surfaces such as interactive whiteboards and the colour of paint on the walls that may increase the luminance in the room (Kloeppele, 2019). For instance, whiteboards may reflect directional light, resulting in glare spots that may result in visual comfort among students.

Africa has a fertility rate of 5.1% in contrast to the global average of 2.4% and a 2030 predicted population of 1.5 billion people (Aloyo, 2015). Consequently, the ever-growing population size poses a challenge in the provision of educational opportunities to every child on the continent. Inadequate school facilities negatively affect the learning process in schools. The environmental quality of schools in Africa has received very little attention from relevant agencies such as the government and administration (Aloyo, 2015). Most governments have aimed at increasing enrolment in schools regardless of the quality of the learning environment. The quality of lighting, which is an aspect of the environmental quality in schools, does not receive adequate consideration when managing schools (Ministry of Education, 2008).

The Kenyan government supervises all schools in the country through the Ministry of Education (MoE). Ideally, a secondary school has classrooms, halls, an administration block, libraries, laboratories, workshops, kitchens, canteens, hostels, staff quarters, and sanitation facilities. The ministry has a quality assurance department that inspects the

effectiveness of the learning space in educational institutions (Ministry of Education, 2012). The department assesses the various buildings in the school environment. However, it is debatable whether the inspectors have adequate training or the necessary tools to evaluate the multiple aspects of the surroundings that collaborate to influence the quality of the learning environment. For instance, assessing the quality and intensity of light involves the use of equipment such as a lux metre that the inspectors generally do not utilise during their assessments.

Comment [CM1]:

Furthermore, the government of Kenya finances the education docket in Kenya through taxes. The government pays for the tuition costs for the students and the teacher's salaries in public schools. MoE used to provide funds to principals who then supervised the building of the school facilities themselves. Conversely, some facilities may vary in size depending on the school. The MoE, through an ongoing project titled Secondary Education Quality Improvement Project (SEQIP), aims at improving infrastructure in schools all over the country (County Director of Education Nairobi City, 2019). The ministry is supervising the construction to ensure that every building matches the required building standards. The Ministry of Education determines the amount of time students spend in learning facilities. According to the Basic Education Regulations, official school hours are from 8:00 to 15:30. This allows for 9 periods of 40 minutes each (Government of Kenya, 2015). Institutions with boarding facilities have evening preps from 19:30 to 21:30. The government determines the amount of time students are exposed to the light in the facilities.

## **2.5 Environmental Factors Affecting Visual Comfort**

### **2.5.1 Types of Light**

Light can be natural or artificial. There are different kinds of indoor illumination sources. Consequently, the amount of light intensity that the occupant of the room is exposed to depends on the type of light source.

#### **Natural Light**

Natural light refers to light from the sun (Van Duijnhoven, Aarts, Aries, Rosemann, & Kort, 2019). Daylighting involves the use of openings such as windows and skylights to illuminate interior spaces using sunlight. The Ministry of Education in Kenya states that openings, which are windows and doors, should cover about 25% of the area of the walls of a room (County Director of Education Nairobi City, 2019).

#### **Incandescent Light Bulb**

This bulb is also referred to as the tungsten bulb. This bulb produces light when a tungsten filament, which is a thin wire, is heated by running electricity through it, causing it to glow brightly (Safari, Dehkordy, Kazemi, Dehghan, & Mahaki, 2015). The filament may be made of carbon, tantalum, or tungsten. This bulb is very inefficient since it discharges a lot of heat.

#### **Fluorescent light**

The luminous efficacy of fluorescent lamps is significantly higher than that of incandescent lamps. The life of fluorescent light bulbs is 8-10 times longer than that of incandescent bulbs. These luminaires can be in the form of fluorescent tubes or compact fluorescent light bulbs. Both designs follow the same operating procedure. The lamps depend on the mercury vapour pressure inside the lamp to produce light (Safari,

Dehkordy, Kazemi, Dehghan, & Mahaki, 2015). The tube conducts electricity through mercury and inert gases inside the tube, making it glow with ultraviolet light.

Consequently, the reaction excites a white phosphor coating that lines the inside of the tube, making the light white. CFLs release less heat and are more efficient than incandescent bulbs. According to Negiloni, Ramani & Sudhir (2019), children demonstrated high sensitivity to flicker in light from fluorescent lamps. Ram & Bhardwaj (2018) established that fluorescent source illumination decreases pupil size and increases visual acuity. Consequently, the choice of indoor lighting in schools may adversely influence the pupil's task performance and learning.

#### **Light Emitting Diode (LED)**

Technological developments have led to LEDs replacing the other light sources due to the increased energy efficiency. These bulbs combine a P-type semiconductor with an N-type semiconductor. When a forward voltage is applied, the semiconductors combine to release energy in the form of light. LEDs convert electric energy directly into light rather than first converting it to heat like the other illumination sources. These lamps are currently the most efficient light bulbs. Additionally, Ram & Bhardwaj (2018) determined that LED lighting improves visual task performance, mood, and students' perception of comfortable reading.

#### **Kerosene lamps**

These lamps use kerosene as fuel. The lamp has a wick that is protected by a glass chimney. The wick, which is doused in kerosene, can be manually lit. These lamps produce about 40 lumens (Shepherd & Perez, 2008). Alternatively, there are pressure

lamps that also rely on kerosene. The user pumps air pressure into the reservoir to force the paraffin into the mantle. Pressure lamps produce up to 100 lumens.

### **Candles**

A candle is a flammable wick that is inserted in wax. A candle produces about 13 lumens (Shepherd & Perez, 2008). It provides comparatively lower light than other illumination sources.

#### **2.5.2 Other Environmental Factors Affecting Visual Comfort**

Students interact with fellow students, teachers, and the schooling surface in the classroom. Therefore, special consideration should be given to the contrasts between the lighting of the work surfaces and walls to prevent luminance that may result in visual comfort. In addition to types of artificial light sources, the characteristics of the room may have an impact on the overall illuminance of the facility (Kloeppe, 2019). These aspects include the orientation of the school facilities; the number of luminaires in the room; the presence or absence of reflective surfaces such as whiteboards and the colour of paint on the walls; the number of windows and doors; the presence or absence of blinds or curtains on windows; and the maintenance of illumination sources.

The presence of adequate numbers of windows and doors will allow sufficient natural light into the school facilities. Windows should cover at least one-fifth of the surface of a room to ensure adequate natural light for reading and writing (Gilavand, Gilavand, & Gilavand, 2016). This approach is an efficient energy-saving method since it will reduce the reliance on artificial lighting during the day. The orientation of the school facilities affects the amount of sunshine that reaches the interior spaces. The school designs should aim at positioning buildings in the North-South direction to shelter the occupants

from the glare caused by the 10:00 am and 4:00 pm sun (Aloyo, 2015). However, in the case of excessive lighting, blinds, and curtains on windows may help reduce glare experienced by the students and teachers.

## **2.6 Recommended Lighting for Educational Institutions**

Different rooms within the school compound require varying levels of illumination depending on the functions and activities that the occupants conduct in the interior space. During the day, the maximisation of natural light is ideal since it is the most energy-efficient method. Since light affects human's circadian rhythms, utilisation of natural light will improve the well-being of both the teachers and the students by enhancing their productivity and concentration (Samani & Samani, 2012). Schools need to consider the positioning of doors and windows to allow for adequate natural light during the day. Utilisation of natural daylight in learning facilities is encouraged and buildings need to be oriented in the North-South direction to protect the occupants from the glare of the 10:00 am and 4:00 pm sun.

Currently, the Ministry of Education in Kenya states that school buildings should provide adequate lighting for the students and the staff. However, the country does not have specific lighting standards per room in schools. International organisations have recommended standards for various rooms depending on their functions. Additionally, visual comfort can start to decrease when illuminance is over 1000lux (Winterbottom & Wilkins, 2009). Table 2.2 shows the levels of illumination for schools as recommended by the International Organization for Standardization [ISO] and International Commission on Illumination [CIE] (ISO & CIE, 2002).

**Table 2.2: Recommended Light Levels for Educational Buildings (ISO & CIE, 2002)**

Areas		Illumination (Lux)
Classrooms		300
Classrooms for evening classes		500
Blackboard		500
Libraries	Bookshelves	200
	Reading Area	500
Laboratories		500
Computer laboratories		500
Artrooms		500 - 750

The following section breaks down the factors to consider when designing indoor lighting in learning institutions as recommended by ISO and CIE (2002).

**Classrooms:** The lighting needs to ensure visual comfort and the ability of the students and teachers to see visual tasks with speed and accuracy. These rooms require several luminaries in a row depending on the size of the classroom. The board should be equipped with separate illumination to provide teachers with adequate light (ISO & CIE, 2002). The recommended range is, therefore, 300-500 lux.

**Lecture halls and auditoriums:** The lighting system should be flexible enough to allow for its reduction during projections or special demonstrations and increased for general use.

**Artrooms:** Coloured lighting in music and art rooms improves student creativity and visual comfort. Since colour is essential, the light sources need to have a high colour rendering potential to display a more natural appearance of colours over a broad range (ISO & CIE, 2002). Exhibitions and models require supplementary lighting from directional concentrating sources.

Laboratories: Good diffusion, directional component, and appropriate colour quality are necessary. Laboratory benches where very comprehensive procedures are carried out require maximum illumination. There should be adequate and convenient outlets for portable lighting equipment essential for reading precision for instruments and microscopes. The lighting fittings should be able to withstand chemical fumes that may be produced during chemical analysis (ISO & CIE, 2002).

Libraries and reading rooms: Printed descriptive matter can be affected by reflections from overhead illumination and contrast (ISO & CIE, 2002). Therefore, high-quality light is needed. The light should reduce the concentration of light directly downward.

### **2.7 Methodological Gaps and Strengths**

A study conducted on how environmental factors in classrooms influence visual task demand on children in India sought to establish the illumination and contrast on the chalkboard (Negiloni, Ramani, & Sudhir, 2019). The illumination levels were measured in the morning between 8:30-9:30 and in the afternoon between 15:30-16:30. The measurement was taken using a calibrated lux meter. The data was collected on a bright, sunny day. The total number and placement of doors, windows, and artificial light sources were documented for each room. The student's desks were categorised as front, middle, and last desk positions. Another study was conducted on lighting and discomfort in classrooms in the United Kingdom (Winterbottom & Wilkins, 2009). Illuminance at the respondent's desks was measured by positioning a lux meter horizontally at their desk. The number of students sampled per room depended on the arrangement of the desks in the classroom. The presence of blinds or curtains and the

percentage of cloud cover were documented. The current study applied a similar methodology to these previous studies. Additionally, apart from measuring illumination levels in the morning and afternoon, the measurements were also taken in the evening to establish the light levels the students were exposed to at night.

The previous research also surveyed the learner's perception of the classroom environment. A questionnaire comprised of questions concerning chalkboard visibility and contrast, illumination levels on their desks, and glare (Negiloni, Ramani, & Sudhir, 2019). The sitting position of the student was documented. A previous study assessing visual comfort in modern university classrooms in Taiwan used a questionnaire to survey the students' perceptions (Chiou, Saputro, & Sari, 2020). The questionnaire assessed the respondents' preferences, physiological symptoms, visual annoyance, and task performance. The questionnaire used in the current study focused on similar factors when assessing student's perception of visual comfort in the learning facilities. However, this study evaluated the visibility of reading materials on the desks in addition to the visibility of the chalkboard.

The previous study in Taiwan sampled four classrooms in one building in the university (Chiou, Saputro, & Sari, 2020). This research had a small sample size which may limit generalisation. The current study focused on a larger sample size of 38 classrooms and 423 students.

## **2.8 Summary of Literature Review**

This chapter focuses on literature review and scholarly work regarding indoor light quality and its impact on visual task performance. Various types of light bulbs have

varying intensities and luminous efficacy. Various studies established that fluorescent source illumination reduces pupil size and has a high flicker frequency that children are highly sensitive to. Artificial lighting also affects visual task performance, mood, and students' perception of comfortable reading. Different rooms in a learning institution require varying illumination levels depending on the activities the students and staff will conduct. ISO and CIE (2002) provide the recommended light levels for learning institutions. The Ministry of Education in Kenya provides various policies that give guidelines on the safety and health of students and teachers in schools. However, there are no clear guidelines that give standards for the illuminance levels of the various spaces in a school compound. There is no documentation on the illumination levels of various rooms in public boarding secondary schools in Nairobi City County and their impact on visual comfort. There is a need to determine the illumination levels and compare them with the internationally set standards. Evaluating the impact of the illumination on the visual comfort of the students in public boarding secondary schools in Nairobi will assist the Ministry of Education in setting national standards.

## CHAPTER THREE: MATERIALS AND METHOD

### 3.1 Introduction

This chapter entails appropriate methodologies for the specific objectives. Data collection methods, the research design, the research area, and data analysis procedures of the study together with the reliability and validity have been described in this chapter

### 3.2 Research Design

This study used an analytical cross-sectional study design and included qualitative and quantitative approaches. Analytical research studies evaluate the cause-effect relationship between two or more variables. (Prakash, 2022). The design evaluates the association between exposure and a disease, condition, or outcome within a defined population. A cross-sectional study is confined to a single time period. This design was appropriate for this study since it entailed the measurement of the association between the exposure to illumination and the visual comfort of public secondary school students at one point in time.

### 3.3 Variables

#### 3.3.1 Independent Variables

The independent variables were categorised based on their nature and how they influence visual comfort.

#### **Socio-demographic factors**

These factors relate to the characteristics of the students and schools that may impact visual comfort.

**Gender:** physical and psychosocial factors of the different genders may influence visual comfort. The respondents were either male or female.

**Form (grade level):** academic level may affect the visual demands of the students. Senior students may have more reading intensive work and have had longer exposure to the illumination quality in the school environment. Secondary schools cater to forms one to four.

