THE EFFECT OF ARTIFICIAL CLASSROOM LIGHTING ON BOARDING SECONDARY SCHOOL STUDENTS' ACADEMIC PERFORMANCE: A CASE OF NAIROBI COUNTY, KENYA

BY

ORIBO CALLEB MAGUTU

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY, DEPARTMENT OF TECHNOLOGY EDUCATION, SCHOOL OF EDUCATION, UNIVERSITY OF ELDORET, KENYA

MAY, 2021

DECLARATION

DECLARATION BY THE STUDENT

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SIGNATURE:…….. DATE: ……..

ORIBO CALLEB M.

DECLARATION BY THE SUPERVISORS

This thesis has been submitted with our approval as the university supervisors.

SIGNATURE: …… DATE: …….

DR SIMON WANAMI

SIGNATURE: …… DATE: …….

PROFESSOR PETER OKEMWA

DEDICATION

This work is devoted to my father Enock Oribo, lovely mother Billiah Nyang'au Oribo, my dear wife Dorcas Nyangasi, brothers and sisters; Robinson, George, Isaac, Rebbecca, Abraham, Yobesh, Morang'a, Joyce, Jane, Elijah and Volta for their constant support and encouragement.

ABSTRACT

The purpose of a good classroom lighting design is to create a well-lit and safe learning environment. This creates a good learning environment where the learners will have a sense of well-being and will be able to perform their visual tasks well. Natural daylight provides the best light for reading while artificial lighting comes in handy in overcast days and at night. The purpose of this study was to assess the effects of artificial classroom lighting on the educational performance of public boarding secondary school students in Nairobi County, Kenya. It attempted to determine the effect of artificial classroom lighting on reading, instruction, health and their ultimate influence on secondary school students' academic performance. The study conceptual framework illustrated a relational interconnection between artificial lighting installation technology, reading, instruction, health, and students' academic performance.This study used a survey and experimental research designs. Stratified, objective and random sampling techniques were used to select the sample. The study adopted the dual coding theory, automatic information processing in reading theory and education productivity theory. Study results were presented in tables and graphs. The study found out that artificial classroom lighting in Nairobi County public boarding secondary schools impacted negatively on students' academic performance. From the findings of this study, it was recommended that the government and stakeholders should install white cool fluorescent lamp fittings with high-efficiency control gear that provide dynamic focused lighting with a range of 300 to 500 lux.

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LIST OF ABBREVIATIONS AND ACRONYMS

1. ASHAE:	American Society of Heating, Refrigerating and Air-Conditioning Engineers
2. BBB:	Boys Boarding School
3. CCT:	Correlated colour temperature
4. CRI:	Colour Rendering Index
5 DCT:	Dual Coding Theory
6. DSE:	Display Screen Equipment
7. E:	Illuminance
8. EEG:	Electroencephalography
9. E_v:	Vertical illumination
10. GBS:	Girls Boarding School
11. HDR:	High Dynamic Range
12. ICT:	Information Communication Technology
13. HCL:	Human Centric Lighting

14. K: Kelvin

15. LED: Light Emitting Diode

16. LOR: Light Output Ratio

17. MBS: Mixed Boarding School

18. M.S.C.P: Mean Spherical Candle Power

19. M.H.S.C.P: Mean Hemispherical Candle Power

20. PC: Personal Computer

21. SAD: Seasonal Affective Disorder

22. SD: Standard Deviation

23. SEN: Special Education Needs

24. SPD: Spectral Power Distribution

25. UGR_L: Unified Glare Rating

26. VDU: Video Display Unit

27. UV: Ultraviolet

ACKNOWLEDGMENT

I would like to express my earnest appreciation and gratitude to the following persons for the help they gave me and whose contribution facilitated the successful completion of my doctoral studies:

My special thanks to my supervisors, Dr. Simon Wanami and Prof. Peter Okemwa for the support, advice, constructive criticism and guidance they gave me throughout the research process.

My lecturers in the department of technology education, whose experience and guidance enriched my knowledge in the area of technology education.

My wife Dorcas Nyangasi, my parents, brothers and sisters who gave me financial assistance and encouraged me to pursue my PhD program.

CHAPTER ONE

INTRODUCTION

1.0 Introduction

This chapter gives the background of the study, the description of the problem, the purpose of the study, the objectives of the study, the research question, the hypothesis, the rationale of the study, the importance of the study, research assumptions, scope, limitations and delimitations of the study, theoretical framework, conceptual framework and operational definition of terms.

1.1 Background to the study

Illuminating a classroom is a key facet of acquiring knowledge and instruction and it important in determinant of students' learning achievement. Light is essential in our lives because it helps us to operate ideally in every environment. It is a powerful source of energy that orchestrates our endogenous daily trend setter with our surroundings and is a means for improving mental recital (Keis *et al*., 2014). Light is often professed as an emblem of security, wealth and modernity (ALAN, 2013). Mott *et al*. (2012) said that light directly affects all aspects of human beings. They pointed out that light is a powerful aid of visual performance, a regulator of a variety of body processes like sleep and attentiveness, an essential component for cognition and mood, a stimulator for the creation of essential hormones such as cortisol and melatonin, and is indispensable in a healthy relaxation-working pattern. They suggested that light is next to food and water in human beings

requirements and is the most desirable environmental component in the regulation of physical disposition. They concluded that diffuse light wavelength affects biorhythms, pulse, brain activity, blood pressure, and respiratory rate. Generally speaking human life and human activities especially the process of acquiring knowledge and skills is centered on light. Mott *et al.* (2012), reported that the eyes have "photoreceptor cells" known as cones and rods which control visual results. They revealed that, the moment light shines on the cones and rods, an intricate chemical response happens which creates electrical whims in the nerves which link photoreceptor cells to the visual cortex at the rear of the brain which interprets the electrical whims as vision. According to Zumtobel (2017) light is a portion of the electromagnetic spectrum observed by the eyes. He said that light wavelength ranges between380 nm and 780 nm. He also claimed that the rods switch on at night and enable people to see grey shades and cones switch on during the day to enable us to see sharpness, details, and colour. This reveals that classroom lighting has a central role in a students' learning process. This also suggests that classroom lighting should be adequately designed so that it can positively influence students'academic achievement.

The most important objective of lighting design in a classroom is to provide a well illuminated and intuitive learning space that allow students to feel well and perform their learning tasks well (Loe *et al.*, 1999 and Etayo *et al*., 2007). Most of the learning is by seeing and one can only see in the presence of light.

BRANZ (2007) reported that although Natural classroom lighting is the best for a learning environment, during overcast days (when additional lighting is needed) or at night, artificial lighting is needed to provide light in the classroom for the learning purposes. It regreted that many of the classrooms being constructed today lack sufficient natural lighting because they are overcrowded and obstract each other from receiving natural light leading to the use of artificial lighting which is less sufficient as compared with natural lighting. From BRANZ (2007) sentiments, it is clear that the use of artificial classroom lighting is inevitable. This artificial classroom lighting in most cases is not sufficient for a learning environment and therefore cause a number of lighting-related problems and illness.

Lighting is a central consideration in the design and functioning of schools (Mousavi *et al*., 2011). Samani and Samani (2012) reported that the light received in the eye has significant visual and non-visual biological effect on the body, controls eye health and eases eye wellness and efficiency. They suggested that appropriate classroom lighting should be comfortable to all students. They asserted that most parts of the school should be well lit and remarkable. The presence of light causes reflectance and the colour on the main surfaces. Reflectance and colour make the classroom an attractive, stimulating and comfortable environment for both the learners and the teachers (Loe *et al*., 1999).

During the 1940_s and 1950_s, the development of economic fluorescent lamps led to the rapid installation of artificial lighting in educational areas, compared to the use of natural

light obtained through windows (Yucan, 2014). Currently, classroom lighting emphasis has shifted from the use of natural lighting to the use of artificial illumination, which has jeopardized the provision of quality lighting in teaching and learning spaces. Electric lighting often delivers illumination levels between 215lux to 1,600 lux as compared to 2700 lux to 100,000 lux delivered by natural light between twilight and noon (Bullina, 2016). Wishaw (2017) reported that artificial lighting is a unique human race innovation and has greatly enhanced the value of human existence. He, however, noted that undesirable effects are emanating from getting exposed to artificial light. He reported that blue light can cause diabetes, circadian rhythm disruption, obesity, cancer, heart disease, and sleep disturbances. He again reported that insufficient artificial lighting suppresses the production of melatonin hormone from the pineal gland in the brain. He concluded that blue-rich light also affects the regulation of numerous hormones and the ability of a human body to resist infections. Nuhfer (2007) warned that artificial lighting may cause havoc with human vision if it is not well designed and installed. He reported that artificial lighting that is rich in yellowish wavelengths produces glare on a white paper which leads to eye strain. According to Mirrahimi *et al*. (2012), artificial lighting causes strain, fatigue and circadian dysfunctions among students. Buckley (2014) indicated that insufficient classroom lighting can cause a number of barriers to learning such as inadequate colour rendering, glare, and flickering. He reported that these barriers can cause headaches, fatigue, boredom, and lack of engagement. Energy Focus (2015) warned that poorly designed artificial lighting emit ultraviolet radiation that damages the eye tissues causing

clouding of the lens (cataract formation) which leads to visual impairment or blindness. Various human body physiological processes such as electric impulses of the brain, melatonin production, core temperature, heart rate variability and blood pressure are influenced by the intensity and color temperature of artificial light (Sleegers *et al*., 2012). Mott *et al*. (2012) supported Sleegers *et al*. (2012) that when human beings are exposed to light they experience physiological changes. Light sends visual messages to the minds of learners that affect their mood and encouragement levels (Samani and Samani, 2012). This shows that artificial lighting affects learners in a number of ways which need to be probed.

The quality and intensity of artificial classroom lighting determine the comfort in a learning space (Gilavand *et al*., 2016). Loe *et al*. (1999) reported that visual well-being is necessary, and it is mandatory to regulate lighting in the general area to avoid eye strain and headaches. He warned that dysplasia can occur in the work area due to a view of the sky, direct sunlight and reflection from a shiny reading material or a computer screen. Therefore, such glaring sources should be eliminated. Higgins (2004) argued that the visual milieu affects students' mental attitude, academic performance and their capability to perceive visual stimuli.

According to Samani and Samani (2012), inappropriate lighting cause many problems, ranging from visual impairment to serious musculoskeletal damages. They reported that discomfort caused by poor lighting during reading, fading of light during close work activities, cause skipping of words and lines when reading or writing, and bloodshot or red

eyes after reading. They further revealed that better installed artificial classroom lighting create a good learning environment that speeds recognition of things, removes eye strain and increases visual stability.

Fluorescent lamps are the most commonly used light fitting in classroom artificial lighting. However, most experts now recommend controlled natural light complemented by appropriate artificial lighting as they create the best lighting conditions for learrning and instruction (Blazer, 2012). A research conducted by Walton *et al*. (2008) disclosed that teachers preferred a combination of different lighting types, each for a particular learning task. An analysis conducted by Suleman *et al*. (2014) established that a good classroom environment has a positive impact on the exam scores of secondary school students. According to Buckley (2014), artificial classroom lighting settings have an intense effect on an individual's behavior, disposition, and inspiration. He reported that the state of artificial classroom lighting can have a negative or positive influence on students' academic performance. He argued that since technology advances are quicker than the built environment, artificial classroom lighting should be planned for tractability. He concluded that provisions should be made to eliminate reflections, glare and visual discomfort when using visual display surfaces. According to Gilavand *et al*. (2016), the aim of classroom lighting is to provide a good and conducive learning environment where students' energy is spent on the learning process rather than straining to see. Samani and Samani (2012) reported that quality artificial classroom lighting enhances students' visual, comfort and interpersonal relations. They testified that when students clearly see the task

they learn well and attain high academic test scores. They advised that if students' visual discomfort is removed or reduced, their level of concentration increases which enhances their academic performance. They concluded that when students are able to see clearly they will be more cooperative and communicated well. Ibanez *et al*. (2017) retorted that it is possible to attain adequate lighting for visual task, but the visibility of a task depends on factors such as the internal surfaces of how the light is illuminated, the light source color characteristics, the window type, and the brightness level. According to Mott *et al*. (2012), lighting affects many echelons of human aspects such as vision, perception, mood, and daily rhythm. They reported that visual impairments induce behavioral problems, reduced level of concentration and hinder learning motivation. They pointed out that accuracy, attention and reading speed are aided by cool white-focused fluorescent lighting, while students' teamwork is facilitated by warm white light.

1.2 Statement of the problem

Many researchers have confirmed that adequate classroom lighting improves student's concentration and academic performance. Keis *et al*. (2014) points out that light is a powerful source of energy that orchestrates an individual's endogenous daily trend setter with his or her surroundings and is a means for improving mental recital. Sleegers *et al*. (2012) and Aloyo (2015) in one accord attest that quality artificial classroom lighting has a positive effect on students' accuracy, reading speed, concentration and academic achievement.

Even though there has been a successful advancement in lighting technology, artificial classroom lighting conditions in many secondary school classrooms are worse or below the required threshold. Many of the secondary school classrooms have unnecessarily inefficient classroom lighting that has been attested to cause discomfort and learning related problems (Samani and Samani, 2012; Blazer, 2012; Mott *et al.*, 2012; Sleegers *et al*., 2012; Cheryan *et a*l., 2014; Glavand *et al*., 2016 and Bullina, 2016). Howard (2018) laments that lighting facilities in education environment are much poorer than anticipated causing learners to be faced with many challenges that curtail their learning processes. Most of the current artificial classroom lighting is based on energy saving, dedicated by rigid and inflexible light codes at the expense of creating a conducive learning and teaching environment (Buckley, 2014). Many researchers have attested that high occurrence of artificial classroom lighting challenges have substantial negative effects on students' learning processes (Mirrahim *et al*., 2012). Johnson (2011) confirms that many students who learn using inadequate artificial classroom lighting feel sick, uncomfortable, and therefore loose concentration in learning. Inadequate light control leads to many health problems such as eye strain, musculoskeletal injuries and decreased attention span (Samani and Samani, 2012).

In Kenya, no study has been conducted to establish how artificial classroom lighting affect students academic performance in secondary schools. The Kenya Ministry of Education Science and Technology policy only mentions that that poor lighting can lead to eye problems and classroom lighting shoul be sufficient. It does not specify the standards to

be met in artificial classroom lighting installation. In response to the artificial classroom lighting challenges, there is a need to install classroom lighting of 300lux – 500 lux maintained illuminance (Bank, 2018), with 80+ Ra colour rendering (Raymond, 2008), and 3,000 – 4,000 K colour temperature (Sleegers *et al*., 2012). This kind of lighting installation will create a comfortable and conducive environment that will make students to concentrate and attain high academic performance. The installation of pendant luminaire should be implemented in the classrooms because they spread artificial classroom lighting uniformly and evenly in the learning environment (Acuity Brands, 2014). It is on this background that the researcher will investigate hpw close the lighting is close to the standards.

1.3 Purpose of the study

The purpose of this study was to assess the effects of artificial classroom lighting on public boarding secondary school students academic performance in Nairobi Countyof Kenya. In this study, the effect of artificial classroom lighting is being investigated because students use it durig the evening preps, private studies and morning preps.

1.4 The objectives of the study

The following objectives guided this study.

1.4.1. Main objective

The main objective of this study was to determine the effects of artificial classroom lighting on public boarding secondary school students' academic performance in Nairobi County of Kenya.

1.4.2 Specific objectives

The specific objectives of this study were:

1. To determine the effect of artificial classroom lighting on reading which affects the academic performance of students in public boarding secondary schools.
2. To establish the effect of artificial classroom lighting on instruction that affect the academic performance of students in public boarding secondary schools.
3. To find out the effects of artificial classroom lighting on students' health which affect students' academic performance in public boarding secondary schools.
4. To determining the effect of artificial classroom lighting installation technology on public boarding secondary schools students academic performance.

1.5 Hypothesis

This study tested the following hypotheses:

H_{01}: There is no significant correlation between artificial classroom lighting and students 'reading that affects students' academic performance in public boarding secondary schools in Nairobi County.

H_{02}: There is no significant relationship between artificial classroom lighting and instruction which affect students' academic performance in public boarding secondary schools in Nairobi county.

H_{03}: There is no significant relationship between artificial classroom lighting and students' health which affects students' academic performance in public boarding secondary schools in Nairobi County.

H_{04}: There is no significant relationship between artificial classroom lighting technology and public boarding secondary school students academic performance.

1.6 Justification of the study

Connecting electricity in all schools in Kenya is one of the government big agenda for facilitating the integration of information communication technology in instruction (world Bank, 2018). The installation of artificial classroom lighting in public schools uses public money which requires prudent management to realize the value of the money. This research focused on providing information on the need for quality installation of classroom artificial lighting. The study examined the effect of artificial classroom lighting on students' academic performance in Nairobi County of Kenya. This study also conducted

an experiment to show that illumination of 300 lux – 500 range improves students' academic performance. This thesis, therefore, tries to fill the existing academic gap by providing information about the effects of artificial classroom lighting on students' academic performance and proper classroom lighting installation standards. The findings of this study will help various concerned parties in the building sector as follows; The regulatory agencies (National Construction Authority, Ministry of Public Works and Housing and etc.) in developing regulations that will guide electrical installation in schools and professionals in electrical installation technology in developing specifications, codes and policy document to guide the installation of electricity in schools.

1.7 Significance of the study

This research will create an awareness of the state of artificial classroom lighting in Kenya public boarding secondary schools. This study is useful in many ways. First, the study advances knowledge on the installation of artificial classroom lighting technologies in Kenya public boarding secondary schools. Second, it contributes to the solution of problems associated with artificial classroom lighting technologies. Third, it reveals the effects of artificial classroom lighting on students' concentration and academic achievement. Fourth, the study recommends the artificial classroom lighting standards that will greatly improve secondary school student learning environment. Fifth, the study provides the Kenya Bureau of Standards (KEBS)with information for standardizing secondary schools' artificial classroom lighting technologies. Finally, the findings of this

study will provide information which will be used by school policy-makers to give guidelines on the proper installation of artificial classroom lighting in secondary schools.

1.8 Research assumptions, scope, limitations, and delimitations of the study

The following are the assumptions, scope, limitations, and delimitations of the study;

1.8.1 Assumption of the study

This research was grounded on the expectations that: all participants were truthful in providing the solicited information; all the participants who took part in the research shared similar experiences, all students in each school were of the same entry behavior and the sample was representative of the population the researcher wished to make an inference to.

1.8.2 Scope of the study

The scope of this study refers to the assessment characteristics under which the study had an effect. This study was mainly related to the effect of artificial classroom lighting on Nairobi County public boarding secondary schools students' academic performance. In this study, reading, instruction, heath and lighting installation technology are independent variables and students academic performance is the dependent variable. The general cost of electricity, wall colour, classroom size, MOEST policies on classroom artificial lighting, classroom design, electric light installation codes & curriculum content are intervening variables. The sample of the study was selected from twenty public boarding secondary schools in Nairobi County of Kenya. The sample population comprised of twenty (20)

principals, two hundred (200) teachers, twenty (20) nurses, and four hundred and thirty-five (435) form three students.

1.8.3 Limitations of the study

Limitations in this study are issues and events that arose in the study that were beyond the researcher's management (Simon, 2011; Mutegi, 2015). This study should have been conucted in all boarding secondary schools in Kenya to improve external validity. However, time and financial contraints dictated the employment of geographical delimitations and smaller samples. Due to the nature of the school some schools were not accessible e.g. schools that were located in military instutions. Some responses were not forthcoming because some respondent did not return the questionnaires.

1.8.4 Delimitations of the study

In this research, the delimitation was a feature that limited the range of items to be included in the study and defined the study's predecessor but was under the control of the researcher (Simon, 2011). This study concentrated on government-owned boarding secondary schools in Nairobi County because artificial classroom lighting influences boarding secondary schools learners' fully and impacts on their academic perfromance. This study specifically focused on artificial classroom lighting installation technologies, distribution, properties, reading, instruction, health and students' academic performance. The participants of this research were picked from twenty (20) state-owned boarding secondary

schools in Nairobi County. The study sought views of school administrators, educators, nurses and learners of public boarding secondary schools in Nairobi County.

1.9 Theoretical framework

This research adopted dual coding, automatic information processing in reading, and education productivity theories.

1.9.1 The Dual coding theory

Dual Coding Theory (DCT) is adopted from Paivio in 1986, and Baddeley in 1992 (Yilmaz-Soylu and Akkoyunla (2009). DCT states that people use two diverse channels to process visual and auditory information. DCT originated from the use of imagery as a retention aid 2500 years ago (Paivio, 2006). The retention overstating changed into a wider use of imagery intended at hastening the attainment of knowledge (Paivio, 2006). DCT involves the interaction of two distinct units, shown in Figure 1.1, a verbal unit dedicated to language and a nonverbal (imagery) unit dedicated to nonlinguistic objects and events (Paivio, 2006). The units are anticipated to contain internal representational units, called logogens (the units which make particular verbal responses available from whatever sources (Morton, 1978) and imagens, that are triggered when one distinguishes, manipulates, or just thinks about words or things. The representations are modality-specific so that we have different logogens and imagens corresponding to the visual, auditory, and haptic (feel), and motor properties of language and objects. The representations are connected to sensory input and response output units as well as to each other so that they

can function independently or cooperatively to mediate nonverbal and verbal behavior. The representational activity may or may not be experienced consciously as imagery and inner speech.

DCT clarifies people's behavior and experience in terms of dynamic associative processes that operate on a rich network of modality-specific verbal and nonverbal (or imagery) representations (Clark and Paivio, 1991).