**Category of school:** the government categorisation of the school influences resource allocation, which affects the resources available for construction and lighting installation. The categories are national, extra county, county, and sub-county schools.

**Illumination levels**

These variables relate to the characteristics of the lighting environment and directly influences the visual comfort of the respondents.

**Quantity of light:** the amount of light (measured in lux) directly influences visual comfort.

**Type of light:** the source of light affects the quantity and quality of light.

**Environmental factors**

These variables relate to the physical and architectural characteristics of the room and other variables that affect the interaction of light with the space and the perception of the occupants.

**Orientation of school facilities:** The direction of the buildings affects the amount of sunshine that reaches the interior spaces.

**Luminaries in the room:** The quantity and positioning of light fixtures influence the uniformity of light distribution and illumination levels.

**Reflective surfaces:** Whiteboards can cause glare, causing visual discomfort. Walls painted with lighter colours reflect light, while darker colours absorb it, hence impacting the quantity and quality of the illumination.

**Number of windows and doors:** these openings allow for natural light. However, poorly managed windows can cause glare and uninform light distribution.

**Maintenance of luminaires:** Proper maintenance of light sources will ensure that all of them are working and that the light is consistent and uniformly distributed in the room.

**Blinds, curtains, or paint on windows:** Occupants can control the quantity of natural light entering the room, preventing glare and enhancing visual comfort.

**Sitting position of the respondent:** the location of a student's desk in relation to light luminaires, windows, and reflective surfaces influences their visual comfort.

### 3.3.2 Dependent Variable

The dependent variable in the study is visual comfort among students in public boarding secondary schools. Visual comfort was measured by assessing the amount of light, perceived comfort of the respondent, the uniformity of light, and the existence of symptoms of visual discomfort such as eyestrain, blurred vision, red eyes, burning sensation in eyes, and headaches.

The study used three indices to determine whether the respondents experienced visual comfort or discomfort. Students experienced visual comfort when they reported all of the following:

- i. Rated the amount of light at their desk as normal.
- ii. Were able to perform all the reading and writing tasks with the lighting in the learning facility.

iii. Experienced no symptom of visual discomfort.

Respondents experienced visual discomfort when they reported at least one of the following:

- i. Rated the amount of light at their desk as poor or excess.
- ii. Have limited visibility of reading and writing materials at the desks, on their boards, or at the computer.
- iii. Experienced at least one symptom of visual discomfort.

### **3.4 Study area**

The study focused on public boarding schools in Nairobi City County, Kenya. Nairobi is the capital city of Kenya and is located approximately at the centre of the country. The county has a geographical coverage of 696km<sup>2</sup> and lies between 1° 9' S, 1° 28' S and 36° 4' E, 37° 10' E. The average daily sunshine hours range from 3.4 and 9.5 hours while the average daily temperatures are from 12°C to 26°C (Aloyo, 2015). It is usually cold and dry with an average of 4 hours of sunlight per day between June and August, but hot and dry with a mean of 9 hours of sunlight per day from January to March. Due to Nairobi's proximity to the equator, the sun is directly overhead in at least two months of the year. The city's current population is 4,397,073 (Kenya National Bureau of Statistics, 2019). The high population places a significant strain on public services such as education. There is a need of ensuring that the educational institutions maintain proper environmental quality, including the illumination quality of the various buildings in the school.

### **3.5 Target population**

The target population was public boarding secondary school students.

### **3.6 Study population**

The study population was public boarding secondary school students in Starehe and Westlands Sub-counties in Nairobi City County. These sub-counties have the highest concentration of public boarding secondary schools in the county. There are 8 boys' and 8 girls' schools bringing the total number of public boarding schools in the two sub-counties to 16 (County Director of Education Nairobi City, 2019). The study population was 16038 students: 7240 boys and 8798 girls. The study focused on the indoor light quality of the learning facilities: classrooms, science and computer laboratories, art rooms and libraries.

### **3.7 Inclusion Criteria**

Current students learning in the selected schools.

Classrooms, science laboratories, computer laboratories, art rooms, and libraries in the selected schools.

Students who gave informed consent

### **3.8 Exclusion Criteria**

Students who were absent during the data collection process

Newly transferred students

### **3.9 Sampling technique**

The public boarding secondary schools were stratified along sub-counties that form Nairobi City County. Starehe and Westlands Sub-Counties in Nairobi City have the highest concentration of public boarding secondary schools in the county. This high population of the desired respondents increased the likelihood of obtaining a sample that represents the broader population, hence improving the external validity of the

study. Boys' schools had comparatively lower populations than girls' schools. Therefore, five boys' and three girls' schools were selected to ensure gender parity. Schools were randomly selected from each stratum. Table 3-1 shows the proportional sampling of students per school depending on the population of the specific school. The students were then randomly sampled from every section of the room. For instance, the rooms were divided into six or eight sections depending on the size and arrangement of the student's desks. Students were then sampled from each segment.

**Table 3.1: Sampling of Public Secondary Schools in Starehe and Westlands Sub-Counties in Nairobi City County, Kenya**

Sub-County	School	Type	Sample School	Population of Sample School	Sample Population per School
Starehe	Jamhuri High	Boys'	Dr Ribeiro	592	35
	Pumwani Boys'	Boys'	Parklands		
	Dr Ribeiro	Boys'	Jamhuri High	1061	63
	Parklands	Boys'			
	Starehe Boys' Centre				
Starehe	Pumwani Girls'	Girls'			
	Pangani Girls'	Girls'	Ngara Girls'	1392	83
	Ngara Girls'	Girls'			
Westlands	Kangemi High	Boys'	Hospital Hill	870	52
	Nairobi School	Boys'	High		
	Nairobi Milimani	Boys'	Kangemi High	531	32
	Hospital Hill		Nairobi	395	24
	High		Milimani		
	Parklands Arya	Girls'	Parklands Arya	814	49
	Highridge Girls	Girls'			
	High	Girls'			
St. George's	Girls'	State House	1438	86	
Girls'	Girls'	Girls'			
State House					
Girls'					
Kenya High					
<b>Total</b>				<b>7093</b>	<b>424</b>

The sample population of the school and the number of desk columns in a classroom determined the number of classrooms sampled per school. Number of students sampled per classroom ranged from 6 to 16. The total number of classrooms sampled was 38. One science laboratory, computer laboratory, art room, and library were sampled in each school with these learning facilities.

### 3.10 Sample Size Determination

The approximation of sample size was facilitated by the use of Fisher's *et al.* formulae (1993) as follows:

The confidence level to be used is 95%

Since the study population is more than 10,000, the following equation applies:

$$n = \frac{z^2 \times p \times q}{d^2}$$

n= sample size

z= standard normal probability for the confidence level

The confidence level used is 95% (0.95) and therefore the value of z is 1.96

p= probability of study population with desired characteristics, which is 50% (0.5)

$$q = 1 - p = 1 - 0.5 = 0.5$$

d= level of significance

$$1 - 0.95 = 0.05$$

$$n = \frac{1.96^2 \times 0.5 \times 0.5}{0.05^2} = 384 \text{ Respondents}$$

To take care of attrition:

$$n = 384 \times 110\% = 423 \text{ Respondents}$$

### 3.11 Pre-Testing

The data collection tools developed were pilot-tested in Nembu Girls' High School in Dagoretti Sub-County, Nairobi City County. The school was selected because of its strategic location and because it is a public boarding school in Nairobi City County. The sample size of the pretest was 22 participants. The main point of interest during the pre-testing of the tools was the ease with which each question was understood by the respondent. Additionally, the accuracy of the information collected, appropriateness of

the questions, format of the questionnaire and length of time taken to dully fill the questionnaire were essential in assessing the reliability of the data collection tool. Consequently, the tools were revised after testing to reflect any change conceived during the pre-test.

### **3.12 Validity**

Content validity was ensured by using the supervisors' judgement to compare the content of the research instruments to the study objectives. A pre-test of the research instruments was conducted and necessary adjustments were made to the instruments to enhance their validity. The respondents selected for the pre-test were not part of the final survey. The lux metre was correctly calibrated and tested daily throughout the data collection period.

### **3.13 Reliability**

Research assistants were trained on administering the questionnaire and taking light meter readings. Ensuring the clarity and sustainability of the language used was essential in guaranteeing the reliability of the instrument. The illuminance levels were measured at the same time frame under similar weather conditions to ensure the reliability of the data collected by the lux metre.

### **3.14 Data Collection Techniques**

An observational checklist (see Appendix 1) was used to make a record of the type of light source used, the position of light switches, the presence or absence of blinds or curtains, the kind of board used, whether all the luminaires were working, the total number and positioning of the doors, windows, and luminaires, and the general maintenance of the lighting equipment.

Illuminance was measured using the Benetech GM1010 Split Light Meter. The source of light, whether natural or artificial, was noted before the illumination levels were measured. The measurement recorded was the light the students were exposed to at the time without any modification. To enable representative sampling across the room, it was then divided into six or eight sections depending on the size and arrangement of the student's desks. Measurements were taken from each section by positioning the light metre horizontally on students' desks. The illumination levels were measured thrice in a single day: between 7:00-8:00; between 13:00-14:00; and between 17:30-18:30 (Negiloni, Ramani, & Sudhir, 2019). Figure 3.1 shows the Benetech GM1010 Split Light Meter.



**Figure 3.1: Benetech GM1010 Split Light Meter**

Additional primary data was collected using a questionnaire (see Appendix 2). The questionnaire sought to determine the influence of the quality of illumination on the physiological symptoms, perceptions of the brightness, and task performance of the respondents. The questionnaire was based on the parameters used in SB Tool to assess visual comfort. The questionnaire was semi-structured and self-administered by the respondents and comprised three sections. The first section involves questions on the respondents' socio-demographic factors such as sex, age, name of the school, and the

desk position in the classroom. The subsequent section sought to assess the task performance of the respondents by evaluating the visibility of the blackboard or whiteboard, glare, and their level of comfort with the existing illumination levels. The last part of the questionnaire addressed the possible symptoms of inadequate or excessive lighting in classrooms. The questionnaire was designed in English. The respondents received oral instructions in English and Swahili to ensure the questions were well understood prior to receiving the questionnaires from the researcher before class sessions began. The students then completed the questionnaire and returned it to the investigator during class breaks.

### **3.15 Data analysis**

The illumination values collected by the lux metre were compared to the existing international standards by ISO & CIE (2002).

Each category of responses in the questionnaire was coded and assigned numbers or letters for ease of data entry and processing. Open-ended questions were coded into categories. Additionally, the respondents categorised their perception of the lighting levels at their desks as poor, normal, or excessive illumination as was done in previous studies (Negiloni, Ramani, & Sudhir, 2019).

Statistical Package for the Social Sciences (SPSS) version 23.0 and Microsoft Excel 2013 were used in data entry, processing and analysis. Data was presented using frequencies, cross-tabulation, figures and tables. Descriptive statistics was used to analyse and summarise data to measure central tendency and spread. Pearson chi-square analysis was used to establish the association between environmental factors influencing visual comfort in learning institutions.

### **3.16 Ethical Considerations**

Approval to undertake this study was acquired from the graduate school of Kenyatta University.

Ethical approval was sought from Kenyatta University Ethics and Research Committee (KUREC) (see Appendix 8).

A research permit was obtained for the National Council for Science and Technology (NACOSTI) (see Appendix 5), the Office of the Governor of Nairobi City County, and the County Department of Education of Nairobi City County (see Appendix 9).

Consent was sought from the relevant school principals and teachers before accessing the respondents. The researcher sought informed consent from all participants. There was confidentiality and anonymity for all participants in the study. (see Appendix 1).

## **CHAPTER FOUR: RESULTS**

### **4.1 Introduction**

This chapter presents the findings of the study based on the study objectives. The data was thematically organized and presented graphically to show the relationships among study variables. Chi-square analysis was conducted to establish the associations between the various environmental factors influencing visual comfort.

### **4.2 Response rate**

A total of 401 dully filled and usable questionnaires out of 423 were obtained from respondents for the study. This represented a 94.8% response rate and a non-response rate of 5.2%. According to Mugenda and Mugenda (2003), this return rate was sufficient for the analysis. The high response rate can be attributed to the data collection procedures. The researcher informed the respondents of the planned survey prior to giving them the self-administered questionnaires. 38 classrooms, 8 science laboratories, 6 computer laboratories, 6 libraries, and 4 art rooms were analysed. Students had designated sitting positions in classrooms only. Sitting locations were randomized during each session in the remaining learning facilities. Only data collected from classrooms were included in the analysis since illumination level data and questionnaire responses were collected from the exact sitting locations.

### **4.3 Socio-demographic Information**

Table 4-1 presents the socio-demographic information of the respondents based on gender, the school category, the sub-county within which the school is located, and their form or grade level. Students from extra county schools accounted for 369, while 32 were from county schools. This indicates that most of the schools in the area are extra

county, which usually receive higher financial allocation than lower ranked schools. 172 respondents came from schools in Starehe Sub-County, while 229 were from Westlands Sub-County. This distribution was based on the number of schools per sub-county. There were 193 male students and 208 female students. This indicates that there was a gender balance in the distribution of the respondents.