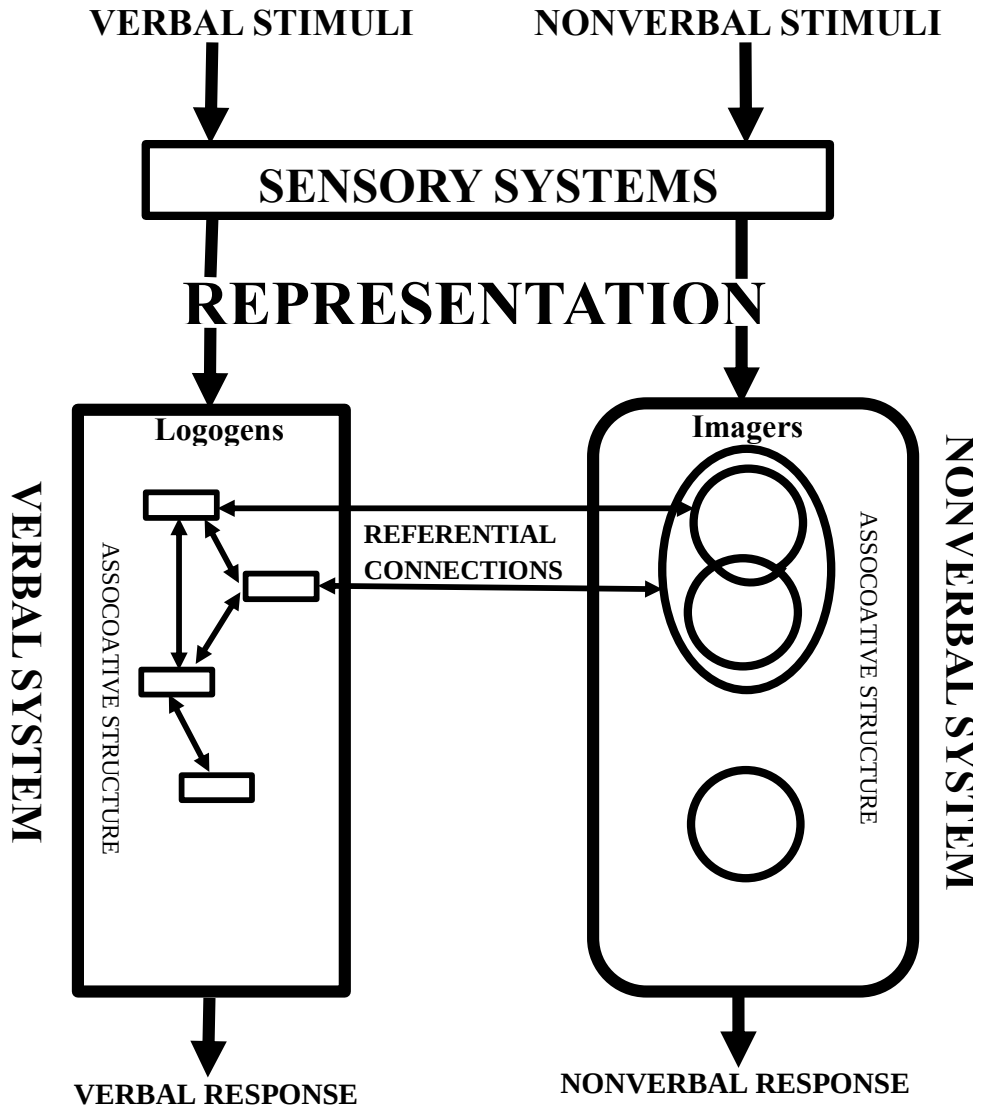

Figure 1.1 Spoken and unspoken symbolic units of DCT (Clark and Paivio, 1991*)*

This theoretical framework was used to help conceptualize that proper luminance; good lighting distribution and uniformity; elimination of glare and flicker; proper lighting systems and lighting control are key factors affecting the learners' concentration and

performance in Nairobi County secondary schools. It clarifies different aspects that affect the creation of a good environment that facilitates learning and concentration. More so, it attempts to identify the key components that can be improved to ensure that there is quality classroom artificial lighting.

The theoretical framework is useful in the identification of factors affecting the quality of classroom artificial lighting technologies. It also brings out a clear picture of the challenges of artificial classroom lighting on learners learning environment.

However, in adopting this theory, the researcher is aware of its wide range of applications, but this has been solved by the researcher in limiting the study to an evaluation of the effects of artificial classroom lighting on students' academic performance in Nairobi County.

1.9.2 The theory of automatic information processing in reading

The theory of automatic information processing in reading states that surface-level processing of words must occur automatically with the cognitive effort so that readers can focus on comprehension (La Barge and Samuel, 1974). Stanorich (1980) extended the theory by saying that good or poor readers can be characterized by how they identify the words themselves. The theory was used by Mott *et al.*, (2012) to highlight the effect of dynamic lighting on student learning. This theory informs the study that if artificial

classroom lighting is improved learners will inprove their reading eloquency and comprehension which will greatly improve their academic performance.

1.9.3 Walberg's theory of education productivity

Walberg's theory of education productivity (Walberg, 1981) postulates that individual student's psychological characteristics and their immediate psychological environment influence educational outcomes: student's ability / prior achievement, motivation and level of development. The theory of educational productivity examines variables that include traits that are intrinsic to the learner, instructional factors, and environmental factors (Kuterbach 2013). One variation of the Carroll model is Walbrg's (1981) theory of educational throughput. The model consists of nine factors designed to affect the cognitive, as well as effective, outcomes of learners. The nine factors include (a) ability or prior achievement, (b) age, (c) motivation (d) self-concept, (e) quantity of instruction, (f) quality of instructional experience, (g) classroom or school environment, (h) peer group environment and (i) Mass media (Rugutt, 2005). This theory suggests that the student's psychological characteristics and their immediate psychological environment influence their educational outcomes (cognitive, skills, and attitudes). This is considered as educational process goals as well as achievement goals to increase educational productivity. This theory informs the study that artificial classroom lighting affects students' psychological characteristics and their immediate psychological environs which influences their academic performance. The improvement of artificial classroom lighting

will improve students' psychological environment and this will improve students' reading concentration and academic performance.

1.10 Conceptual framework

This conceptual framework specified the area of research interest.

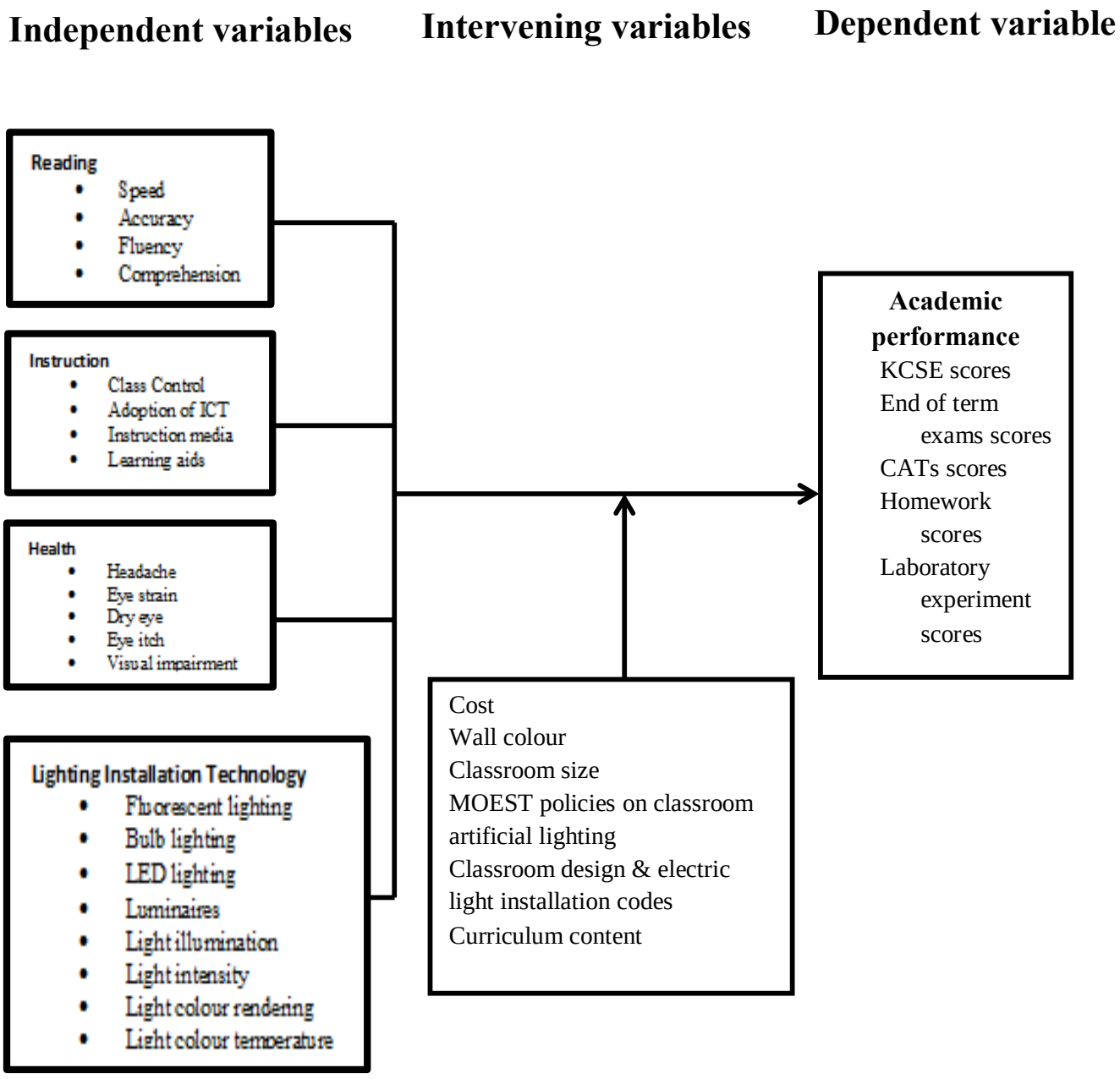

Figure 1.2 Relationships between artificial classroom lighting and boarding secondary school students' academic performance

Figure 1.2 represents a research framework constructed from preliminary studies on artificial classroom lighting effects on students' academic performance. The conceptual framework specified the area of research interest. It illustrates the effects of artificial classroom lighting on learners' academic performance in Kenyan public boarding secondary schools. The conceptual framework consists of independent variables, a dependent variable and an intervening variable. The independent variable is the antecedent of the dependent variable. A dependent variable is one that depends on other variables. Intervening variables are variables that modify the relationship between independent and dependent variables (Vogt, 2011). Reading, instruction, students' health classroom lighting installation technology are independent variables and academic performance is the dependent variable. The cost of electricity, wall colour, classroom size, MOEST policies on classroom artificial lighting, classroom design, electric light installation codes & curriculum content are intervening variables. These factors help demonstrate how learners' learning and academic performance are affected by classroom artificial lighting. Improving the quality of artificial classroom lighting is the option for facilitating learners' learning and improving academic performance.

1.11 Operational definition of key terms

An operational definition is a description that assigns construct or variables that specify the activities or operations required to measure or manipulate construct or variables (Phillips, 2018). An operational definition refers to a variable that describes what the

investigator must do to measure the variable. The following definitions of terms are provided to ensure uniformity and understanding of these terms throughout the study;

1. Artificial classroom lighting:

This is classroom lighting from a source apart from the Sun, Moon, and Stars.

2. Students' academic performance:

Students' learning achievement in relation to the sufficiency of the artificial classroom in terms of illumination, intensity and colour rendering.

3. *Reading:*

The act of looking at the text and understanding what it says

4. Instruction:

What is to be known or done

5. Colour rendering:

This is a general expression for the presence of surface colors when illuminated by light from a given source, consciously or unconsciously, with their presence under light from a reference source.

6. Colour rendering index:

It is a measure of the degree to which the colors of the surfaces illuminated by a given light source correspond to similar surfaces under reference illumination, given the appropriate allowance for color optimization conditions.

7. Colour temperature:

This is the temperature at which a full radiator (or 'black body') will be heated to achieve the same quality (color quality) as the light source.

8. Correlated colour temperature (CCT):

This is the temperature of a full radiator that emits chromosomal radiation close to the light source.

9. Luminous intensity:

It is the candle power of a point source in any particular direction.

10. Visual discomfort:

It is a pain in or around the eyes, often associated with headache and/or nausea, and sometimes symptoms such as red, itchy, or watery eyes.

11. *Illuminance:*

It is the amount of light measured on a flat surface (or the total luminous flux phenomenon on a surface, or the total luminous flux phenomena on a surface, per unit area).

1.12 Summary

Light is one of the elements that play key roles in human life and it is essential in our daily lives because it helps us to operate ideally in every environment. Natural classroom lighting has a positive impact on students' academic performance, but at night and during overcast days, artificial classroom lighting comes in handy. Although artificial classroom lighting provides countless advantages on students learning, most of the secondary school artificial classroom lighting produce glare, flickers and reflections that have been proved to cause discomfort, strain, fatigue, circadian dysfunction, headaches, red (bloody) eyes after reading, decreased attention span, impaired visual performance, grave musculoskeletal injuries and poor students' academic performance. The aim of this study was to determine artificial classroom lighting effects on public boarding secondary school students' academic performance with the aim to improve academic achievement. The study adopted dual coding, automatic information processing in reading and education productivity theories. Installation technology, reading, instruction and health were the independent variables. Students' academic performance was the dependent variable. Luminaries, cost of light fittings, cost of electricity bills, wall colour, MOEST policies, curriculum content, and design & wiring installation codes were intervening variables.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviewed literature related to artificial classroom lighting effects on public boarding secondary school students' academic performance. The literature studied include: an overview of artificial classroom lighting installation trends; natural and artificial classroom lighting; lighting requirements and application in school building; artificial classroom lighting challenges; students' concentration and academic achievement; artificial classroom luminaries and fixtures; artificial classroom lighting psychological, physiological, biological and health influences; lighting technology and integrated lighting systems; disability issues; fluorescent lighting and light-emitting diodes; physical utilities; artificial classroom lighting layouts, controls, colour rendering, temperature and uniformity; wall illumination; lighting levels, power density and energy codes; melanotic effects of light, human-centric illuminance, lighting quality and dynamic lighting.

2.1 Overview of artificial classroom lighting installation trends

The following are a global, regional and local overview of artificial classroom installation trends.

2.1.1 Global overview of artificial classroom lighting installation trends

The energy codes effected in the whole of the United States of America typical comprise of the maximum connected lighting power density of 2 watts, 100 lux per square meter and 92 mean lumen per watt (Halonen *et al*. 2010), with automatic controls (McCowan *et al*., 2017). In Great Britain lighting of the educational building should be 500 lux, 19 UGR_L, 0.6 Vo / 80 Ra with good vertical luminance on main displays and $\leq 200cd / m^2$ for standard & standard whiteboards (Raymond, 2003). In New Zealand and Australia, recommendations for learning space lighting is 240 lux illumination, warm intermediate IB or 2 lamp appearance with maximum glare index of 19, T-8 or T-5 fluorescent lamps and pendant luminaire (BRANZ, 2007). The global artificial classroom lighting trends meet the required standards. This suggests that the global energy codes effected for artificial classroom lighting range betweem 240 lux to 500 lux with minimum glare index. This shows that required artificial classroom lighting standards are achievable.

2.1.2 Regional overview of artificial classroom lighting installation trends

In South Africa classroom lighting is recommended at 200 lux, classroom size of 52.78 M^2 (7.44 m X 7.09 m) (Bibberd, 2019). In Libya, classroom lighting recommends six (6) 58 Watts tubular fluorescent lamps with an automatic lighting control system and a classroom size of 47.88 m^2 (6 m X 7.98 m) 3.18 m high. The regional artificial classroom lighting trends show that even though there are laid down standards that govern artificial classroom lighting installation, the regional standards do not meet the specified stands or artificial

classroom lighting. This shows that in Africa, artificial classroom lighting does not meet the required standards.

2.1.3 Local overview of artificial classroom lighting installation trends

In Kenya, it is specified that a classroom should be 7.5 m X 5.85m X 6.0 m, accommodate at most thirty (30) students in one-seater desk or forty (40) students in two-seater desk (MOEST, 2008). The Kenya Ministry of Education Science and Technology policy only mentions that that poor lighting can lead to eye problems and classroom lighting shoul be sufficient. It does not specify the standards to be met in artificial classroom lighting installation. This study will help in establishing artificial classroom lighting standards which will help to leverage classroom lighting environment and make it conducive for learning.

2.2 Natural Classroom Lighting

The natural light from the sun is the best source of light which comes with a number of elements which contribute to students' well-being and high academic performance. Many researchers have confirmed that daylight positive influence students concentration and academic achievement (Baker and Bernstein, 2012). BRANZ Ltd (2014) reported that good daylighting significantly improve both students' health and academic achievement. Many students who learn using daylight concentrate more and achieve high academic performance. A study by Garibaldi and Josias (2015) discovered that natural light promotes a feeling of mental and physical well-being, and its' merits are more than just

being a source of light. They revealed that national daylight improve academic performance more than artificial light. According to Higgins (2004), natural light has been reported to have a positive effect on the human body, but in some parts of the world, relying on a natural light source is not achievable. It is true that natural light from the sun is the best for learning environments as compared to artificial lighting but not much research has been done to establish specifically how artificial classroom lighting affects students' academic as individuals and their academic performance.

Natural lighting has a great benefit to body health and mind. A healthy body gives the mind a favorable environment to acquire knowledge that boosts students' academic performance. Singh and Arora (2014) conducted a study on the impact of illumination on student's health exposure and concentration in two public schools in Delhi-Nec. The study revealed that natural light from the sun has a profound effect on the body and mind. Samani and Samani (2012) piloted a study on the effect of indoor lighting on students' academic performance. The study focused on knowledge internalization perspective. The study showed that natural classroom lighting quality had a significant impact on students' academic performance. The study also revealed that insufficient classroom lighting makes students to feel sleepy and lack concentration in learning. A study on the impact of school facilities on student achievement, attendance, behavior and teacher turnover rate in selected Texas high schools by McGowen (2007) showed that students who learned in the classroom with natural lighting performed ninenteen to twnenty six percent (19 – 26%) better than their peers in the classroom without sufficient natural lighting. The study also

revealed that natural classroom lighting creates a learning environment that boosts students' academic achievement. Mirrahimi *et al*. (2012) conducted a study in Malaysia on the impact of natural lighting on student health and achievement. The study focused on the impact of daylight on students' well-being and academic performance. The study showed that daylighting is an efficient way to provide better learning conditions in schools. The study also revealed that poor daylighting in classrooms causes discomfort, which has a far-reaching negative effect on students' physical and mental wellbeing. The study further established that natural lighting has the potential to improve students mental health.

2.3 Artificial Classroom Lighting

Natural light comes with a number of health benefits, but in its absence at night and during overcast days, artificial classroom lighting comes in handy although it is low rated as compared to natural light. This is in agreement with Loe *et al*. (1992) who revealed that in the absence of or inadequacy of daylighting, artificial lighting is the only lighting option. Higgins (2004) advised that effective classroom lighting is achieved when natural light is complemented with automated electric lighting that brightens and dims in response to natural lighting levels. He further proposed that a combination of indirect and direct lighting produces good lighting for a learning environment. Currently, the student population has increased greatly prompting more classrooms to be constructed close to each other obstructing natural daylight entry into the classroom. This leaves artificial lighting to be the only option to illuminate the classrooms which may not be sufficient or healthy for a leaning learning space.

Different learning task areas have diverse illumination requirements some of which requiring integration of artificial and natural lighting. Teachers teaching different subjects use light in diverse ways to support their exclusive teaching styles. Walton *et al*. (2008) suggested that to attain high academic performance, classroom lighting system should be flexible to support every teacher's diverse teaching needs. This indicated that there is a need to design artificial lighting technologies to control the intensity of classroom lighting so that it corresponds to requirement of the activity taking place. Adequate artificial classroom lighting enhances students' academic achievement and teachers' instruction. Artificial classroom lighting has a substantial effect on secondary school students' academic achievement. Sleegers *et al.* (2012) measured the effects of light vertical illumination between 350 lux to 1000 lux of a correlated colour temperature of 3000 K to 120000 K on Dutch primary school children. The results of this study showed that quality artificial classroom lighting has a positive effect on students' accuracy and speed of learning. Therefore, there is a need to ensure that our classrooms are well lit with quality light. Blazer (2012) reported that fluorescent lamps are the commonly used classroom lighting installation. A preference study by Walton *et al*. (2008) shows that teachers were in favor of an integrated classroom lighting system because it had a positive impact on the way they taught. This indicates that artificial classroom lighting can be designed so that it creates an environment that favors both students' achievement and support teaching processes.

The artificial classroom lighting should be designed to ensure that it is well distributed at the task area. Light Illumination of 300 lux to 500 lux is suitable for classroom lighting at the working plane. Light illumination levels are measured approximately 32 inches above the floor, 28 inches for the desk and 34 inches for the bench (BRANZ Ltd, 2014). Walton *et al*. (2008) Indicated that classroom lighting should be given the right amount of flexibility to meet the needs of a high-performance classroom. They continued to say that schools with high academic performance begin in the classroom because the high-performance classroom is designed to support new teaching methods. They concluded that apart from the rapid growth in video presentations across all levels of education, there should be a provision for the use of whiteboards, laptops, tablet PCs and electronic smart boards in the current classroom.

Apart from just lighting the classroom, the colour of classroom lighting is paramount since it also greatly affect the learning environment. Benya and Benya (2001) reported that fluorescent T8 or T5 linear lamp technology with electronic ballasts provide the greatest energy efficiency and superior color that is conducive for lighting. They reported that the latest second-generation T8 lamps produce ten percent (10%) more light per watt than the original T8 lamps, and fifty percent (50%) more watt than the older T12 lamps and it is still the most commonly used lamp in schools. He said that although second-generation T8 lamps are currently around thirty (30%) percent more expensive than ordinary T8 lamps, they have better color and light output that is worth the cost because their light output is twenty percent (20%) more. They concluded that in comparison with T8 generic

lamps, buying of second generation lamps for typical classroom lighting would only attract an additional cost of about Ksh. 515 per year. This shows that T8 and T5 lamps technology with electronic ballast are good choices for classroom lighting but T8 lamp is superior than T5 lamp.

2.3.1 Science Work and Laboratories

All laboratories and workshops where learning takes place rely on the presence of light which enables the learners to see the activity taking place. The design of artificial lighting for science laboratories and workshops should be done well to ensure that they eliminate glare which blurs visual performance. Loe *et al.* (1999) reported that higher illuminance is appropriate in high school laboratories where complex laboratory practicals are carried out which need accurate readings, measurements and correct observations. They revealed that high illumination can be achieved by the use of general lighting or local task lighting accompanied by general lighting. They argued that adjustable bench lights are suitable where fixed benching is used, particularly where controlled directional lighting is suitable. They also indicated that directional lighting eliminates distraction or glare at the surrounding work positions and reduce physical encumbrance. They advised that creating a benchtop with material that is light-coloured creates a comfortable visual condition and eliminates awkward peculiar reflections. They recommended the installation of preferential and directional lighting to illuminate demonstration benches. They also indicated that ideals for laboratories also apply to preparation rooms attached to laboratories. They concluded that good lighting is particularly important for lab users to

ensure good visual performance, prevent accidents and gurantee safe handling of equipment.

2.3.2 Design, Technology Rooms, and Workshops

Artificial lighting designs for design technology and workshops should be done so that they provide for harmonized lighting with colours for special tasks. Loe *et al*. (1999) revealed that design rooms and workshops should be installed with general lighting complemented with individual task lighting where directionality of light is significant. They suggested that provision should be made to avoid interference with the position of machines and the people around. They reported that lathes and other machine tools require task lighting lights for safety reasons. They advised that all luminaires should be robust. They warned that discharge lamps should be avoided in the workshops because they do not enable people in the workshop to see rotating machines due to stroboscopic effect. They concluded that design rooms with display area should be installed with preferential lighting. Workshops should be well lit to enale people to use machines and equipment safely.

2.3.3 Libraries

Artificial lighting in the library is critical since it is a learning space where most reading takes place. Loe *et al*. (1999) indicated that lighting in the library should be coordinated to accomplish many tasks such as lighting for general surrounding, vertical book stacks, study and surfing. They suggested that it is essential that the lighting system is designed

in such a way that there is no conflict between the installation and the presence of different parts of the lighting distribution throughout the library. They recommended that special attention should be paid to the design to avoid problems with vein reflexes, glare and use of Visual Display Units (VDU). They suggested that ambient lighting from overhead luminaires could be used for normal reading tables and browsing. They also advised that the vertical spine of the books on the stack should be lit by special lighting with asymmetric light distribution. They proposed that increased light for the lower shelves could be obtained by the use of light-colored floor covers or by tilting the book stacks outward. They noted that it was not possible to provide ceiling-mounted lighting directly related to the book stack, a continuous line or lines of luminaires should be positioned at right angles to the line of the book stack. The suggested that the type of luminaire and its spacing should be chosen to provide uniform illumination on the vertical spine of the books. They concluded that supplementary tables should be provided for study tables and Karel and for digit control desks.