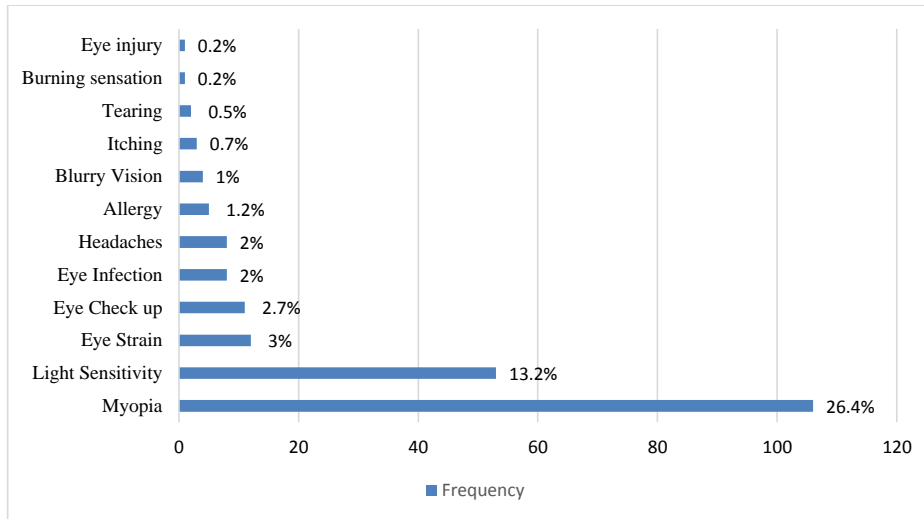
Of the 401 students, 129 were in form one, 107 in form two, 85 in form three, and 80 in form four. The number of classroom streams tended to be progressively higher in Form 1 than in Form 4. This is an indication of an upsurge in enrolment in secondary schools due to the 100% transition from primary to secondary policy by the Kenyan Government.

43.14% (173) of the students had existing eye problems that had been addressed by an eye doctor. This indicates that more than half of the respondents had yet to seek medical attention due to the effects of poor or excessive lighting, or they have not been majorly affected by the quality of illumination in schools.

**Table 4.1: Socio-demographic Information**

	<b>Variable</b>	<b>Frequency (Percent)</b>
Gender	Male	193 (48.1%)
	Female	208 (51.9%)
Sub-County	Starehe	172 (42.9%)
	Westlands	229 (57.1%)
School Category	Extra County	369 (92%)
	County	32 (8%)
Form (Grade level)	1	129 (32.2%)
	2	107 (26.7%)
	3	85 (21.2%)
	4	80 (20%)
Existing eye problem	Visit to an eye doctor	173 (43.1%)
	No visit to an eye doctor	228 (56.9%)

Figure 4.1 presents results on the reasons respondents visited an eye doctor. Results indicate that the most common eye problems were myopia (26.43%) and light sensitivity (13.22%).



**Figure 4.1: Reason for a visit to an eye doctor**

#### 4.3.1. Sociodemographic Characteristics and Visual Comfort during the Day

##### (i). Gender

The null hypothesis was rejected,  $X^2(1) = 15.657$ ,  $p < .05$ . The phi value  $> .10$ . There was a significant association between gender and visual comfort during the day. The association was weak.

##### (ii).Sub-county

The null hypothesis was accepted,  $X^2(1) = .599$ ,  $p > .05$ . There was no association between the sub-county where the school is located and visual comfort during the day.

(iii). School category

The null hypothesis was rejected,  $X^2(1) = 10.299$ ,  $p < .05$ ). The phi value  $> .15$ . There was a significant association between school category and visual comfort during the day. The association was strong.

(iv). Form (Grade level)

The null hypothesis was accepted,  $X^2(1) = .660$ ,  $p > .05$ ). There was no association between form (grade level) and visual comfort during the day.

(v). Existing eye problem

The null hypothesis was rejected,  $X^2(1) = 28.497$ ,  $p < .05$ ). The phi value  $> .25$ . There was a significant association between existing eye problems and visual comfort during the day. The association was very strong.

#### **4.3.2. Sociodemographic Characteristics and Visual Comfort at Night**

(i). Gender

The null hypothesis was rejected,  $X^2(1) = 10.391$ ,  $p < .05$ ). The phi value  $> .10$ . There was a significant association between gender and visual comfort at night. The association was weak.

(ii). Sub-county

The null hypothesis was accepted,  $X^2(1) = 2.110$ ,  $p > .05$ ). There was no association between the sub-county where the school is located and visual comfort at night.

(iii). School category

The null hypothesis was accepted,  $X^2(1) = 2.110$ ,  $p > .05$ ). There was no association between the school category and visual comfort at night.

(iv). Form (Grade level)

The null hypothesis was accepted,  $X^2(1) = .660$ ,  $p > .05$ ). There was no association between form (grade level) and visual comfort at night.

(v). Existing eye problem

The null hypothesis was rejected,  $X^2(1) = 26.101$ ,  $p < .05$ ). The phi value  $> .25$ . There was a significant association between existing eye problem and visual comfort at night. The association was very strong.

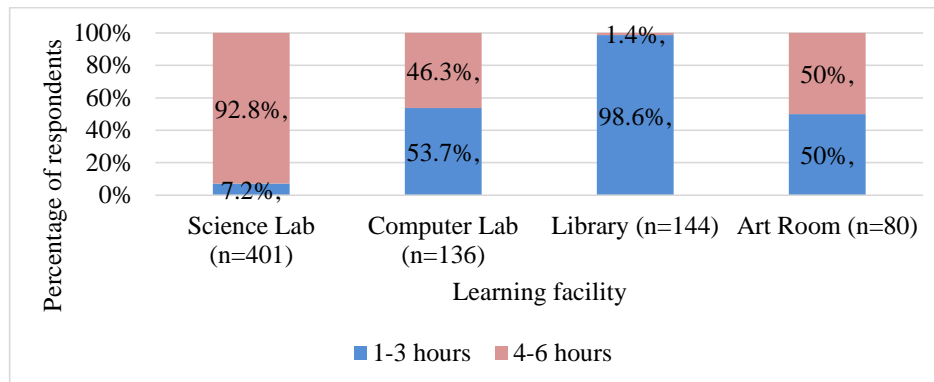
#### **4.4 Duration of exposure to light in learning facilities**

Figure 4.2 presents the proportion of students according to the hours spent in each learning facility in a week. The results indicate that the length of one lesson, which is 40 minutes, is uniform across all schools in Kenya. Although some learning facilities are not used daily by students, they are used at varying degrees during the week based on the school timetable per the Ministry of Education requirements. Consequently, the study sought to establish the number of lessons the respondents spent in the facilities in a week.

Every school follows the regulations stipulated by the Ministry of Education. The students have nine 40-minute lessons and two-hour-long evening preps every weekday. This time adds up to 40 hours per week in learning facilities. All the respondents use classrooms daily. During school hours, classrooms are the default rooms that students use when they are not in science laboratories, computer laboratories, libraries, or art rooms.

100% of the respondents use classrooms and science laboratories. 136 students use the computer laboratories, 144 use the libraries, and only 80 respondents use the art rooms.

Of the 8 schools, all had science laboratories, 6 had computer laboratories, 6 had libraries, and 4 had art rooms.

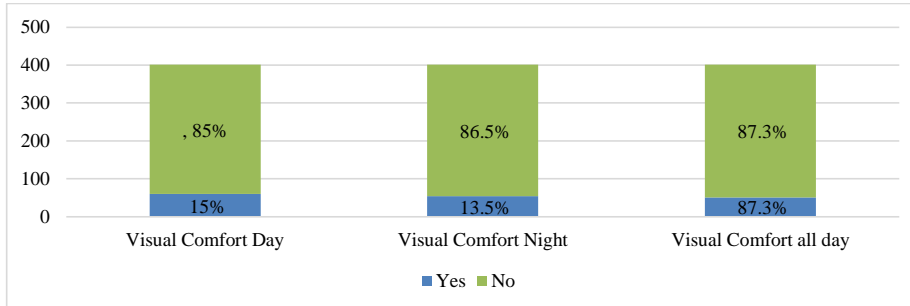


**Figure 4.2: Duration (hours) of exposure to light in learning facilities**

#### 4.5 The Proportion of Students Reporting Visual Comfort

##### 4.5.1. Students Reporting Visual Comfort

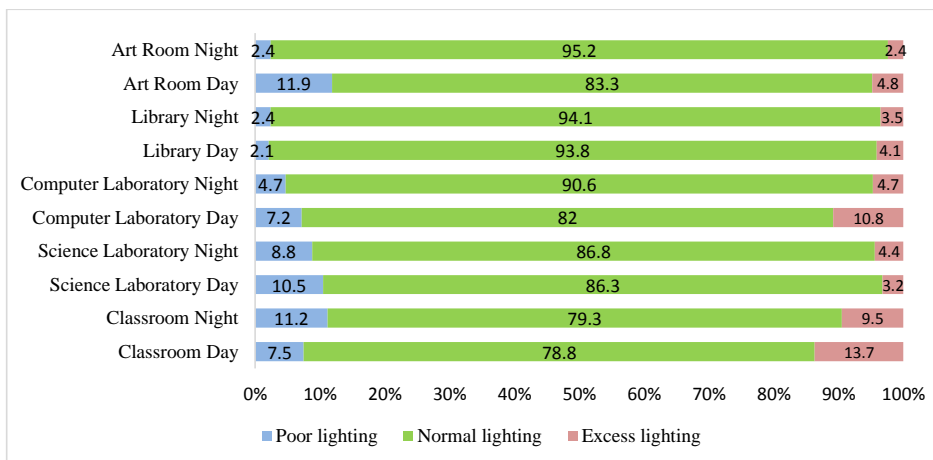
The study used three indices to determine whether the respondents experienced visual comfort or discomfort: Rating of light, task performance and symptoms of visual discomfort. Figure 4.3 presents the results on the proportion of students experiencing visual comfort. The results indicate that 15% of the respondents experience visual comfort during the day, 13.5% at night, and 12.7% in both day and night. A majority of the students experience visual discomfort in classrooms.



**Figure 4.3: Proportion of students experiencing visual comfort**

**4.5.2. Rating Amount of Light at the Desk**

Respondents were asked to rate the amount of light they receive at their desks during the day and at night. This was intended to assess whether they were comfortable with the amount of light they were exposed to in various learning facilities. Figure 4.4 presents results on the rating of the amount of light at the student’s desk. Results indicate that at least 78% of the students stated that the light they receive at their desks is normal both during the day and night. This means that the majority of the students claim to be comfortable with the amount of light they receive.

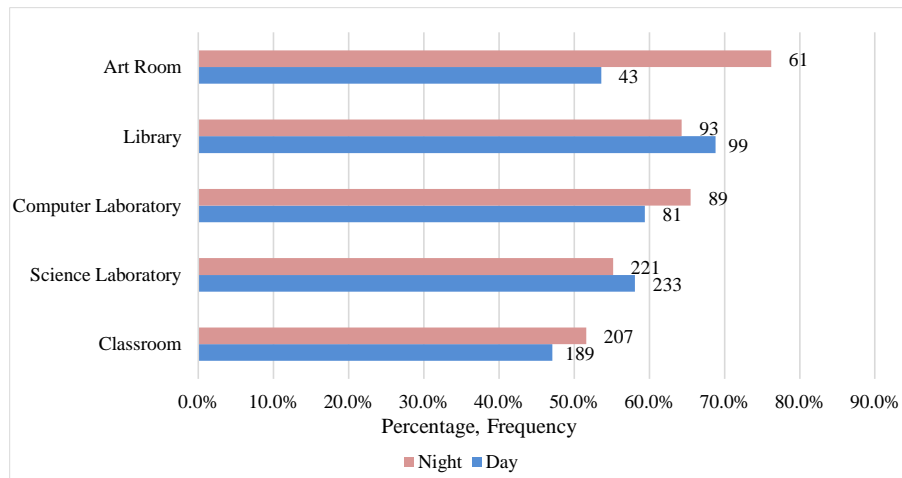


**Figure 4.4: Rating the amount of light at the desk**

### 4.5.3. Task Performance

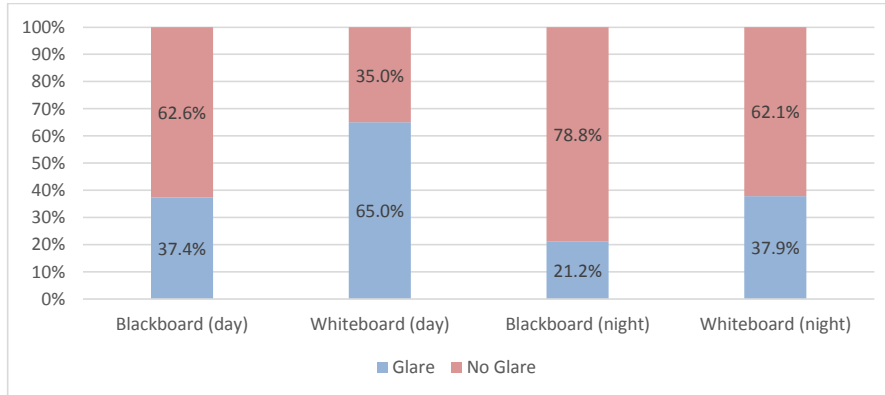
#### i. Visibility of boards

Figure 4.5 presents results on the visibility of blackboards and whiteboards. Results indicate that classrooms had the lowest proportion of students (47.1% during the day and 51.6% at night) who could see everything written on the boards. The percentage of students reporting having the ability to read everything written on boards increases at night in classrooms. This implies that there is adequate artificial lighting on the boards at night. Reduced ability to perform visual tasks lowers the visual comfort of the students.



**Figure 4.5: Visibility of boards**

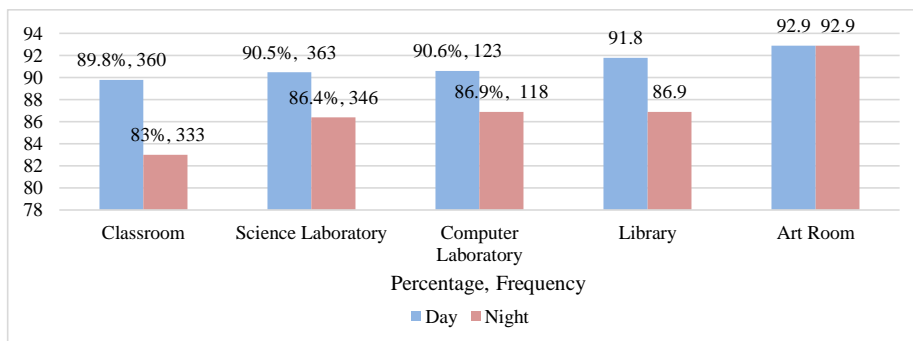
Additionally, the study compared the presence of blackboards and whiteboards and respondents experiencing glare. Figure 4.6 presents the results on the proportion of students experiencing glare from whiteboards and blackboards in classrooms. The results indicate that whiteboards increase the probability that the users will experience glare both during the day and night.