2.3.4 Areas with Display Screen Equipment

Display Screen Equipment (DSE) is aphrase given to VDUs. DSEs have become progressively important teaching assistants in both primary and secondary schools. The classroom with DSE requires special lighting design. Loe *et al.*, (1999) indicated that one of the main problems in the use of DSEs is unwanted reflections that may occur in a DSE screen. These reflections can be quite bright making it difficult for students to read monitor

characters. They suggested that the light in front of the screen should be such that the lighting on any surface is reduced so that the screen characters are not obstructed from being read.

2.4 Artificial lighting challenges in the educational environment

Glare, flicker, and reflections are the main challenges faced in artificial classroom lighting. This is because they cause visual impairment and discomfort. Visual impairment makes students strain in order to see what is written on the chalk/whiteboard or white paper (samani and samani, 2012). Straining to see make students spend a lot of energy struggling to see and therefore get fatigued (Mott *et al*., 2012). Fatigue deters the learning process and ultimately students' overall academic performance while discomfort makes the student lose learning morale.

2.4.1 Glare

Glare is unwanted light in the visual field (Ibanez and Sacht, 2017). Glare is the greatest challenge in a teaching and learning environment. In a study commissioned by Australia Ministry of Education that assessed teachers' perspective on the quality of light in the classroom, BRANZ (2007) revealed that students and teachers don't like glare and flicker. McCowan *et al*. (2017) indicated that both reflected and direct glares are the major problems in classrooms. They warned that inadequately designed lighting is also the main cause of disability glare in classroom environment. They suggested that the maximum dazzle index could be given for lighting installations so that they could be designed

accordingly. Direct overhead brightness is produced by too much brightness in the light fixtures themselves (Ibanez and Sacht, 2017). Reflected brightness is a problem when light glare is reflected on work surfaces such as white paper and computer screens. Dazzle casts shadows on work surfaces that distort effective visual perception.

Dazzling causes visual discomfort when parts of the room are overly bright (Ibanez and Sacht, 2017). The glare index is a numerical index that enables the illumination brightness to be ranked in order of severity by lighting installations.

One of the key aspects of achieving an adequate classroom learning environment is to provide a balanced lighting distribution. Loe *et al*. (1999) argued that when the sky luminance seen through a window is very high and close to the line of sight of a visual task of very low brightness, the lack of detail in contrast to the task causes glare with disabilities, making it impossible to see the details. They pointed out that discomfort can be experienced equally even when parts of the interior have a lot more light than the over-all surroundings. They concluded that dazzling disability of daylight discomfort may be a more common occurrence than dazzle and that in most circumstances, its degree is not on the size or shape of the window, but in the light of the sky seen in the general direction of view. Glare is classified as direct glare and reflected glare

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2.4.1.1 Direct glare

There is a lack of glare control on very bright surfaces due to direct glare luminaires (Zumtobel, 2017). Direct glare causes loss of concentration, recurrent mistakes, and tiredness. To eliminate direct glare we should use luminaires with restricted luminance intensities and fix canopies on windows.

2.4.1.2 Reflected glare

Reflected glare causes tiredness and lack of concentration on the task. Reflective glare is caused by reflective surfaces, incorrect luminaire distribution, and incorrect workstation conditions (Zumtobel, 2017). Reflected glare causes loss of concentration, recurrent mistakes, and tiredness. To overcome reflected glare we should install similar luminaire in a workstation (layout), use indirect lighting and matt surfaces. According to Ibanez *et al*. (2017), the shelf lighting strategy will aid in improving lighting conditions because it will prevent glare, can be easily controlled with shutters and can facilitate light incidence distribution within the environment. They recommended the installation of luminaries close to the boards. The installation of luminaires helps to reduce artificial classroom lighting reflected glare.

2.4.2 Flicker

Flicker is a constant repeat on and off states of light. Flicker is due to poor servicing and maintenance of artificial classroom lighting and it is the greatest menace in the classroom. It makes the learning environment very uncomfortable for teaching and learning. BRANZ

(2007) discovered that older types of discharge lamps and fluorescent lamps sometimes cause flicker that causes discomfort, annoyance, and can be dangerous with machinery when one is moving around in the workshop. He suggested that the use of high-frequency control eliminates flicker by increasing the oscillation rate to a non-detectable high frequency. There is a need to ensure that the artificial classroom is well designed and serviced regularly to avoid flickering. High-frequency electronic ballasts are better for fluorescent lamps because they avoid subliminal flicker.

2.5 Luminaires

A luminaire is a surface which reflects rays of light. Luminaries play a key role in improving artificial classroom lighting system. The luminaire holds the lamp and guides the light in the required direction. Luminaires include all components for fixing, protecting lamps and connecting them to the power supply. They also provide optical control that warrants that light is directed where it is needed as well as shielded from areas where it is not needed. A luminaire is a complete lighting unit consisting of lamps and fitting (SEAI, 2010). According to Etayo *et al*. (2007), luminaries use reflectors or diffusers. They argued that although the choice of high-quality lighting lamps is important for the installation of an efficient lighting system, the choice of lighting should be based on luminaire efficiency. They also pointed out that the optical elements of the luminaire absorb light, so not all light from the lamp will be emitted from the luminaire. They defined the efficiency of a luminaire as its light output ratio (LOR) which is equal to the total light output of the luminaire's to total light output of the lamp contained in the luminaire. They

also recommend that luminaires with more than 80% LOR should be used. Luminaires are used to operate at very high frequencies to provide lighting that improves the appearance of the space (Loe *et al*., 1999). Luminaires should be the key fixtures in artificial classroom lighting because they condition artificial classroom lighting making it conducive for teaching and learning purposes.

Benya and Benya (2001) recommended the use of suspended indirect luminaires in the classrooms. They pointed out that indirect luminaires with relatively low-cost sheet metal bodies have become reasonably competitive in offering light. They said that indirect lighting provides better quality light by illuminating the ceiling, which redirects the light evenly and without glare. They also argued that direct-indirect luminaires, which are more efficient than indirect luminaires alone, work well in orbitals. They reiterated that luminaires are slightly more expensive to install, but high-performance direct-indirect lighting consumes about 20 percent less energy for the same lighting level as lighting alone. They recommend that a ceiling of at least 9 feet 6 inches is needed, and the walls and roof should be light colored. Pendant direct-indirect luminaires are the best choice of artificial classroom light because they create a conducive environment for teaching and learning.

Not all light from a lamp will pass through the luminaire due to the presence of diffusers, and reflectors. Each luminaire has a light output ratio that measures the light output emanating from the luminaire. The most popular type of lavender luminaire will have a specific light output ratio between 36% and 80% (SEAI, 2010). A high-efficiency

luminaire with translucent diffusers can have a light output ratio of up to 93%. In practice, the light output ratio in the region of 65% + will reduce the number of luminaires required for a particular location for louvered luminaires and 80% + for luminaires with translucent diffusers and reduce the cost of ownership. Flush/recessed luminaires cast shadows on the upper levels of the walls and have a tendency to create a dark roof that looks visibly depressed in large rooms. They are not allowed in the new school lighting design. The roof and upper walls look dark with flush-mounted luminaires. The lighting design is aimed at increasing the lighting level (lux) by 50% or more until the ceiling is admittedly bright. According to Ibanez *et al*. (2017) adequately positioned luminaires improve the quality of artificial classroom lighting and favors the execution of activities by providing direct illumination on the work area. Installation of Pendant direct-indirect luminaires with translucent diffusers significantly improves the quality of artificial classroom lighting.

2.5.1 Selecting luminaires for classroom artificial lighting

There are three basic types of luminaires suitable for all-purpose teaching and learning spaces. They include recessed box (or trough) type, surface mounted box type and suspended (pendant) type.

BRANZ (2007) reported that one of the important factors affecting the choice of the luminaire is light distribution (how much light is directed outward, upward and downward). Acuity Brands (2014) reported that high-quality recessed lighting help to create more successful learning environments and is used in suspended ceilings. However,

they underscored that pendant luminaires are more suitable for a learning space since they provide a good balance between indirect and direct lighting. They concluded that the suspended form of classroom lighting maximizes energy savings, delivers quality lighting, and provides an optimal lighting environment for learning.

Installation of pendant luminaires is the most suitable artificial classroom installation technology because they are available with various types of diffusers, provide a good balance between indirect and direct lighting and are best suited for learning spaces.

Table 2.1 Analysis of luminaries for classroom artificial lighting

Luminaire	Characteristics
Recessed	• Only suitable for suspended ceilings. • Provide direct light. • It can be applied with a range of diffusers. • May have a high degree of brightness. • Do not light the roof.
Surface-mounted	• Suitable for most roofs. • Depending on the design and type of diffuser used, direct lighting and dome can give indirect light. • Can throw some light on the roof. • Brightness is reduced by some direct light
Pendant	• Suitable for most learning places. • It can give a high proportion of direct and indirect light depending on the design. • It can lighten the roof. • Gives minimum brightness and even diffusion of light.

Source: Acuity Brands (2014)

2.6 Students Concentration

Artificial classroom lighting has far-reaching effect on student concentration. A research conducted by Sleegers *et al*. (2012) revealed that artificial lighting had a significant effect on focus and academic performance (F, (1.35, 117.05) = 79.28; $p<0.001$, $\eta p^2 = 0.477$). The study showed that on average, students in the control group performed better on concentration performance than their peers in the experimental school and, overall, students' performance increased at constant time points, indicating a potential learning effect. The study also revealed that the focus light setting had a positive effect on students' concentration. Further analysis of the study indicated that on average, girls outperformed boys in focus lighting ($F(1.85) = 7.92$, $p < 0.01$, $\eta p^2 = 0.085$. The study concluded that pupils in the focus lighting setting performed better on concentration performance ($M = 159.57$; $SD = 27.78$) than pupils in the general performance setting ($M = 157.69$; $SD = 31.21$).

This establishes that artificial classroom lighting has a significant relationship with students' concentration and performance. According to HWWE (2014), it is important to be aware of the impact of the built environment on the concentration performance of students as they spend 80–90% of their indoor time at school or at home. It reported that sufficient lighting significantly improves students' frame of mind, concentration and learning performance. It contended that if students are uncomfortable with the insufficiency and colour quality of lighting their ability to learn will suffer. Mott *et al.* (2012) reported that mood determines the sharpness of cognitive abilities which are the

basic building blocks of a good academic performance. This suggests that artificial classroom lighting in all schools should be adequate in order to provide a conducive learning environment. A conducive and comfortable classroom environment motivates learners to concentrate in in their studies.

2.7 Student Academic Achievement

Students'academic achievement is greatly influenced by the nature of their classroom lighting. Classroom artificial lighting design has a positive or a negative impact on students' academic performance (Kunz, 2014). Mott *et al.* (2012) studied two groups of eight-four (84) third-grade students of which one group learnt using a maintained 6000K - 100fC average lighting and the other group learned using general lighting. The study aimed at determining whether dynamic lighting had any effect on students' learning. The study showed that focus lighting significantly increased oral reading and fluency. The study revealed that the nature of the task, light spectrum and distribution determines the learners' level of academic performance. The study also indicated that girls performed better on cognitive tasks in warm white lighting environments, while boys performed better on cognitive tasks in cool white lighting. Both boys and girls responded differently in light illumination levels and color index. In another study of the effect of light and gender by Knez (2001) found out that women were more sensitive to light than men. They also discovered that men and women performed differently in different types of light. Again Mott *et al*. (2012) conducted two experiments to analyze the effects of color temperature and illumination levels on the frame of mind and mental performance tasks, including long-

term recall, free recall, and performance evaluations among boys and girls. After each experiment, each subject was administered a test to measure the frame of mind. Results showed that girls performed better on cognitive tasks in warm white light environments, whereas boys performed better on cognitive tasks in cool white lighting conditions.