**Figure 4.6: Respondents experiencing glare from boards**

#### ii. Visibility of reading materials on learners' desks

Figure 4.7 presents results on the visibility of reading materials on their desks. Results indicate that classrooms had the lowest proportion of students (89.8% during the day and 83% at night) who were able to see everything written on their reading materials on their desks. This implies that the ability of students to see reading materials on their desks reduces at night. This may be due to lower illumination levels of artificial light sources at night. Reduced ability to perform visual tasks lowers the visual comfort of the students.



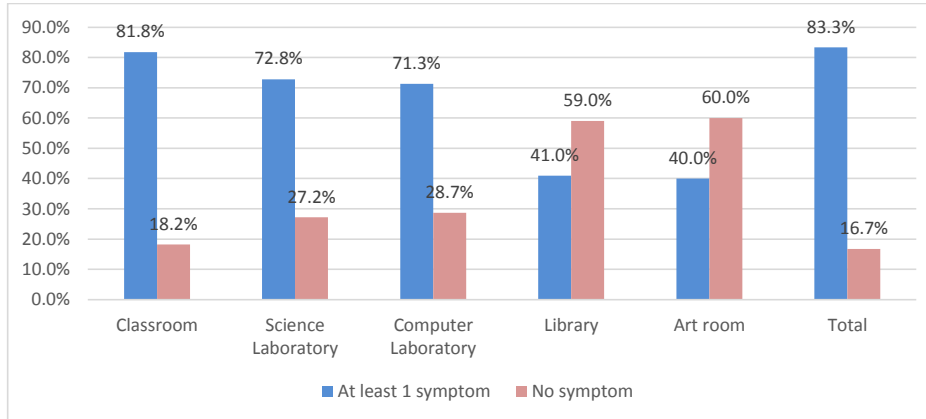
**Figure 4.7: Visibility of reading materials**

**iii. Visibility of the computer**

Results indicate that no school had computers in any other room besides the computer laboratory. 70.5% of the computer laboratory users during the day and 79.7% at night could see everything written on the computer. This implies that computer laboratories had adequate indoor illumination.

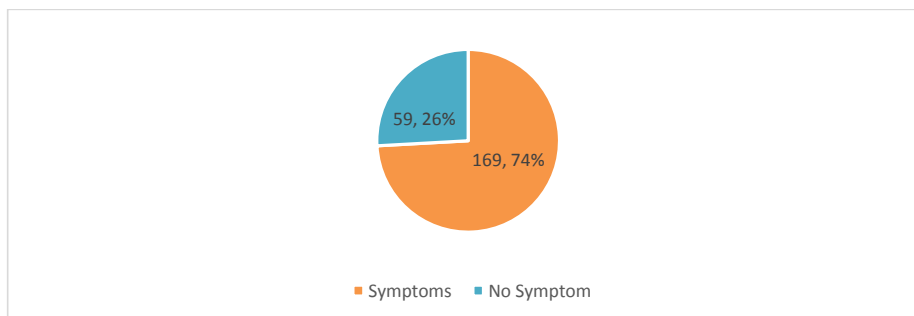
**4.5.4. Symptoms of Visual Discomfort**

The purpose of this segment was to establish the number of participants who experienced at least one physiological symptom during learning sessions. Figure 4.8 presents results on the proportion of respondents experiencing at least one physical symptom. Results indicate that 334 (83.3%) students reported experiencing at least one physical symptom in a school facility. Classrooms had the highest proportion of respondents who experienced at least one physical symptom at 81.8% in classrooms. This can be attributed to the fact that students spend considerably more extended time in classrooms than in any other learning facility. Also, a higher percentage (92.8%) of the respondents use science laboratories for 4-6 hours a week. This affects the visual comfort or discomfort of the respondents. Computer laboratories have computers whose screens produce artificial light that increases the probability of visual discomfort.



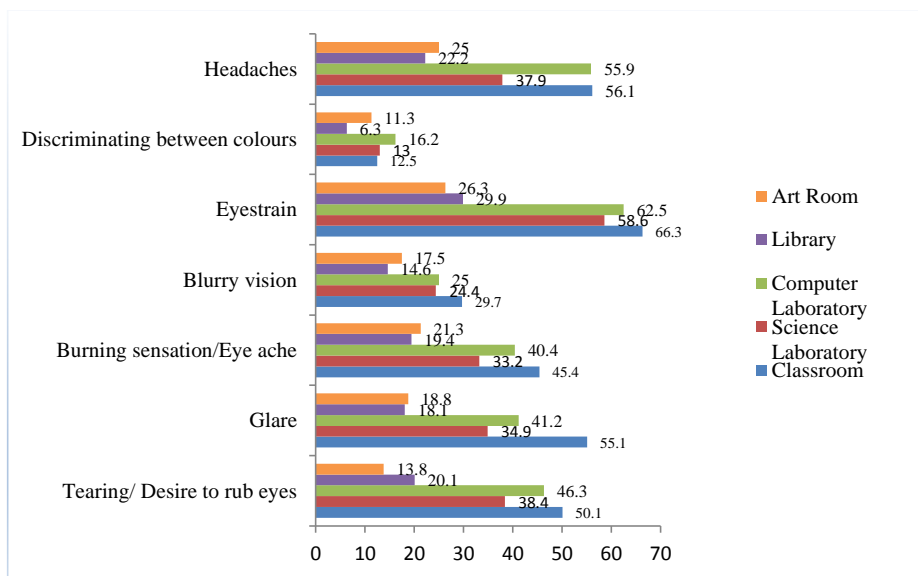
**Figure 4.8: Respondents experiencing at least one physical symptom**

Figure 4.9 presents the proportion of respondents experiencing at least one physiological symptom of visual discomfort among those who have not visited an eye doctor. The results indicate that of the 228 students who have not visited an eye doctor, 169 (74.1%) of them have at least one symptom. This implies that although 56.9% of the respondents have not visited an eye doctor, many are still experiencing physical symptoms of visual discomfort. Some respondents may have yet to seek medical attention for the effects of poor or excessive lighting, or they have not been majorly affected by the quality of illumination in the learning facilities.



**Figure 4.9: Occurrence of symptoms among respondents without visit to an eye doctor**

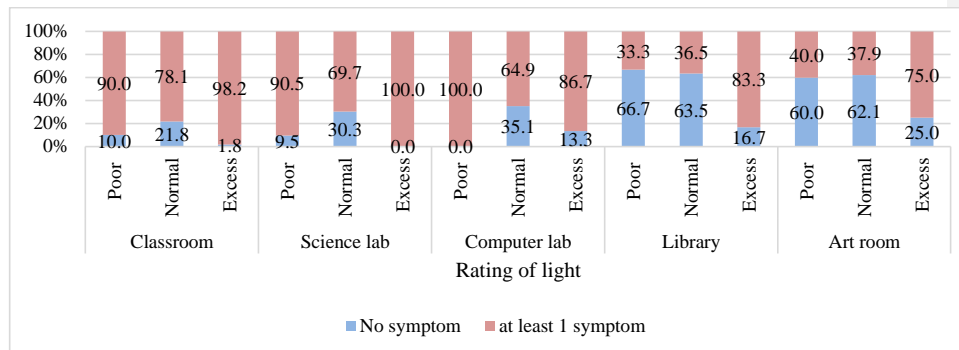
Figure 4.10 presents the results on the symptoms of visual discomfort. The results indicate that the most common symptom in all learning facilities was eyestrain. That is 66.3% in classrooms, 58.6% in science laboratories, 62.5% in computer laboratories, 29.9% in libraries, and 26.3% in art rooms. Other common symptoms are headaches, glare, tearing, and desire to rub eyes. The least common symptom in all learning facilities is difficulty discriminating between colours. That is 12.5% in classrooms, 13% in science laboratories, 16.2% in computer laboratories, 6.3% in libraries, and 11.3% in art rooms.



**Figure 4.10: Symptoms of visual discomfort**

The result from this section was compared to the student's perception of the visual comfort level to help verify whether physiological symptoms are associated with feelings of discomfort. Figure 4.11 presents the results on the rating of light and the percentage of respondents reporting at least one symptom of visual discomfort. The

results indicate that the highest percentage of respondents who reported experiencing no symptoms also rated the light as normal in every learning facility.



**Figure 4.11: Rating of light and occurrence of symptoms of visual discomfort**

Duration of exposure was then compared to the occurrence of at least one symptom of visual discomfort to establish whether the duration of exposure to light influences the occurrence of symptoms of visual discomfort. Table 4.2 presents the results on the relationship between the duration of exposure and the occurrence of symptoms of visual discomfort. The results indicate that a higher number of students who spend 4-6 hours in science laboratories (74.7%) and computer laboratories (79.4%) experience at least one symptom of visual discomfort. This implies that spending more time in the learning facilities increases the probability of respondents experiencing at least one physical symptom of visual discomfort.

**Table 4.2: Duration of exposure and occurrence of symptoms of visual discomfort**

Learning facility	Duration (hours)	Symptoms of visual discomfort	
		No symptom Frequency (Percent)	At least one symptom Frequency (Percent)
Science Laboratory	1-3	15(51.7)	14(48.3)
	4-6	94(25.3)	278(74.7)
Computer Laboratory	1-3	27(37)	46(63)
	4-6	13(20.6)	50(79.4)
Library	1-3	88(62)	54(38.0)
	4-6	0 (0)	2(100)
Art room	1-3	22(55)	18(45)
	4-6	26(65)	14(35)

#### 4.5.5. Visual comfort and existing eye problems

Various indicators of visual comfort were compared to the prevalence of existing eye problems. Table 4.3 presents the results on visual comfort and existing eye problems. The results indicate that the highest percentage of students (59.8%) did not have existing eye problems and rated the light at their desks as normal. Respondents with eye problems also reported poor visibility of the boards (57.3%) and reading materials (70.7%). Symptoms of visual discomfort were also more prevalent among students with existing eye problems, with 71.9% reporting the occurrence of at least one symptom during the day while 50% reported at night. This indicates that visual comfort is difficult to achieve for students with existing eye problems. This aligns with the prevalence of myopia and light sensitivity as the most common symptoms since illumination is an environmental risk factor for myopia.

**Table 4.3: Visual comfort and existing eye problems**

Indicators of visual comfort	Time		Existing eye problem	
			Yes	No
<b>Rating of Light</b>	Day	Poor	15 (50.0%)	15 (50.0%)
		Normal	127 (40.2%)	189 (59.8%)
		Excess	31 (55.4%)	25 (44.6%)
	Night	Poor	25 (55.6%)	20 (44.4%)
		Normal	128 (40.3%)	190 (59.7%)
		Excess	20 (52.6%)	18 (47.4%)
<b>Visibility on board</b>	Day	Yes	52 (27.4%)	138 (72.6%)
		No	121 (57.3%)	90 (42.7%)
	Night	Yes	60 (29.0%)	147 (71.0%)
		No	113 (58.2%)	81 (41.8%)
<b>Visibility of reading materials</b>	Day	Yes	144 (40.0%)	216 (60.0%)
		No	29 (70.7%)	12 (29.3%)
	Night	Yes	132 (39.6%)	201 (60.4%)
		No	41 (60.3%)	27 (39.7%)
<b>Symptoms of visual discomfort</b>	Day	Yes	164 (71.9%)	64 (28.1%)
		No	9 (5.2%)	164 (94.8%)
	Night	Yes	164 (50.0%)	164 (50.0%)
		No	9 (11.0%)	73 (89.0%)
<b>Visual Comfort</b>	Day	Yes	7 (11.7%)	53 (88.3%)
		No	166 (48.7%)	175 (51.3%)
	Night	Yes	6 (11.1%)	48 (88.9%)
		No	167 (48.1%)	180 (51.9%)

#### 4.6 Conformity of indoor illumination levels to the ISO/CIE standards

The illumination levels in the facilities differed at different times of the day. The results were compared to the ISO and CIE standards. Since visual comfort can start to decrease when illuminance is over 1000lux, levels above 1000 were noted.

##### 4.6.1. Light levels in classrooms

The recommended level for classrooms is 300 lux. Table 4.4 presents results on the mean classroom illumination levels per school. Results indicate that only 2 schools recorded a mean of more than 300lux in the morning. In the afternoon, 6 schools recorded illumination levels above the recommended level. In the evening, only one

school achieved the recommended illumination level. The mean illumination of 4 schools had achieved the recommended level. This implies that natural light in the afternoon contributes to the high number of schools that meet the recommended light levels. The lower levels of natural light in the morning and evening contributed to the high number of schools whose light is lower than the recommended levels.

**Table 4.4: Light levels in classrooms per school**




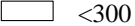

School	Light level (Lux)			Mean
	7:30	13:00	18:00	
Jamhuri High	291.34	959.34	423.44	558.04
Dr. Ribeiro Parklands	278.31	557.34	128.44	321.36
Ngara Girls	232.63	335.12	217.74	261.83
Hospital Hill	219.04	263.69	173.29	218.68
Kangemi High	218.05	268.26	206.51	230.94
Parklands Arya	295.22	314.17	284.77	298.05
State House Girls	469	347.99	234.15	350.38
Nairobi Milimani	383.47	374.42	273.37	343.75
<b>Mean</b>	305.92	426.11	243.63	325.22
<b>Legend</b>	 >300	 <300		

Table 4.5 presents results on the mean illumination levels in the classrooms. Results indicate that of the 38 classrooms, 14 classrooms achieved the recommended illumination level at 7:30, 20 classrooms at 13:00, and 10 classrooms at 18:00. 1 classroom recorded more than 1000 lux at 7:30 and 4 at 13:00. The lowest levels recorded were 115.31 lux at 7:30, 66.91 lux at 13:00, and 56.71 at 18:00. The highest levels recorded were 1289.93 lux at 7:30, 1141.9 lux at 13:00, and 651.09 at 18:00. 19 classrooms had a mean that achieved the recommended levels.

**Table 4.5: Light levels in classrooms**



School	Classroom	Light level (Lux)			Mean
		7:30	13:00	18:00	
Jamhuri High	1	275.85	936.33	629.92	<b>614.03</b>
	2	149.22	464.69	117.61	<b>243.84</b>
	3	325.97	1127.58	485.42	<b>646.32</b>
	4	380.44	1126.17	485.48	<b>664.03</b>
	5	325.23	1141.90	398.80	<b>621.98</b>
Dr.Ribeiro Parklands	1	293.85	537.97	154.99	<b>328.94</b>
	2	259.48	1032.25	124.78	<b>472.17</b>
	3	187.93	332.91	116.32	<b>212.38</b>
	4	371.97	326.23	117.68	<b>271.96</b>
Ngara Girls	1	115.31	66.91	112.24	<b>98.15</b>
	2	302.83	382.44	293.61	<b>326.29</b>
	3	245.81	258.67	226.08	<b>243.52</b>
	4	243.85	665.99	228.49	<b>379.44</b>
	5	272.80	400.34	247.14	<b>306.76</b>
	6	215.16	236.35	198.85	<b>216.79</b>
Hospital Hill	1	184.43	159.37	223.48	<b>189.09</b>
	2	135.14	158.51	142.78	<b>145.48</b>
	3	172.81	271.24	141.72	<b>195.26</b>
	4	332.56	214.11	67.80	<b>204.82</b>
	5	270.28	515.23	290.68	<b>358.73</b>
Kangemi High	1	390.38	368.89	276.48	<b>345.25</b>
	2	145.61	225.55	171.05	<b>180.74</b>
	3	192.06	269.61	160.70	<b>207.46</b>
	4	144.17	208.98	217.83	<b>190.33</b>
Parklands Arya	1	151.86	154.01	148.54	<b>151.47</b>
	2	314.95	385.92	333.31	<b>344.73</b>
	3	312.74	354.38	317.60	<b>328.24</b>
	4	401.34	362.37	339.62	<b>367.78</b>
State House Girls	1	168.84	201.18	56.71	<b>142.24</b>
	2	1289.93	487.73	308.84	<b>695.50</b>
	3	556.83	543.35	651.09	<b>583.76</b>
	4	179.73	381.71	169.93	<b>243.79</b>
	5	295.15	125.76	95.94	<b>172.28</b>
	6	207.87	424.63	202.75	<b>278.42</b>
Nairobi Milimani	1	319.33	365.65	299.99	<b>328.33</b>
	2	469.78	304.17	265.23	<b>346.39</b>
	3	321.76	605.42	385.58	<b>437.59</b>
	4	423.00	222.46	142.67	<b>262.71</b>

**Legend**       >300       <300       >1000

#### 4.6.2. Light levels in science laboratories

The recommended level for science laboratories is 500 lux. Table 4.6 presents results on the mean illumination levels in the science laboratories. Results indicate that only one school met the recommended level in the morning. No school recorded the recommended illumination level in the afternoon and evening. No school had mean illumination that met the recommended level.



**Table 4.6: Light levels in science laboratories**

School	Light level (Lux)			Mean
	7:30	13:00	18:00	
Jamhuri High	337.38	380.84	305.44	341.22
Dr.Ribeiro Parklands	149.16	179.95	188.79	172.63
Ngara Girls	271.15	300.93	255.68	275.92
Hospital Hill	124.49	205.38	29.49	119.78
Kangemi High	331.75	356.49	277.58	321.94
Parklands Arya	320.89	341.64	266	309.51
State House Girls	564.28	434.95	339.21	446.15
Nairobi Milimani	221.44	253.23	219.83	231.5
<b>Mean</b>	290.07	306.67	235.25	277.33
<b>Legend</b>	 >500	 <500		

#### 4.6.3. Light levels in computer laboratories

The recommended level for computer laboratories is 500 lux. Table 4.7 presents results on the mean illumination levels in the computer laboratories. Results indicate that no school met the recommended levels at any time of day. No school had mean illumination that met the recommended level.



**Table 4.7: Light levels in computer laboratories**

School	Light level (Lux)			Mean
	7:30	13:00	18:00	
Jamhuri High	316.54	384.25	343.18	347.99
Dr.Ribeiro Parklands	106.48	102.04	111.93	106.81
Ngara Girls	290.36	375.68	299.8	321.95
Hospital Hill	357.48	370.06	323.11	350.22
State House Girls	105.55	248.63	133.68	162.62
Nairobi Milimani	222.08	259.99	197.7	226.59
<b>Mean</b>	233.08	290.11	234.9	252.69
<b>Legend</b>	 >500	 <500		

**4.6.4. Light levels in libraries**

The recommended level for libraries is 500 lux. Table 4.8 presents results on the mean illumination levels in the classrooms. Results indicate that only one school had illumination levels above the recommended standards in the morning and afternoon. In the evening, no school met the recommended levels. No school had mean illumination that met the recommended level.

**Table 4.8: Light levels in libraries**

School	Light level (Lux)			Mean
	7:30	13:00	18:00	
Jamhuri High	339	554.88	308.89	400.92
Ngara Girls	331.86	448.63	330.3	370.26
Hospital Hill	297.54	407.03	288.45	331
Kangemi High	321.3	376.06	308	335.12
Parklands Arya	405.8	475.7	316.11	399.2
State House Girls	532.46	466.38	310.8	436.55
<b>Mean</b>	371.33	454.78	310.43	378.84
<b>Legend</b>	 >500	 <500		

**4.6.5. Light levels in art rooms**

The recommended level for art rooms is 500-750 lux. Table 4.9 presents results on the mean illumination levels in the art rooms. Results indicate that only one school had illumination levels within the recommended standards in the afternoon and none in the

morning and evening. Only 1 school had mean illumination that met the recommended level.

**Table 4.9: Light levels in art rooms**




School	Light level (Lux)			Mean
	7:30	13:00	18:00	
Jamhuri High	292.2	337.25	281.89	303.78
Ngara Girls	186.84	270.06	184.65	213.85
Hospital Hill	367.15	399.13	245.19	337.15
State House Girls	1050	702.26	322.56	691.61
<b>Mean</b>	474.05	427.18	258.57	386.6
<b>Legend</b>	 500-750	 <500	 >750	

Table 4.10 presents the results on the number of facilities whose illumination achieved the recommended levels. The results indicate that most of the learning facilities did not meet the recommended illumination levels. This is attributed to the lack of national standards for the illumination of educational facilities. Consequently, principals and other relevant authorities lack guidelines on how to ensure adequate indoor illumination in the learning facilities.

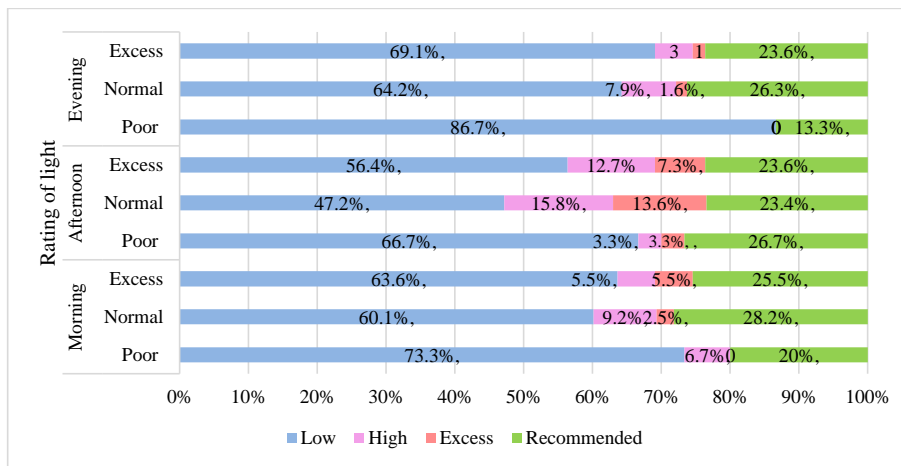
**Table 4.10: Number of facilities with the recommended light levels**

Facility	Time			Mean for the day
	7:30	13:00	18:00	
Classrooms	14	20	10	19
Science Labs	1	0	0	0
Computer Labs	0	0	0	0
Libraries	1	1	0	0
Art Rooms	0	1	0	1

#### 4.6.6. Illumination levels and visual comfort

The illumination levels were compared to the visual comfort reported by the students. The results were compared to the rating of light, task performance, and the prevalence of physiological symptoms of visual discomfort. The illumination levels were put into four categories: low (<300 lux), recommended (300-500 lux), high (501-1000 lux), and

excess (>1000 lux). These categories were based on the recommended values for classrooms. Figure 4.12 presents the results on the rating of light and the illumination levels. The results indicate that 28.2% of respondents rated the light as normal and aligned with the recommended levels in the morning. 25.5% rated the light as excessive despite it matching the recommended standards.



**Figure 4.12: Rating of light and illumination levels**

Table 4.11 presents the respondents’ ability to perform visual tasks and the recommended illumination levels. Results indicate that the visibility of reading materials was generally high (at least 90%) regardless of the time of day and the illumination levels. Board visibility is more affected by variations in illumination levels. This implies that it is more susceptible to glare, viewing angles, and sitting position of the students.

**Table 4.11: Task performance and Illumination levels**

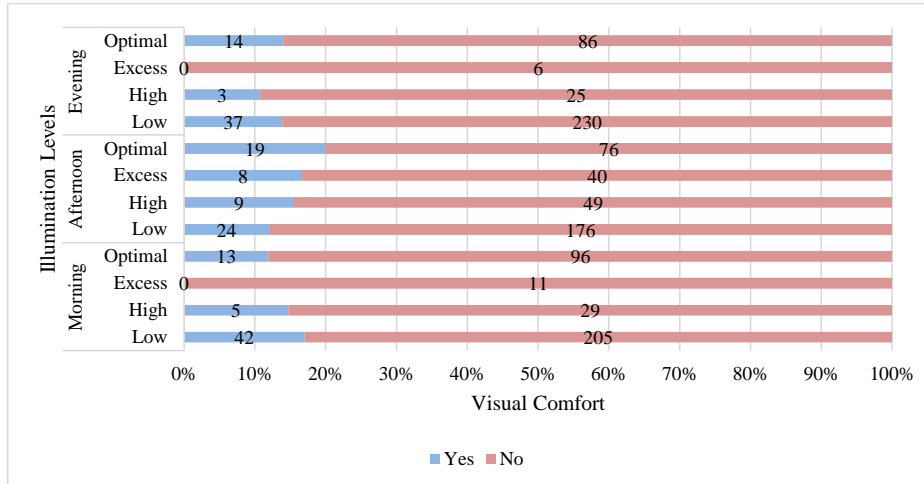
Time of Day	Illumination Levels	Visibility of Reading Materials		Visibility of Board	
		Yes Frequency (Percent)	No Frequency (Percent)	Yes Frequency (Percent)	No Frequency (Percent)
<b>Morning</b>	<b>Low</b>	223 (90.3%)	24 (9.7%)	121 (49.0%)	126 (51.0%)
	<b>High</b>	32 (94.1%)	2 (5.9%)	16 (47.1%)	18 (52.9%)
	<b>Excess</b>	9 (81.8%)	2 (18.2%)	3 (27.3%)	8 (72.7%)
	<b>Optimal</b>	96 (88.1%)	13 (11.9%)	50 (45.9%)	59 (54.1%)
<b>Afternoon</b>	<b>Low</b>	181 (90.5%)	19 (9.5%)	89 (44.5%)	111 (55.5%)
	<b>High</b>	48 (82.8%)	10 (17.2%)	29 (50.0%)	29 (50.0%)
	<b>Excess</b>	45 (93.8%)	3 (6.3%)	27 (56.3%)	21 (43.8%)
	<b>Optimal</b>	86 (90.5%)	9 (9.5%)	45 (47.4%)	50 (52.6%)
<b>Evening</b>	<b>Low</b>	243 (91.0%)	24 (9.0%)	129 (48.3%)	138 (51.7%)
	<b>High</b>	27 (96.4%)	1 (3.6%)	15 (53.6%)	13 (46.4%)
	<b>Excess</b>	5 (83.3%)	1 (16.7%)	1 (16.7%)	5 (83.3%)
	<b>Optimal</b>	85 (85.0%)	15 (15.0%)	45 (45.0%)	55 (55.0%)

Table 4.12 presents the occurrence of symptoms of visual discomfort and the recommended illumination levels. Results indicate that symptoms of visual comfort are prevalent in all illumination levels. Excess illumination (>1000 lux) resulted in symptoms of visual discomfort in 100% of the occupants. The lowest percentage (75.8%) of respondents who experienced symptoms across all conditions was those with the recommended light levels in the afternoon. This implies that optimal lighting may reduce visual discomfort.