This indicates that gender moods are affected differently by the level of illumination. Studies by Mott *et al*. (2012) and sleegers *et al*. (2012) reported that brighter lighting of 500 lux has a more positive effect on reading, writing, and mathematics as compared to standard lighting of 300 lux. They further explained that apart from the effects of illumination, light from different colour correlated temperatures of 4000 K and 17000 K had a positive effect on educational achievement.

Samani and Samani (2012) studied the effect of indoor lighting on students learning performance to determine whether there was a significant relationship between performance quality and students' learning performance. The study used survey data collected from one hundred and fifty (150) students from Alpha Course in Malaysia. The study revealed that there was a significant relationship between the quality of the light and students' academic performance. The study further suggested that appropriate light quality increases productivity and performance, but reduces eye strain and fatigue. Hathaway (1993) conducted a pilot study on the effects of type of light on children with the aim of investigating the physical development and school performance effects of various lighting systems on experimental students. Statistical evidence showed that students who learned

under the full-spectrum fluorescent lamp with ultraviolet supplement had better academic achievement. Dudley *et al*. (2011) conducted real-life case studies throughout Oregon State, focusing on lighting, air, and noise. The study involved one group of students who learned in insufficient artificial classroom environment and another group of students who learned in sufficient artificial classroom lighting environment. The result of this study showed that artificial classroom lighting influences students' academic achievement. Blackmore *et al*. (2010) reviewed learning spaces literature to determine the relationship between learning space and students' learning. Empirical comparisons were made between learning space and students' academic performance. The result of the study showed that artificial lighting has a considerable effect on learners academic performance.

The visual environment affects a learner's ability to observe visual stimuli and academic performance. Fielding (2006) and Pulay (2010) reported that students who have motivation in their school's internal environment are more academically successful. A good color rendering light source is important in all classes. This is in agreement with Loe *et al.* (1999) who recounted that light sources with good colour rendering make learners to be attentive and to score high grades.

Knez (1995) and Blazer (2012) revealed that insufficient artificial lighting negatively affect students 'academic performance while adequate artificial lighting positively affect students' academic performance. Though, Veitch (1997) argued that light has no effect on the frame

of mind or academic performance. Sleegers *et al*. (2012) reported that good lighting increase human performance.

2.8 Artificial classroom lighting psychological influence

Artificial classroom lighting has a detectable psychological effect on students. Mott *et al.* (2012) reported that lighting plays a central role in arousing emotions (Mott *et al*., 2012). They also noted that brightness, color, direction, contrast and time are the parameters used to create the lighting conditions. Lighting can be used to make the architectural space visually appealing. In addition, the well-being of the user can be directly affected by light. Samani and Samani (2012) reported that the psychological effect of light is strong and cautioned that light has a visible psychological effect on students. Granito and Santana (2016) studied the psychology of learning space to determine the attitudes of students and instructors on how classroom space and environment impact on teaching and learning. The study utilized four groups comprising two groups of students and two groups of faculty. The results of this study revealed that a dark classroom naturally encourages learners to fall asleep. Gsribaldi and Josias (2015) assessed how space, crowding, layout, safety, and security could support the socialization process of students in order to determine how the built environment of schools relates to their socialization process. This study showed that artificial lighting affected students' moods and attitudes. Winterbottom and Wilkins (2009) examined ninety (90) classrooms in eleven secondary schools and six (6) social educational authorities to determine whether artificial classroom lighting inconveniences learners. The study measured glare, the illuminance at desks, and the luminance of

whiteboard variables. This study showed that eighty percent (80%) of the students who learned in classrooms that were lit with 100 Hz fluorescent light suffered from headache and visual impairment. This reveals that inadequate artificial classroom light make students to suffer from headache and visual impairement.

2.9 Artificial classroom lighting physiological influence

Artificial classroom lighting affects hormonal balance in the body. Gilavand *et al*. (2016) examined the impact of environmental factors on elementary students learning and academic achievement to determine whether the school's open spaces, noise, and light had a significant impact on primary students' academic achievement. This study indicated that the quality of artificial lighting inhibits stress hormones. Studies show that the intensity and color temperature of artificial light affect various physiological processes in the human body, such as blood pressure, heart rate variability, electroencephalography (EEG), core temperature, and melatonin (Sleegers *et al*., 2012).

Cheryan *et al*. (2014) examined lighting, noise, air quality, and heating to determine whether classroom designs maximized students' achievements. The study showed that male undergraduate students performed best on the test of the related word when they had learned at room temperature of 25℃ and performed significantly worse as the temperature became more extreme in either direction. The study also showed that the optimum temperature for learning appears between 22℃ and 27℃. Artificial light affects the human internal clock that regulates hormones or other essential bodily functions necessary for

sleep, body temperature, and heart rate (Samani and Samani, 2012). According to Caballero-Arce *et al*. (2012), long-term short-wavelength light exposure is a potential cause of fatigue, while the short-wavelength light phase shift is highly effective for circadian rhythms that activate the nervous system. Harvard Health (2017) revealed that blue light more powerfully suppresses the secretion of melatonin, red light also suppresses melatonin but has the least power shift circadian rhythm. According to Kunz (2014), white light has a greater psychological effect than bright cold white light that suppresses melatonin. Adequate artificial classroom lighting inhibits the secretion of stress hormone but insufficient artificial classroom lighting inhibits melatonin and shifts circadian rhythm which activates the nervous system.

2.10 Artificial classroom lighting effect on health

Light greatly affect human health. Insufficient artificial classroom lighting can cause a number of light related illnesses. Light has an impact on health than it is assumed (KAN, 2015). According to Kunz (2014), the range of biological effects of light is considerable. He revealed that artificial light has positive or negative effects on human health. Bullina (2016) analyzed illuminance and colour temperature measurement across twenty-one (21) classrooms to determine the composition and use of lighting in public K-12 classrooms. Statistical evidence revealed that artificial lighting provided in the classrooms caused health problems to some students. Harvard Health (2017) conducted an experiment that compared the effect of 6.5 hours of exposure to blue light versus corresponding light to green light. Study results showed that there is an association between artificial light and

certain types of cancer, diabetes, heart disease, and obesity. Thurbar (2009) conducted laboratory-based studies and field observations of narrow range species in order to determine artificial lighting pollutants. The results of the study revealed that human health problems are associated with exposure to light that inhibit the production of melatonin which is associated with some cases of breast cancer. Inadequate light control leads to many health problems such as increased body temperature, eye strain, musculoskeletal injuries and decreased attention span (Samani and Samani, 2012). Research has indicated that both natural and artificial light affects people's health. To eliminate these complaints, Karpen (1993) suggested the use of full-spectrum polarized light as it is glazed and flicker-free. Since the use of VDU in schools has increased, the idea of installing glare-free artificial classroom lighting is important. Inadequate artificial classroom lighting cause headache, musculoskeletal injuries, cancer, heart disease, and obesity. The most common complaints of inappropriate lighting are headache, eye strain, visual impairement and fatigue.

2.11 Artificial classroom lighting effects on biological systems of the human body

The extent of the effect of light on the biological systems of the human body is astounding (Kunz, 2014). Thurber (2009) indicated that light is the most potent agent that interacts with biological systems. Caballero-Arce *et al*. (2012) with regard to mental and physical health outcomes, examined the location of lighting to determine the importance of proper lighting in space habitats and to analyze the optical effects of light on humans. The result of the study indicated that light affects human beings' mental and physical, health and

circadian system. The study also revealed that warm white light (3000 K) facilitates relationships and improves well-being. According to Samani and Samani (2012), the penetration of light into the human eye has essential non-visible biological effects on the human body, and it affects people's biological clock such as sleep and waking periods. Prolonged exposure to artificial lighting alters human biological functions, which in turn produces shifts in mental states (Caballero-Arce *et al*., 2012). Kunz (2014), conducted a scientific experiment on the effects of LED desk lamps on human body biological systems. The results of the study were validated against the data that was contained in the corporate database. This study included a theoretical evaluation of the results for other studies from different regions. The results of the study showed that the biological effects on suppression of the production of melatonin in the evening varied. According to sleegers *et al*. (2012) one of the biological effects of light is inhibition and suppression of cortisol and melatonin in people exposed to various lighting systems. Inadequate artificial lighting can inhibit the secretion of body hormones that are important in the normal functioning of the human body. Therefore, inadequate artificial classroom lighting affect the biological systems of a human body.

2.12 Integrated lighting system

The use of controlled artificial classroom lighting is suitable for the integration of ICT in teaching and learning. It provides the light that creates the best learning environment. Walton *et al*. (2008) indicated that integrated orbit lighting is a sustainable design approach that reduces energy consumption by 48% from the level of ASHAE 90.1 (2004). They

reported that energy consumption is expected to decrease further as the use of audio-visual presentations has become common in the classroom. They suggested that integrated classroom lighting is also durable because traditional designs require fewer luminaires, lamps, ballasts, packaging and contractor-supplied parts. Most experts now agree that controlled daylight, when necessary, combined with appropriate artificial lighting provides students with the best lighting conditions (Blazer, 2012).

2.13 Disability issues

Installation of artificial classroom lighting should take into account of special education needs. Appropriate luminaires should be used to concentrate and focus light on the target task. Good quality lighting is important for students learning, especially those with special educational needs (SEN). Natural lighting supplemented with artificial lighting should be used to avoid glare and provide good visual contrast and color. Etayo *et al*. (2007) suggested that the light level should be sufficient to allow the learner to see the teacher's face, whiteboard and computers screens clearly, without reflection, shadows, and harsh contrasts. They reported that hearing-impaired students need to be able to see the instructor's lips clearly, so the correct light level and direction is important. This is because if the light is directed too much downwards, it will create harsh shadows, making it difficult for lips to be read. They recommend that some visual impairment involve a degree of color blindness and that it is important that tone, as well as colour, should be produced on illuminated objects. They concluded that students with visual impairment often require higher than normal levels of illumination.

A good colour choice and contrast of artificial classroom lighting promotes the learning capability of visual and hearing-impaired students. Light and acoustic criteria are important for both the visual and hearing impaired. If one sensory channel is impaired then more dependence is placed on the other channel. Loe *et al*. (1999) indicated that color and contrast are particularly important for hearing and blind people. They reported that the light in the reception or learning areas produces harsh shadows that impede the reading of the lips. They recommend the use of an electrical socket outlet that contains contrast-colored back paper at the standard height that is helpful to the visually impaired. This can be done through the use of colored surfaces rather than more elaborate or extended lighting schemes to help the visually impaired to identify locations (SEAI, 2010). In some situations, local lighting or more use than normal work lights may help. Control of glare from overhead lighting is important for students with a visual impairment, and measures should be taken to reduce it. Special education needs learners require sufficient light higher than normal with tone and colour to enable them to read their instructor's lips.