**Table 4.12: Occurrence of symptoms of visual discomfort and illumination levels**

Time of Day	Illumination Levels	Symptoms of visual discomfort	
		No symptom Frequency (Percent)	At least one symptom Frequency (Percent)
<b>Morning</b>	<b>Low</b>	51 (20.6%)	196 (79.4%)
	<b>High</b>	6 (17.6%)	28 (82.4%)
	<b>Excess</b>	0	11 (100.0%)
<b>Afternoon</b>	<b>Optimal</b>	16 (14.7%)	93 (85.3%)
	<b>Low</b>	30 (15.0%)	170 (85.0%)
	<b>High</b>	11 (19.0%)	47 (81.0%)
<b>Evening</b>	<b>Excess</b>	9 (18.8%)	39 (81.3%)
	<b>Optimal</b>	23 (24.2%)	72 (75.8%)
	<b>Low</b>	52 (19.5%)	215 (80.5%)
	<b>High</b>	4 (14.3%)	24 (85.7%)
	<b>Excess</b>	0	6 (100.0%)
	<b>Optimal</b>	17 (17.0%)	83 (83.0%)

Figure 4.13 presents the illumination level and visual comfort. Results indicate that optimal illumination achieves a marginally higher percentage of respondents reporting visual comfort. Respondents exposed to excess illumination levels had the highest (up to 100%) rates of visual discomfort. However, the slight variations indicate that visual comfort is influenced by other environmental factors in addition to the illumination levels.



**Figure 4.13: Illumination Levels and Visual Comfort**

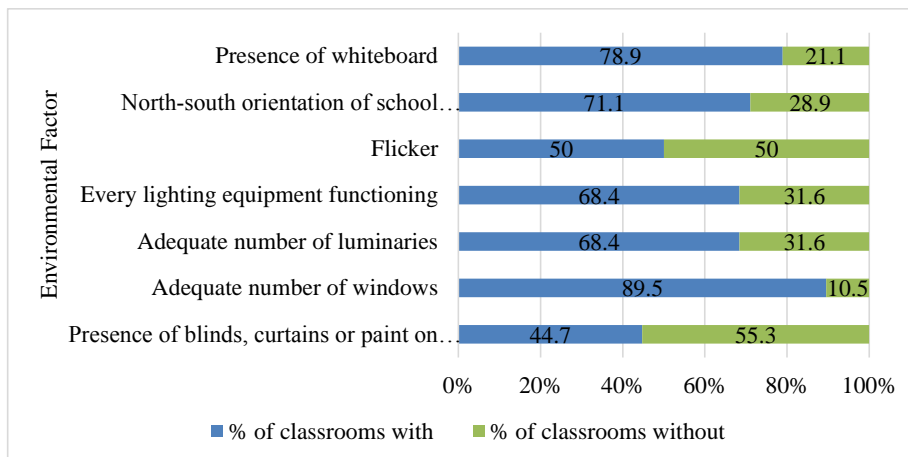
#### 4.7 Environmental Factors Associated with Visual Comfort or Discomfort

Due to the small number of other learning facilities sampled, the study focused on classrooms to determine environmental factors associated with visual comfort. Chi-square analysis was conducted to establish the associations between the various environmental factors in classrooms.

##### 4.7.1. Environmental Factors in Classrooms

Figure 4.14 presents results on the environmental factors in classrooms. Results indicate that out of 38 classrooms, 17 had blinds, curtains, or paints on windows. This enables the learners to regulate the quantity of natural light entering the room. Consequently, the students can use the curtains to prevent experiencing glare. 34 classrooms had an adequate number of windows. This increases the amount of natural light in the room, reducing the reliance on artificial light. 26 classrooms have a sufficient number of luminaries. This enhances the uniformity of light in the rooms. Every lighting equipment in 26 classrooms was functioning. This enhances the uniformity of light in

the rooms. 19 classrooms had at least one light source that was flickering. Proper maintenance reduces the exposure to flickers since faulty bulbs are replaced on time. This enhances the uniformity of light in the rooms. 27 classrooms had a north-south orientation. School designs and buildings need to be constructed in the north-south orientation to protect the occupants from the glare from the 10:00 am and 4:00 pm sun. 30 classrooms had whiteboards. The presence of whiteboards, which are reflective surfaces, may increase the occurrence of glare. The type of light source influences the amount and quality of light received in a room. Although the observational checklist provided an exhaustive list of possible types of light, all the classrooms in every school relied on both natural light and fluorescent tubes. Every classroom had brightly painted walls. This enhances the brightness of the room.



**Figure 4.14: Environmental factors in classrooms**

#### **4.7.2. Environmental Factors Associated with Visual Comfort during the Day**

Chi-square analysis was conducted to assess the associations between the various environmental factors. Results indicate that there was a significant association between visual comfort during the day and the following environmental factors:

(i). Presence of blinds, curtains, or paint on windows

The null hypothesis was rejected,  $X^2(1) = 3.982$ ,  $p < .05$ ). The phi value  $> .10$ . There was a significant association between the presence of blinds, curtains, or paint on windows and visual comfort during the day. The association was moderate. The presence of blinds, curtains, or paint on windows gives the respondents a level of control over the amount of natural light they are exposed to through the windows, reducing the exposure to glare. Consequently, they may control their level of visual comfort in the classrooms.

(ii). Number of windows

The null hypothesis was rejected,  $X^2(1) = 6.986$ ,  $p < .05$ ). The phi value  $> .10$ . There was a significant association between number of windows and visual comfort during the day and visual comfort at night. The association was moderate. The size and number of windows affect the amount of natural light the students are exposed to in the classroom during the day.

(iii). Number of luminaries

The null hypothesis was accepted,  $X^2(1) = 2.333$ ,  $p > .05$ ). There is no association between number of luminaries in the classroom and visual comfort during the day. This can be attributed to classrooms mainly depending on natural light instead of artificial light during the day.

(iv). Functioning lighting equipment

The null hypothesis was accepted,  $X^2(1) = .045$ ,  $p > .05$ ). There is no association between functioning lighting equipment and visual comfort during the day. This can be attributed to classrooms mainly depending on natural light instead of artificial light during the day.

(v). Presence of flicker

The null hypothesis was accepted,  $X^2(1) = .542$ ,  $p > .05$ ). There was no statistically significant association between the presence of flicker in a classroom and visual comfort of the students during the day. This can be attributed to classrooms mainly depending on natural light as opposed to artificial light during the day.

(vi). Presence of whiteboard

The null hypothesis was rejected,  $X^2(1) = 5.895$ ,  $p < .05$ ). The phi value  $> .10$ . There was a significant association between the presence of a whiteboard and visual comfort during the day. The association was moderate. Whiteboards increase the area covered by reflective surfaces in classrooms, which may result in glare.

(vii). Orientation of classroom

The null hypothesis was rejected,  $X^2(1) = 4.163$ ,  $p < .05$ ). The phi value  $> .10$ . There was a statistically significant association between the orientation of the classroom and the visual comfort of the students during the day. The association was moderate. Rooms with windows in the north-south orientation avoid the 10:00 and 15:00 glare, enhancing the visual comfort of the room's occupants.

(viii). Sitting positions of the student

The null hypothesis was accepted,  $X^2(1) = 13.450$ ,  $p > .05$ ). There was no statistically significant association between the sitting position of the respondent and their visual comfort during the day.

#### **4.7.3. Environmental Factors Associated with Visual Comfort at Night**

Chi-square analysis assessed the environmental factors associated with visual comfort at night. Results indicate the following for each of the environmental factors:

(i). Presence of blinds, curtains or paint on windows

The null hypothesis was rejected,  $X^2(1) = 4.212$ ,  $p < .05$ ). The phi value  $> .10$ . There was a significant association between the presence of blinds, curtains, or paint on windows and visual comfort at night. The association was moderate.

(ii). Number of windows

The null hypothesis was accepted,  $X^2(1) = 1.040$ ,  $p > .05$ ). There was no association between the number of windows and visual comfort at night. There is very little natural light at night. Consequently, the number of windows has no effect on visual comfort at night.

(iii). Presence of whiteboard

The null hypothesis was rejected,  $X^2(1) = 10.968$ ,  $p < .05$ ). The phi value  $> .15$ . There was a statistically significant association between the presence of a whiteboard in a classroom and the visual comfort of the students at night. The association was strong. Whiteboards increase the area covered by reflective surfaces in classrooms, which may result in glare, a symptom of visual discomfort.

(iv). Sitting positions of the student

The null hypothesis was rejected,  $X^2(1) = 17.404$ ,  $p < .05$ ). The phi value  $> .15$ . There was a statistically significant association between the sitting position of the respondent and their visual comfort at night. The association was strong. The illumination of the rooms may not be uniform for every sitting position. Students who are seated directly below a luminaire may be exposed to higher levels of illumination than those who are not.

## **CHAPTER FIVE: DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS**

### **5.1 Introduction**

This section presents a discussion of the findings of this study and other related studies.

It is organized by the objectives of the study.

### **5.2 Summary**

This study's broad objective was to assess visual comfort in public boarding secondary schools in Nairobi City County, Kenya. The study also sought to determine the indoor illumination levels in various buildings, establish the environmental factors associated with visual comfort, and establish the prevalence level of visual comfort among public boarding secondary school students. The study focused on public boarding secondary schools due to the higher enrolment rates. Additionally, these students spend most of the year within the learning facility both day and night whenever the school is in session. Inadequate and excessive lighting can result in various physiological and psychological effects including lethargy, anxiety, headaches, eyestrain, nausea, backaches, neck aches, shoulder pain, lack of mental alertness, and daytime sleepiness. Learning institutions need to provide quality illumination in their facilities to guarantee visual comfort and improve the visual performance of students and staff. Currently, Kenya does not have any lighting standards for schools. The study compared international standards by ISO and CIE.

According to the findings, all 401 respondents use classrooms and science laboratories, 136 students use computer laboratories, 144 use libraries, and only 80 use art rooms. Classrooms were the only facilities used daily. Students spent more than 10 hours a day

in these rooms. The majority of the respondents used science laboratories for 4-6 hours and computer laboratories and libraries for 1-3 hours each per week. Half the art students use the rooms for 1-3 hours per week. More than half of the respondents had yet to seek medical attention due to the effects of poor or excessive lighting or they have not been majorly affected by the quality of illumination in schools. Conversely, the majority of the respondents experienced at least one physical symptom while using the school facilities.

The findings showed that illumination levels varied with the time of day. The majority of the students were comfortable with the illumination they were exposed to in the various learning facilities. Regarding task performance, more than half of the respondents reported proper visibility of boards in all the learning facilities. The majority reported proper visibility of reading materials on their desks and computers.

### **5.3 Discussion of findings**

#### **5.3.1 Sociodemographic factors**

The findings showed that there was a weak but significant association between gender and visual comfort both during the day and at night. Social norms may cause girls to be more likely to report discomfort than boys. A study that reviews existing literature on visual comfort assessment established that there is no association between gender and the occupants' visual perception (Blanco Cadena, et al., 2022). The variations in environmental design among the schools may result in subtle differences in visual comfort. There is no significant association between the sub-county and visual comfort during the day and at night. Public boarding schools have standardised infrastructure; hence, they may follow similar standards for architectural designs, limiting differences.

Additionally, the climatic conditions of Nairobi are relatively uniform, resulting in minimal variability. There was a strong association between school category and visual comfort during the day and no association at night. Resource allocation by the government relies on the school category. National and extra-county schools receive more funding than county and sub-county schools. This may translate to modern infrastructure, investment in blinds, and proper management of luminaires, which may influence visual comfort. Conversely, all schools rely on fluorescent tubes at night regardless of their category. The uniformity may reduce the impact of the school category at night. There was no significant association between grade level and visual comfort during the day and at night. Homogenous learning environments in schools imply that students are exposed to similar lighting conditions regardless of the grade level.

### **5.3.2 The proportion of students reporting visual comfort**

The findings revealed that only 15% of the respondents experience visual comfort during the day, 13.5% at night, and 12.7% day and night. This was indicated by the percentage of respondents who reported having the ability to perform all visual tasks, rated the light at their desks as normal, and didn't experience any symptom of visual discomfort.

The findings revealed that more than 78% of the students claim to be comfortable with the amount of illumination they receive at their desks both day and night. Additionally, most students who rated the light as poor or excessive reported experiencing at least one symptom of visual discomfort in all the learning facilities. Although most of the students reported being comfortable with the quality of illumination, a large percentage

also reported experiencing at least one symptom of visual discomfort. This implies that the students adapted to the low light levels, resulting in reported comfort by the majority. The findings support the study conducted in Malaysia that established that the respondents' acceptance of low illuminance levels may be due to their expectations and adaptations to the lighting conditions (Dahlan, 2015). A further study conducted in India also reported similar results (Negiloni, Ramani, & Sudhir, 2019). Response bias and the understanding of normal illuminance levels by children may explain the findings.

Regarding task performance, the findings revealed that the proportion of students reporting having the ability of the respondents to read everything written on boards increases at night in classrooms. Also, the ability of students to see reading materials on their desks reduces at night. Computer laboratories had adequate indoor illumination. This is indicated by the fact that more than 70% of students could see reading materials both during the day and at night. The findings support the study in modern university classrooms in Taiwan, where tasks on students' desk surfaces also had the highest scores.

The study findings also found that 83.3% of the participants experienced at least one physical symptom while using the school facilities. A higher percentage of students (74.7% in science laboratories and 79.4% in computer laboratories) with longer durations of exposure reported experiencing at least one symptom of visual discomfort. The most common symptoms in all the learning facilities were eyestrain, headaches, and glare. These findings were highly agreeable with a study conducted in university

classrooms in Taiwan that found a high proportion of learners had vision-relative physiological symptoms (Chiou, Saputro, & Sari, 2020).

### **5.3.3 Indoor Illumination Levels and Visual Comfort**

The illumination levels varied from inadequate to excessive compared to the recommended levels. The study findings established that schools recorded higher illumination levels at 13:00 than at 7:30 and 18:00 due to sunlight. Results indicate that 36.8% of the classrooms attained the recommended illumination level at 7:30, 52.6% at 13:00, and 26.3% at 18:00.