2.14 School Lighting Requirements

Schools have a diversity of learning areas, and many of these are used for different learning tasks and at different times of the day. Therefore, the type of lighting system to be chosen should be particularly suited to the various tasks that occur in each type of learning area. Sustainable Energy Authoroty of Ireland reveals that T5 (16 mm) tubular fluorescent lamps have been reported to be the recommended option as they only work with high-frequency control gears. It highlighted that appropriate lighting in schools provides visual comfort,

good visibility, good color rendering and uniform lighting (SEAI, 2010). It suggested that when considering new lighting, it is necessary to focus on the teaching work to be done in the area, rather than just the selection of the cheapest possible lighting fitting for the field of learning. It recommended that schools lighting should have good visibility guarantee for all learning tasks; keeping in mind the function of each place, e.g. classroom, library, laboratory, communal area and etc.; keep in mind the visual needs of students, staff and other users; use the most efficient lamps and luminaires (light fittings) to illuminate the space; adding daylight and light-colored walls and ceilings to reduced artificial lighting requirements to the minimum requirement level; use appropriate lighting controls and enhance lighting control; and guarantee easy maintenance and cleaning;

It concluded that in order to achieve the appropriate lighting objectives for the different learning areas, the school building should have a good color appearance of about of 3,000 - 4,000 K; a good 'color rendering' performance of about Ra 100 to provide good color representation; a functional or task lighting of about 300 – 500 lux to enable students and teachers to complete their activities easily and without visual discomfort; an electronic high-frequency ballasts operating fluorescent tubes to overcome glare on computer screens; and a ‘bright’ and ‘interesting / attractive’space

Scherba and Liu (2010) reported that the recommended artificial classroom lighting should provide 30 foot-candles at 30 inches above the floor for general classrooms. They suggested that science and art rooms should be illuminated to 50 foot-candles. Raynham

(2003) recommends artificial classroom lighting to be dimmable with wall illuminance of fifty percent (50 %) of the task area or Ev = 100 lux and ceiling illuminance of a minimum of thirty percent (30 %) of the task area or Ei = 50 lux.

In Kenya, there is no policy document addressing lighting in schools conclusively. Safety Standards Manual for Schools in Kenya of 2008 only says schools to have adequate lighting (Minisry of Education, 2008). Ministry of Education Guidelines on Health and Safety Protocols for Reporting of Basic Educationeducation Institutions Amid COVID-19 Pandemic of 2020 just says ensure lighting. State Department for Vocational and Technical Training COVID-19 General Guidelines and Protocols for the Opening of TVET Colleges of June 2020 only says ensuare adequate lighting. The National Schools Health Policy just says schools to have adequate lighting. The Education Act Cap 211 is totally silent on schools lighting. This indicates that there is no government or Ministry of Education Science and Technology policy guidelines document which provides stardards and specification on lighting in schools. This study remains the only document which can be used as a reference for guidelines for lighting in schools.

2.15 Light Emitting Diodes (LED) Lighting Technology

A light emitting diode (LED) is a semiconductor device that emits light when a current flows through it. The spectrum of LEDs offers a major advantage because it only produces visible light without any ultraviolet or infrared radiation (Zumtobel, 2017). The LED technology has significantly evolved and is being tested to determine if it can be the best

alternative form of artificial lighting that can substantially eliminate udesirable elements of artificial classroom lighting. The Energy focus (2015) reported that LED lighting is the best choice for a learning environment for a school that wants to create a safe, healthy, comfortable and green atmosphere for its students and teachers. It maintained that LED lighting rewards range from safety to monetary savings (from electricity costs and less frequent bulb replacement to learning safety). It testified that LED lighting eliminates undesirable artificial lighting related features that directly affects students' vision and learning ability. It revealed that LED is a front-line solid-state technology that is forecasted to oust all artificial lighting technologies by 2030. It argued that LED bulbs consume less energy and produce more lumen per watt, resulting in higher magnitudes of illumnination. It reinforced that white tubular LED lamps produce better quality light that is a closest spectral match to sunlight without spike or color output. Happek (2009) and Zumtobel Lighting (2017) reported that in comparision with their fluorescent counterparts, LEDs are 100% visually efficient; contain no mercury or hazardous waste and are 100% recycled. They revealed that high-quality LED products last 20 times longer than any other artificial light source, require minimal maintenance and cost less. They concluded that LED or OLED-based solid-state lamps can achieve higher values by emitting individual bands in the blue-red region, without significant radiation outside the requirement of the human eye. These factors make LEDs fluorescent lamp lighting the best choice for lighting a learning and teaching environment.

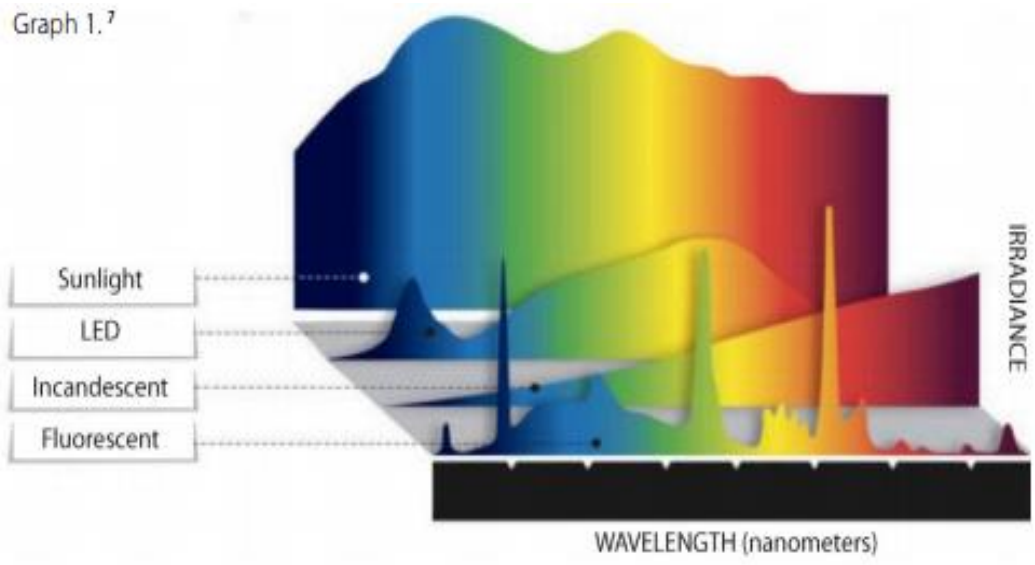


Figure 2.4 Types of lighting wavelengths graph (Happek, 2009)

LED has a high luminous efficacy (lumen / watt), long life service, broad-spectrum of white light (warm white daylight white), no infrared or UV radiation, compact size, good for excellent color rendering index (Ra), luminous flux and service life highly temperature-sensitive, no any environmentally harmful material (eg mercury), a resistance to vibration and impact, saturated color, immediate start, i.e. 100% luminous flux after switching, no ignition, boosting or cooling time, high precision digital dimming and no transfer of color locations during dimming.

Luminous flux and service life depend a lot on temperature (rise at low temperature). (Zumtobel lighting GmbH, 2017). Davis and Wilkerson (2017) carried out a study on tuning the light in classrooms which assessed trial LED lighting in three classrooms at the

Carrollton-Farmer Branch Independent School District in Carrollton. The study involved the use of lighting control system that enabled the variation of the specral power distribution (SPD) of the light in four pre-determined conditions involving nominal CCTs of 3000 K, 3500 K, 4200 K, and 5000 K. The study revealed that the LED lighting system provided for pre-set scene control that varied the on/off status and dimming levels of individual luminaire zones within the room that best supported classroom tasks such as audio visual presentations and student speeches. The study further showed that a combination of spectral tuning and dimming in the classroom provides more opportunity to vary lighting parameters that may affect circadian and behavioral responses of students, teachers, and other users of the classroom than when using fluorescent lighting systems.

Viitanen (2017) indicated that selecting LED as a light source can reduce power consumed by a fluorescent lamp light initially employed at 43 W / m to 10 W / m at the length of the corridor by seventy five percent (75%), reduce maintenance costs and gurantee a longe life of about 50000 hours. Laike (2015) reported that LEDs have the ability to create better lighting environments by varying intensity and spectral distribution. This indicates that the advancement of LED lighting technology is growing and case studies show that the technology is already well suited in work lighting applications.

Acuity Brands (2014) reported Staple LED luminaire from Peerless supports well the modern instructional technology and emits emits diffuse, uniform, color-compatible, and dazzling and flicker-free lighting that is good for lighting classrooms. It concluded that

staple LED luminaires have integrated sensors and relays that give a provision for daylight dimming and occupancy detection, among other capabilities. However, Harvard Health (2017) argued that LEDs are more effective than fluorescent light, but they emit less amount of light in the blue spectrum. An experimental study that involved 40 (20 females and 20 males) conducted by Ram *et al*. (2018) whose purpose was to investigate visual performance during reading under different illuminations sources, found out that visual performance under LED is poor, uncomfortable for prolonged reading and cause early symptoms of fatigue. Light-emitting diode lighting technology is evolving and advancing so much but its application and importance have not been realized in Kenya and other developing nations. However, there is a possibility that LED lighting may be the long-awaited solution for artificial classroom lighting related problems. LED lighting consumes less energy, produce more lumen per watt, contains no mercury or hazardous waste, lasts twenty (20) times longer than any other artificial light source, eliminates glare, suppresses flicker, subdues dazzling, eradicates spike, has no infrared or ultraviolet radiations and produces better quality light that is close spectral match to sunlight. It also support well the modern instructional technology.

2.16 Fluorescent Lighting

Fluorescent lights are gas-filled tubes, with a phosphorescent coating on the inner surface, in which the electric current is controlled through a voltage ballast into a tungsten-cooled electrode. When the light is switched on, a ballast voltage quickly evaporates small amounts of mercury within the tube which emit ultraviolet (UV) light. The inner surface

coating absorbs UV light and changes it to visible light, creating a white glow. For over a hundred years, fluorescent lighting has been the groundbreaking technology in lighting (Energy Focus, 2015). As from 1940, learners have been learnt in classrooms fitted with fluorescent lamp lighting.

2.16.1 Fluorescent Lamp Selection

There are different types of fluorescent lamps fittings each designed for a particular task lighting. Therefore, the choice of artificial classroom lighting needs to be done carefully to ensure that it will positively influence students' academic performance.

2.16.1.1 T-8 lamps

T-8 and T-5 are the fluorescent lamps which have dominated artificial classroom lighting. Power Smart (2009) defines a T8 lamp as a tube-shaped lamp with a diameter of 8/8 in. Caliper (2009) reported that T8 lamps are designed for electronic ballast, which uses solid-state components, are smaller, lighter, quieter and run cooler than magnetic ballast. He argued that T8 lamps are designed for maximum light output at an ambient temperature of approximation 25^0C (77^0F). T8 lamps have higher efficiency as compared to T12 (Myer *et al*., 2009). McCowan *et al*. (2017) reported that T8 fluorescent lamps dominates classroom lighting installations throughout the world. They indicate that T8 lamps produce light of good colour rendering index and greater lumen output. Table 2.16.1.1 illustrates the performance characteristics of assorted fluorescent lamps.

Table 2.16.1.1 Comparison of Fluorescent Lamp Types

Source of light	Lamp type	Efficacy Lumens/watt	Lumen Maintenance	Average Life	Colour correlated index
Fluorescent	T-12 Cool White –EE	62.2	87%	20,000	62
	T-8 80 Series Lamp	101.7	95%	20,000	86
	T-8 90 Series Lamp	62	93%	20,000	95
	T-5	98.6	97%	16,000	85
	T-5 HO	100	97%	16,000	85

(Source: McCowan et al. 2017)

T-8 lamb offers reduced energy consumption and redoubled lumen output. Heschong *et al*. (2002) reported that the T-8 fluorescent lamp/ballast systems are efficient and long life lasting artificial classroom lighting. They revealed that many classrooms that were designed with luminaire type had been retrofitted with T8 lamps electronic ballast. T8 fluorescent lamps are suitable for artificial classroom lighting installation because they are the most efficient lighting designs for learning spaces and offer better colour rendering.