The majority of the schools did not achieve the recommended light levels. A study conducted in classrooms in India found that indoor illumination was lower than their national recommendation of 150 lux (Negiloni, Ramani, & Sudhir, 2019). In science laboratories, only one school met the recommended level in the morning and none in the afternoon and evening. In computer laboratories, no school met the recommended levels at any time of day. In libraries, only one school had illumination levels above the recommended standards in the morning and afternoon, and none in the evening. In art rooms, only one school had illumination levels within the recommended standards in the afternoon and none in the morning and evening. The findings were compared to a study conducted in secondary schools in the United Kingdom that recorded 64% of the classrooms had minimum illuminance of 300 lux with lights on and blinds closed (Winterbottom & Wilkins, 2009). The study found that 88% of classrooms exceeded the recommended levels in the United Kingdom due to daylight and excessive lighting. However, variations in the daily weather conditions, seasons, and time of day can affect the illuminance levels. The UK study collected data once a day during an unspecified

time frame, as opposed to the current study, which collected in the morning, afternoon, and evening. The differences in architectural design may also influence the amount of natural and artificial light the students are exposed to.

71% of the respondents' rating of the amount of light does not align with the light levels at their desks. This suggests that students may be experiencing subjective discomfort even though the illumination levels may be technically optimal. User perceptions of illuminance tend to be inaccurate and are developed over time (Winterbottom & Wilkins, 2009). Additionally, other environmental factors influence visual comfort alongside illumination levels. Ratings of discomfort depend on the occupant and the task.

The study findings established that the recommended levels don't always guarantee significantly better visibility of reading materials over low or excessive illumination levels. Despite the levels being below the recommended, the visibility of reading materials at the students' desks was high at 90%. Students may adjust their posture since they are close to reading materials. Conversely, the visibility of boards relies on ambient illumination since they are further away from the students. This makes it more susceptible to other environmental factors like glare and light uniformity. Even though high illumination levels may enhance visibility, they may also result in glare on whiteboards and other reflective surfaces, which may lower visibility.

The study findings determined that students exposed to the recommended lighting levels have a lower probability of experiencing symptoms of visual discomfort than those exposed to levels below or above the recommended levels. However more than 75% still experience symptoms even at optimal levels. Additional environmental and

architectural factors may influence visual comfort. Discomfort is more prevalent in the evening among the occupants exposed to illumination that failed to meet the recommended levels. This may be a result of prolonged exposure to the illumination throughout the course of the day. The learning facilities rely on artificial light in the evening and at night. The use of fluorescent tubes in all of the rooms exposes the occupants to flickering and lack of light uniformity, increasing the occurrence of physiological symptoms of visual discomfort.

#### **5.3.4 Environmental factors associated with visual comfort**

The study findings established that various environmental factors are associated with visual comfort or discomfort in schools. Every school in the study relied on natural light and fluorescent tubes in all the learning facilities. Most classrooms relied more on daylight than on artificial light during the day. Fluorescent bulbs are more prone to flickering than any other bulb type. Flickering may cause visual discomfort symptoms such as headaches and eye strain. Children display a relatively high sensitivity to flickers (Winterbottom & Wilkins, 2009). Since there are newer technologies that offer more visual comfort than fluorescent tubes such as LED bulbs, the luminaires should be replaced.

The study findings established that there was a moderately significant association between visual comfort during the day and the presence of blinds, curtains, or paint on windows. The occupants' ability to control lighting levels using blinds and curtains may enhance adaptation to the lighting conditions, increasing visual comfort.

The study findings established that there was a moderately significant association between visual comfort during the day and the number of windows. These findings are

consistent with a study conducted in secondary schools in the United Kingdom that found a weak but significant association between illuminance and total window area (Winterbottom & Wilkins, 2009). Window area and the presence of blinds increases the students' exposure to daylight while ensuring they can control it if it becomes excessive.

There was a moderately significant association between visual comfort during the day and the presence of a whiteboard and orientation of the classrooms. The presence of reflective surfaces such as whiteboards increases the probability of the occupants experiencing glare. Additionally, the building's orientation affects the amount of sunlight that enters the room. Buildings with east-west orientation. These results concur with a study that established that daylight, outside view, uniformity, glare, and lighting level may influence indoor visual comfort (Andargie, Touchie, & O'Brien, 2019).

Conversely, there was no significant association between visual comfort during the day and the number of luminaries, every lighting equipment functioning, the presence of flickers, and the sitting position of the respondents. These variables are mainly associated with artificial light as opposed to natural light. This aligns with the study findings that the occupants mainly rely on daylight for illumination during the day and therefore these variables do not have a significant association with their visual comfort during the day. Management of natural light is vital in enhancing visual comfort during the day. This includes north-south orientation of buildings, reduction of reflective surfaces, ensuring adequate window area, and installing blinds and curtains.

The study established that there was a moderately significant association between visual comfort at night and the presence of blinds, curtains, or paint on windows. Data was

collected at 18:00. Although the sun had begun setting, there may still be some minimal natural light that may enter the room. There was a strong significant association between visual comfort at night, and the presence of a whiteboard and the sitting position of the respondents. Reflective surfaces can still cause glare in artificial lighting. Uneven distribution of luminaires may result in excessive lighting for those seated beneath them, while those further away may have low lighting.

There was no significant association between visual comfort at night and the number of windows, the number of luminaries, functioning lighting equipment, the presence of flicker, and the orientation of the classrooms. Optimising artificial illumination is essential in enhancing visual comfort at night. This includes ensuring adequate number and distribution of luminaires depending on the size of the room. The seating arrangement of students should be considered when designing classroom layouts and lighting systems.

#### **5.4 Conclusion**

From the findings, the study concludes that students in public secondary schools in Nairobi City County experience visual discomfort. Only a minority of students reported experiencing visual comfort consistently throughout the day and night. The findings revealed that there is an association between visual comfort and sociodemographic factors like gender and school category. Girls tend to report discomfort more than boys due to societal norms. Higher-rated schools, such as national and extra-county schools, tend to provide better visual environments due to better government funding.

Although most of the students (more than 78%) reported being comfortable with the quality of illumination, a large percentage also reported experiencing at least one

symptom of visual discomfort. The most common symptoms in all the learning facilities were eyestrain, headaches, and glare. This implies that the students adapted to the low light levels resulting in reported visual comfort by the majority. This aligns with previous studies that found that occupants often adapt to low illumination levels, influencing their perception of visual comfort. Additionally, students who spent longer durations in a learning facility had a higher probability of experiencing at least one symptom of visual discomfort. This suggests the need to improve the indoor illumination design to lessen the adaptation of the occupants to suboptimal lighting, which may result in visual discomfort over time.

There were variations in illumination levels across different times of day. Most learning facilities recorded illumination levels lower than the recommended lux in the morning and evening. Most classrooms achieved the recommended lighting in the afternoon.

Regarding environmental factors, there is a significant association between visual comfort during the day and the presence of blinds, curtains, or paint on windows, the number of windows, the orientation of the classrooms, and the presence of whiteboard. There was a significant association between visual comfort at night and the presence of blinds, curtains, or paint on windows, the presence of a whiteboard, and the sitting position of the respondents. Conversely, there was no significant association between visual comfort during the day and the number of luminaries, every lighting equipment functioning, the presence of flickers, and the sitting position of the respondents. There was no significant association between visual comfort at night and number of windows, the number of luminaries, every lighting equipment functioning, the presence of flicker, and the orientation of the classrooms.

Overall, the study concludes that the current indoor illumination quality in public boarding secondary schools is insufficient to fully support the visual comfort of students. Enhancing infrastructure, utilising modern efficient lighting technology, and designing adaptable lighting environments can improve visual comfort, eventually promoting a better learning experience for students.

## **5.5 Recommendations**

### **5.5.1 Recommendations from the study**

This study provides empirical evidence on the relationship between indoor illumination quality and visual comfort among public boarding secondary school students in Nairobi City County, Kenya. It fills a critical knowledge gap due to the paucity of studies on this field especially in Kenya and highlights the importance of optimal illumination in educational settings. The findings offer valuable insight for policymakers, educators, and other relevant authorities in designing classroom environments that enhance students' health, well-being, and performance through improved visual comfort.

This study makes recommendations to the Ministry of Education and relevant authorities in schools. The following recommendations aim at reducing visual discomfort in public secondary schools in Kenya:

1. The Ministry of Education and school authorities should educate students on the signs of visual discomfort. This will enable them to communicate more effectively, hence allowing faster responses to visual discomfort issues.
2. The Government of Kenya, through the Ministry of Education, should formulate national illumination guidelines for different rooms depending on the visual tasks carried out and facilitate their adoption in all schools in Kenya.

3. The Ministry of Education and school authority should conduct periodic auditing of illumination in the learning facility to ensure that illumination levels remain within the recommended ranges.
4. The Ministry of Education and school authorities improve illumination quality in schools by changing environmental factors such as installing blinds, curtains, or paint on windows, building learning facilities in a north-south orientation, and installing LED bulbs instead of fluorescent tubes to enhance visual comfort.

#### **5.5.2 Recommendations for further research**

The current study assesses visual comfort in public boarding secondary schools in Nairobi City County, Kenya. Consequently, future research can be conducted in other regions in Kenya due to the varying climatic and socioeconomic conditions. These researchers can compare their results with current results.

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## APPENDICES

### **Appendix 1: Letter of Introduction and Informed Consent**

My name is Cynthia Vugudza Magero, a student at Kenyatta University taking a Master of Science in Environmental Health. I am carrying out a study on “*Indoor Light Quality and Visual Comfort in Public Boarding Secondary Schools in Nairobi City County, Kenya*”. The information obtained is for academic purposes only and may help the Ministry of Education with baseline data which can help in coming up with strategies and interventions risks posed by poor indoor light quality in schools.

#### **Procedures to be followed**

Participation in this study will require that I ask you some questions and also examine you to assess the effect of indoor light quality on your visual comfort as a student. Light levels will be measured to ascertain the amount of light you are exposed to in lux. Observations on the environmental factors will also be observed to determine the quality of light. I will record the information from you in a questionnaire.

#### **Voluntarism**

You have the right to refuse participation in this study. You will get the same service whether you agree to join the study or not and your decision will not change the care you will receive. Please remember that participation in the study is voluntary. You may ask questions related to the study at any time.

You may refuse to respond to any questions and you may stop an interview at any time. You may also stop being in the study at any time without any consequences to the services you receive from this school or any other organizations now or in the future.

#### **Discomforts and risks**

Some of the questions you will be asked are on the intimate subject and maybe embarrassing or make you uncomfortable. If this happens, you may refuse to answer these questions if you choose so. You may also stop the interview at any time. The interview may add approximately half an hour to the time you wait before you receive your routine services.

**Benefits**

If you participate in this study you will help us to learn how to maintain indoor light quality within the set standards and reduce the risk of light-related health effects thus improving productivity in the long run and improving the working conditions.

**Reward**

If you agree to participate in this study, there will be no monetary gain as the study is for academic purposes only.

**Confidentiality**

The interviews will be conducted privately in the school facilities or at any place preferred by participants. Your name will not be recorded on the questionnaire. The questionnaires will be kept in a locked cabinet for safekeeping at Kenyatta University. Everything will be kept private and only shared with the study team.

**Contact Information**

If you have questions about the study call the Investigator Cynthia Magero:

0716934707 or Supervisors Dr Jackim Nyamari: 0722589335 or Dr Redempta Mutisya 0724563316.

However, if you have questions about your rights as a study participant: You may contact Kenyatta University Ethical Review Committee Secretariat at [chairman.kuerc@ku.ac.ke](mailto:chairman.kuerc@ku.ac.ke)

**Participant's statement**

The above information regarding my participation in the study is clear to me. The study has been explained to me and I have been given a chance to ask questions and my questions have been answered to my satisfaction. My participation in this study is entirely voluntary. I understand that my records will be kept private and that I can leave the study at any time. I understand that I will still get the same care treatment whether I decide to leave the study or not and my decision will not change the care that I will receive from the school today or that I will get from any other school at any other time.

Name of Participant \_\_\_\_\_

Signature/ thumb print of Interviewee \_\_\_\_\_

Date \_\_\_\_\_

Name of Representative/Witness \_\_\_\_\_

Relationship to subject \_\_\_\_\_

**Investigator Statement**

I, the undersigned I have explained to the volunteer in a language she/he understands, the procedures to be followed in the study and the risks and benefits involved.

\_\_\_\_\_  
Name of the Interviewer

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

**Appendix 2: Observational Checklist for Classrooms**

<b>Variable</b>	<b>Form 1</b>	<b>Form 2</b>	<b>Form 3</b>	<b>Form 4</b>
Presence of blinds or curtains	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Uniform positioning of light sources	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Adequate number of windows	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Is every lighting equipment functioning?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Presence of whiteboard	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Presence of glare on board	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Presence of flicker	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
The north-South orientation of school facilities	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Are the walls painted?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
If yes, is the paint colour	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No

bright?				c) N/A
Type of light source used	a) Natural light b) Incandescent lamps c) Fluorescent Tubes d) CFL bulbs e) LED bulbs f) Pressure lamps g) Kerosene lamps h) Candles	a) Natural light b) Incandescent lamps c) Fluorescent Tubes d) CFL bulbs e) LED bulbs f) Pressure lamps g) Kerosene lamps h) Candles	a) Natural light b) Incandescent lamps c) Fluorescent Tubes d) CFL bulbs e) LED bulbs f) Pressure lamps g) Kerosene lamps h) Candles	a) Natural light b) Incandescent lamps c) Fluorescent Tubes d) CFL bulbs e) LED bulbs f) Pressure lamps g) Kerosene lamps h) Candles

**Appendix 3: Observational Checklist for Learning Facilities**

<b>Variable</b>	<b>Science Laboratory</b>	<b>Computer Laboratory</b>	<b>Library</b>	<b>Art Room</b>
Presence of blinds or curtains	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Uniform positioning of light sources	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Adequate number of windows	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Is every lighting equipment functioning?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Presence of whiteboard	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Presence of glare on board	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Presence of flicker	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
The north-South orientation of school facilities	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
Are the walls painted?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
If yes, is the paint colour bright?	a) Yes b) No	a) Yes b) No	a) Yes b) No	a) Yes b) No

	c) N/A	c) N/A	c) N/A	c) N/A
Type of light source used	a) Natural light b) Incandescent lamps c) Fluorescent Tubes d) CFL bulbs e) LED bulbs f) Pressure lamps g) Kerosene lamps h) Candles	a) Natural light b) Incandescent lamps c) Fluorescent Tubes d) CFL bulbs e) LED bulbs f) Pressure lamps g) Kerosene lamps h) Candles	a) Natural light b) Incandescent lamps c) Fluorescent Tubes d) CFL bulbs e) LED bulbs f) Pressure lamps g) Kerosene lamps h) Candles	a) Natural light b) Incandescent lamps c) Fluorescent Tubes d) CFL bulbs e) LED bulbs f) Pressure lamps g) Kerosene lamps h) Candles

#### Appendix 4: Questionnaire

Dear Respondent, My name is Cynthia Magero, a student at Kenyatta University. I am carrying out a study on indoor light quality and visual comfort in public boarding secondary schools in Nairobi City County, Kenya. The purpose of this questionnaire is to gain insight into students' perception of the classroom environment concerning visual comfort in public boarding secondary schools. To help address the above, your contribution to this research is important. Therefore, you are kindly requested to provide the researcher with accurate information. Your responses will be processed by computer and will be treated as confidential. Provide the following information by *ticking/ writing the applicable number in the blocks or space provided. You may use separate paper if space is not enough.*

#### PART A: Demographic Characteristics

Name of the Respondent..... (Optional)

1. Sex of respondent
  - a) Male ( )
  - b) Female ( )
2. What is the name of your school?  
 .....  
 .....
3. Which form are you in?
  - a) Form 1
  - b) Form 2
  - c) Form 3
  - d) Form 4
4. Which sub-county is your school located in?
  - a) Starehe
  - b) Westlands
5. What is the category of your school?
  - a) National
  - b) Extra county
  - c) County
  - d) Sub-County
6. What is your desk position? .....

Front of the room/ Blackboard/ whiteboard			
1	2	3	7
4	5	6	8

7. Have you ever visited an optician/ ophthalmologist/ eye doctor over an eye problem?

- a) Yes
- b) No

If yes to the above, what was the reason?

.....  
.....

8. Do you have any history of myopia (short-sightedness)?

- a) Yes
- b) No

9. How many 40-minute lessons do you spend in the following learning facilities in a week? (Answer all that are relevant)

- a) Classroom.....
- b) Science laboratory.....
- c) Computer laboratory.....
- d) Library.....
- e) Art room.....

**PART B: VISUAL COMFORT OF STUDENTS IN LEARNING FACILITIES  
DURING THE DAY**

Type of Room	Classroom	Science laboratory	Computer laboratory	Library	Art room
Question					
10. How would you rate the amount of light at your desk?	a) Poor lighting b) Normal lighting c) Excess lighting	a) Poor lighting b) Normal lighting c) Excess lighting	a) Poor lighting b) Normal lighting c) Excess lighting	a) Poor lighting b) Normal lighting c) Excess lighting	a) Poor lighting b) Normal lighting c) Excess lighting
11. Do you experience any glare (harsh bright light) on the blackboard?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
12. Do you experience any glare on the whiteboard?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	d) Yes a) No b) N/A	c) Yes a) No b) N/A
13. Do you experience any glare on the computer?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
14. Are you able to see everything that is written on the board?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
15. Are you able to see everything that is written on reading materials on your desk?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
16. Are you able to see everything that is written on the computer?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A

**VISUAL COMFORT OF STUDENTS IN LEARNING FACILITIES AT NIGHT**

Type of Room	Classroom	Science laboratory	Computer laboratory	Library	Art room
Question					
17. How would you rate the amount of light at your desk?	a) Poor lighting b) Normal lighting c) Excess lighting	a) Poor lighting b) Normal lighting c) Excess lighting	a) Poor lighting b) Normal lighting c) Excess lighting	a) Poor lighting b) Normal lighting c) Excess lighting	a) Poor lighting b) Normal lighting c) Excess lighting
18. Do you experience any glare on the blackboard?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
19. Do you experience any glare on the whiteboard?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
20. Do you experience any glare on the computer?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
21. Are you able to see everything that is written on the board?	Yes No N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
22. Are you able to see everything that is written on reading materials on your desk?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
23. Are you able to see everything that is	a) Yes b) No	a) Yes b) No	a) Yes b) No	a) Yes b) No	a) Yes b) No








written on the computer?	c) N/A	c) N/A	c) N/A	c) N/A	c) N/A
--------------------------	--------	--------	--------	--------	--------

**POSSIBLE SYMPTOMS OF VISUAL DISCOMFORT**

Do you experience any of the following after spending more than 2 consecutive hours in the learning facility?

Type of room	Classroom	Science laboratory	Computer laboratory	Library	Art room
Symptom					
24. I feel excessive tearing or a desire to rub my eyes	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
25. I experience glare	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
26. I experience a burning sensation/aching in my eyes	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
27. I see blurry images?	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
28. I experience eyestrain/ my eyes get tired	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
29. I find difficulty discriminating between colours	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A
30. I experience headaches	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A	a) Yes b) No c) N/A

Appendix 5: NACOSTI Research License

 REPUBLIC OF KENYA	 NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION
Ref No: 518907	Date of Issue: 15/February/2021
<b>RESEARCH LICENSE</b>	
	
<p>This is to Certify that Ms.. Cynthia Vugdza Magero of Kenyatta University, has been licensed to conduct research in Nairobi on the topic: Visual Comfort in Public Boarding Secondary Schools in Nairobi City County, Kenya. for the period ending : 15/February/2022.</p>	
License No: NACOSTI/P/21/9004	
518907 Applicant Identification Number	 Director General NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION
 16/2/2021.	Verification QR Code 
<p>NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.</p>	



**Appendix 7: Research Authorisation****KENYATTA UNIVERSITY  
GRADUATE SCHOOL**E-mail: [dean-graduate@ku.ac.ke](mailto:dean-graduate@ku.ac.ke)Website: [www.ku.ac.ke](http://www.ku.ac.ke)P.O. Box 43844, 00100  
NAIROBI, KENYA  
Tel. 020-8704150

Our Ref: Q23/CTY/PT/37630/2016

DATE: 15<sup>th</sup> October, 2020Director General,  
National Commission for Science, Technology  
and Innovation  
P.O. Box 30623-00100  
**NAIROBI**

Dear Sir/Madam,

**RE: RESEARCH AUTHORIZATION FOR MS. MAGERO CYNTHIA VUGUDZA  
REG. NO. Q23/CTY/PT/37630/16**

I write to introduce Ms. Magero Cynthia Vugudza who is a Postgraduate Student of this University. She is registered for M.Sc. degree programme in the **Department of Environmental & Occupational Health.**

Ms. Magero intends to conduct research for a M.Sc. thesis Proposal entitled, **"Visual Comfort in Public Boarding Secondary Schools in Nairobi City County, Kenya."**

Any assistance given will be highly appreciated.

Yours faithfully,

**PROF. ELISHIBA KIMANI  
DEAN, GRADUATE SCHOOL**

**Appendix 8: Ethical Approval**

**KENYATTA UNIVERSITY  
DIRECTORATE OF ETHICS REVIEW COMMITTEE**

Fax: 8711242/8711575  
 Email: [chairman.kuerc@ku.ac.ke](mailto:chairman.kuerc@ku.ac.ke)  
 Nairobi, 00100

P. O. Box 43844,

Tel: 8710901/12

Website: [www.ku.ac.ke](http://www.ku.ac.ke)  
 Our Ref: KU/ERC/APPROVAL/VOL.1

Date: 20<sup>th</sup> January, 2021

Magero Cynthia  
 P.O Box 43844-00100  
 NAIROBI

Dear Ms.Magero,

**RE: APPLICATION NUMBER: PKU/2200/11344 VISUAL COMFORT IN PUBLIC BOARDING  
 SECONDARY SCHOOLS IN NAIROBI CITY COUNTY**

This is to inform you that **KENYATTA UNIVERSITY DIRECTORATE OF ETHICS REVIEW COMMITTEE** has approved version 4 of the study protocol together with the attached consent forms dated 12.09.2020. Your application approval number is **PKU/2197/11344**. The approval period is **20<sup>th</sup> January, 2021 TO 20<sup>th</sup> January, 2022**.

This approval is subject to compliance with the following requirements;

- i. Only approved documents including (informed consents, study instruments, MTA) will be used
- ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by **KENYATTA UNIVERSITY DIRECTORATE OF ETHICS REVIEW COMMITTEE**.
- iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to **KENYATTA UNIVERSITY DIRECTORATE OF ETHICS REVIEW COMMITTEE** within 72 hours of notification
- iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to **KENYATTA UNIVERSITY DIRECTORATE OF ETHICS REVIEW COMMITTEE** within 72 hours

- v. Clearance for export of biological specimens must be obtained from relevant institutions.
- vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
- vii. Submission of an executive summary report within 90 days upon completion of the study to **KENYATTA UNIVERSITY DIRECTORATE OF ETHICS REVIEW COMMITTEE.**

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) <https://oris.nacosti.go.ke> and also obtain other clearances needed.

Yours sincerely



**Prof. Judith Kimiywe**

**DIRECTOR- KENYATTA UNIVERSITY ETHICS REVIEW COMMITTEE.**



## Appendix 9: Data Collection Clearances



REPUBLIC OF KENYA  
 MINISTRY OF EDUCATION  
 STATE DEPARTMENT OF EARLY LEARNING AND BASIC  
 EDUCATION

Telegrams: 'SCHOOLING', Westlands  
 Telephone:  
 When replying please quote  
 Our Ref:

SUB-COUNTY EDUCATION OFFICE  
 WESTLANDS SUB-COUNTY  
 P.O BOX 13788-00800  
 NAIROBI.

17<sup>th</sup> FEBRUARY 2021

PRINCIPAL,  
 NAIROBI SCHOOL,  
 KANGEMI HIGH,  
 PARKLANDS ARYA,  
 STATE HOUSE GIRLS,  
 KENYA HIGH SCHOOL.

**RE: RESEARCH AUTHORIZATION**

The bearer of this Letter: **Ms. Cynthia Vugudza magero, Kenyatta University** has been authorized to carry out research on "*Visual comfort in public boarding school in Nairobi City County*". This permit is valid until 15<sup>th</sup> February, 2022.

Kindly accord her the necessary assistance of Education

Sub-County Director of Education  
 Westlands Sub-County  
 P. O. Box 13788-00800, Nairobi  
 Sign: *[Signature]* Date: 17/2/2021

ROSARIO K. MBUNO  
 Ag. SUB-COUNTY DIRECTOR OF EDUCATION  
WESTLANDS



REPUBLIC OF KENYA  
MINISTRY OF EDUCATION  
STATE DEPARTMENT OF EARLY LEARNING AND BASIC  
EDUCATION

Telegrams: 'SCHOOLING', Westlands  
Telephone:  
When replying please quote  
Our Ref:

SUB-COUNTY EDUCATION OFFICE  
WESTLANDS SUB-COUNTY  
P.O BOX 13788-00800  
NAIROBI.  
1<sup>ST</sup> MARCH 2021

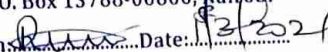
PRINCIPAL,  
HOSPITAL HILL HIGH SCHOOL,  
HIGHRIDGE GIRLS,  
NAIROBI MILIMANI,  
ST. GEORGE'S GIRLS,

**RE: RESEARCH AUTHORIZATION**

The bearer of this Letter: **Ms. Cynthia Vugudza magero, Kenyatta University** has been authorized to carry out research on "*Visual comfort in public boarding school in Nairobi City County*". This permit is valid until 15<sup>th</sup> February, 2022.

Kindly accord her the necessary assistance.

Sub-County Director Of Education  
Westlands Sub-County  
P. O. Box 13788-00800, Nairobi

Sign:  Date: 13/2/2021

**ROSARIO K. MBUNO**

**Ag. SUB-COUNTY DIRECTOR OF EDUCATION**

**WESTLANDS**



Republic of Kenya

MINISTRY OF EDUCATION

STATE DEPARTMENT OF EARLY LEARNING AND BASIC EDUCATION

Telegrams: "SCHOOLING", Nairobi  
Telephone: Nairobi 020 2453699  
Email: [rcenairobi@gmail.com](mailto:rcenairobi@gmail.com)  
[cdenairobi@gmail.com](mailto:cdenairobi@gmail.com)

REGIONAL DIRECTOR OF EDUCATION  
NAIROBI REGION  
NYAYO HOUSE  
P.O. Box 74629 - 00200  
NAIROBI

When replying please quote

Ref: RDE/NRB/RESEARCH/1/66 Vol.1

DATE: 16<sup>th</sup>, February, 2021

Cynthia Vugudza Magero  
Kenyatta University  
NAIROBI.

SUB-COUNTY DIRECTOR  
OF EDUCATION  
18 FEB 2021  
STATE DEPARTMENT OF EARLY LEARNING AND BASIC EDUCATION  
P.O. Box 30124 - 00100, NAIROBI

forwarded to  
Jemhuri bog  
- nyere sig  
-> Nairobi

RE: RESEARCH AUTHORIZATION

We are in receipt of a letter from the National Commission for Science, Technology and Innovation regarding research authorization in Nairobi County on the topic: "Visual comfort in public boarding school in Nairobi City County, Kenya."

This office has no objection and authority is hereby granted for a period, ending 15<sup>th</sup> February, 2022 as indicated in the request letter.

Kindly inform the Sub County Director of Education of the County you intend to visit.

HESBON NYAGAKA  
FOR: REGIONAL DIRECTOR OF EDUCATION  
NAIROBI.



Copy to: Director General/CEO  
National Commission for Science, Technology and Innovation  
NAIROBI.