2.16.1.2 T-5 lamps

T5 fluorescent lamps are better than T8 fluorescent lamps but they are more expensive, have a shorter life span and a higher mercury content. Zhang Ngai (2000) reported that T5 with 5/8” lamps offer better luminous efficiency when compared to T8 lamps. They

disclosed that High fashion of T5 lamp (T5H0 lamp) provides approximately 5000 lumens for a 4 feet lamp. They further reported that luminaire using the T5H0 lamp provide a high lumen package in small profile while at the same time offer opportunity to create a better photometric performance. They concluded that T5 and T5H0 lamps are designed with an optimal operating temperature of 35^0C instead of 250C for T8 and T12 lamps. According to E3EEE (2015), T5 linear fluorescent lamps can produce the same quantity of lumens using less power than a T8. It also reported that T5 lamps incurs fewer labor costs due to the compactness of the lamp (SEAI, 2010).

McCowan *et al*. (2017) reported that high-efficiency T5 hollow fluorescent lamps of three hundred lux is appropriate for general purpose classroom lighting and are suitable for higher mounting heights. They suggested that T5 tubular fluorescent lamps of five hundred (500) lux are suitable for special subjects classrooms. They however noted that T5 lamps don't produce full lumen output till they reach the close temperature, present tough disposal problems, are expensive than T-8 lamps, have a shoter life than T8 lamps, and are less extensive than T8 lamps.

2.16.1.3 Biax lamps

Biax lamp is good for artificial classroom lighting because they offer good efficacy, colour rendering, have a low mercury content, and decreased energy consumption. Biax lamps comprise of all types of compact fluorescent lamps. Biax lamps are effective and provide good colour rendering that match the eighty series T8 lamps (McCowan *et al.*, 2017). Two

feet biax lamps are the best selection for two by two fixtures but they are more expensive than linear fluorescent lamps. According to GE Lighting (2013), Biax lamps have high lumens per watt efficiency, a wide range of wattage, increased surface brightness, broad range of colours (300K, 4,000K, 5, 000K) and offers energy-saving throughout the life of the lamps. It revealed tha Biax lamps have low mercury content, and can be used with dimmable electronic gear along with emergency modules. A study conducte in the Unites States of America by Sandal *et al*. (2006) revealed that Biax lamps have decreased energy consumption by one-half as compared to incandesce lamps. Biax lamps can be integrated with T-8 or T-5 lamps to optimize artificial classroom lighting and create a good learning environment that can stimulate academic performance.

2.17 Current Impact of Fluorescent Lighting on Students

When a fluorescent tube filled with a mixture of mercury and inert gases shatters, the mercury and other inert gases escape to the atmosphere posing a health risk. Although this does not frequently happen, when it happens the few learners who will be affected will have undesirable challenges which will make them suffer for the rest of their live. This happening should be avoided at all costs. The mercury in the atmosphere enters the body through the lungs and skin making the body organs to malfunction. Energy Focus (2015) reported that mercury is a hazardous material. It reinforced that when a fluorescent lamp tube shatters everyone in the classroom is exposed to the danger of inhaling mercury which can damage key body systems. It also argued that mercury gas in fluorescent lamps

produces ultraviolet radiation that damages eye and skin tissues. They contended that prolonged exposure to ultraviolet radiation causes eye macular degeneration, eye cataract formation and damages the eye yellow pigment. It warns that students learning using insufficient spectrum light environments often have a hard time focusing. Some people have an enormously sensitive vision, especially in the scoptic (low-light) range, and low-spectrum light can elicit visual impairment, dyslexia or other learning disabilities, dizziness, headaches and nausea. Prolonged exposure to ultraviolet radiation can cause blindness. Poorly designed and installed artificial classroom lighting put the students at risk of visual impairment. A greater percentage of learning takes place through visuals. Therefore, it is vital to design and install artificial classroom lighting properly to ensure that learner visual health is protected.

2.18 Physical Utility

Smooth curves and continuous radiation across the entire spectrum of visible wavelengths result in more vivid, saturated, discriminating color rendering and spontaneous visual acuity. Fully directional down-lighting also delivers more lighting on tasky area, rather than the diffuse radiance produced by a gas-filled fluorescent tube.

Luminous efficacy, correlated color temperature and color rendering of LED lights enhaces visibility creating a better learning environment. Visualization is key factor in a human being's ability to take part and respond to learning requirements. A healthy circadian rhythm (sleep/wake cycle) is essential in mental experience. An individual’s roughly

twenty four (24) hour cycle is controlled by hormonal responses activated by full-spectrum artificial or sunlight provided light (Energy and Focus, 2015).

A Western Reserve University study conducted by Energy Focus (2015) revealed that when the illumination needed to initiate circadian responses is made available, it triggers increased attention, attentiveness, and involvement among students. It concluded that LED lighting increases learner's productivity as compared to fluorescent lighting.

2.19 Classroom Lighting Layouts

The classroom layout scheme is a key factor in artificial classroom lighting design and installation because it determines the concentration and focusing of light on the targeted task area. BRANZ (2007) illustrated and discussed some common lighting schemes as follows:

Arrangement A (Figure 2.5) is an acceptable light installation strategy because its recessed light fixtures are schemed parallel to the windows to give good integration with daylight, it has three rows of recursive directional luminaires will provide good transmission of light on the working plane; its rows of lights are switched on separately so that the level of artificial classroom light can be adjusted in areas corresponding to the accessible light levels of the day, has a board that is is separately lit by a pellet-type luminaire and has a occupancy sensor with manual on-switch will save power

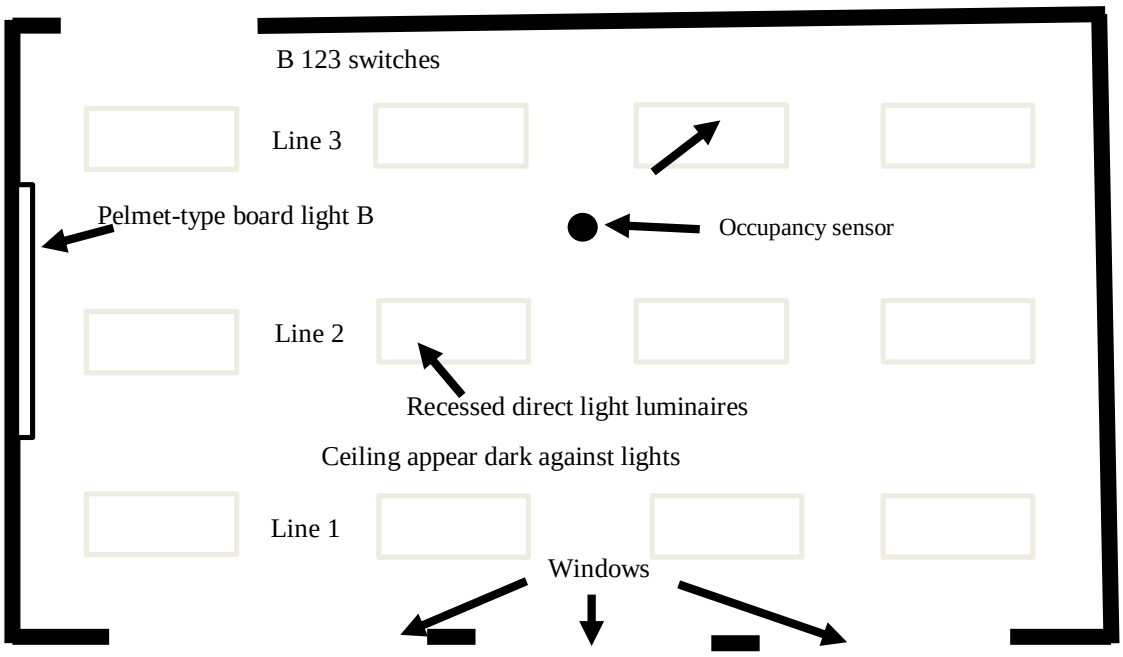


Figure 2.5 Classroom lighting system arrangement A plan (BRANZ, 2007)

Arrangement B (Figure 2.6) is a better lighting system than Arrangement A because its surface-mounted semi-direct luminaires will give a wider, greater, even diffusion of light, has a wide spreading of light will scatter some light onto the ceiling and walls and reduce glare, it distributes light widely allowing the economy of two lines of fixtures, its continuous luminaires reduce contrast and improve light dissemination, its board is separately lit by a wall washer-type luminaire, and has a occupancy sensor with manual on-switch will save power.

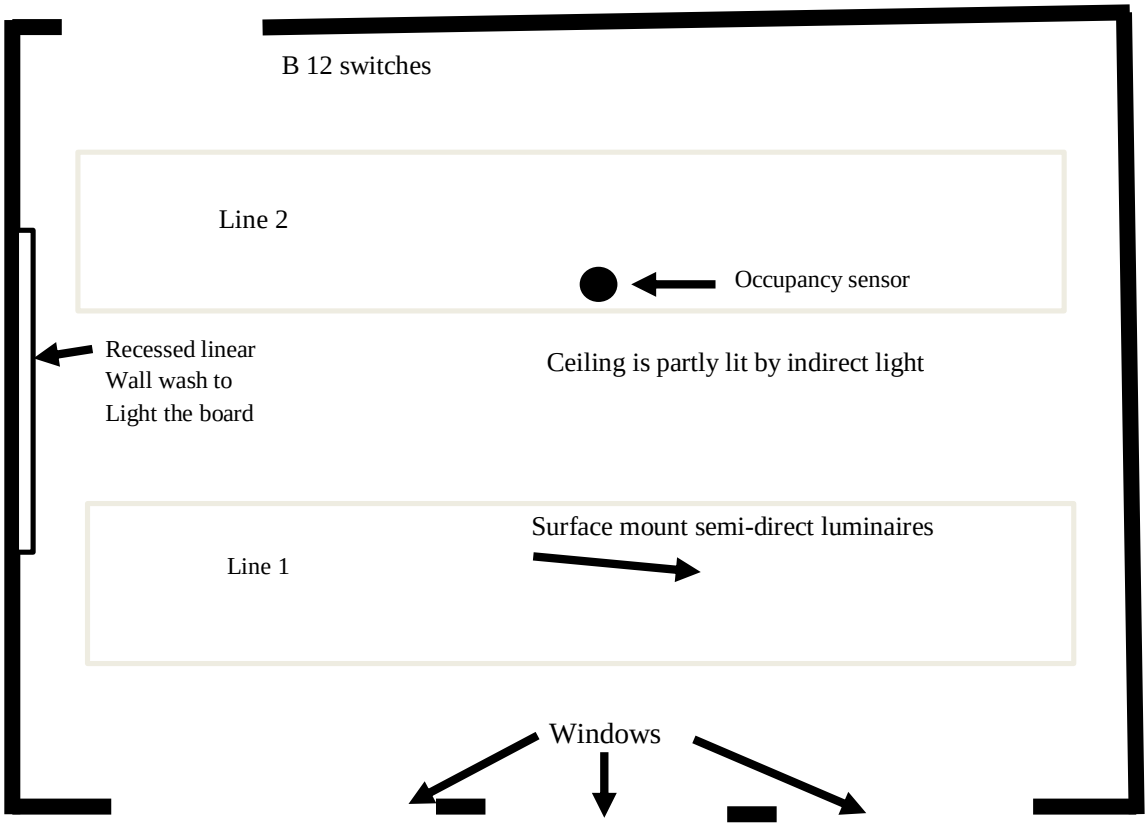


Figure 2.6 Classroom lighting system arrangement B plan (BRANZ, 2007)

Arrangement C (Figure 2.7) is better than Arrangement B because its indirect/direct pendant luminaires give a more comfortable, even, diffusion of illumination, its indirect lighting component illuminates the ceiling and minimize glare, its board is separately lit by a bracket-type luminaire, it is the utmost cost-effective plan and it has a occupancy sensor with manual on-switch will save power.

Flexibility ought to be the main priority when deigning a lighting layout. The arrangement should permit future adjustments in instruction approches.

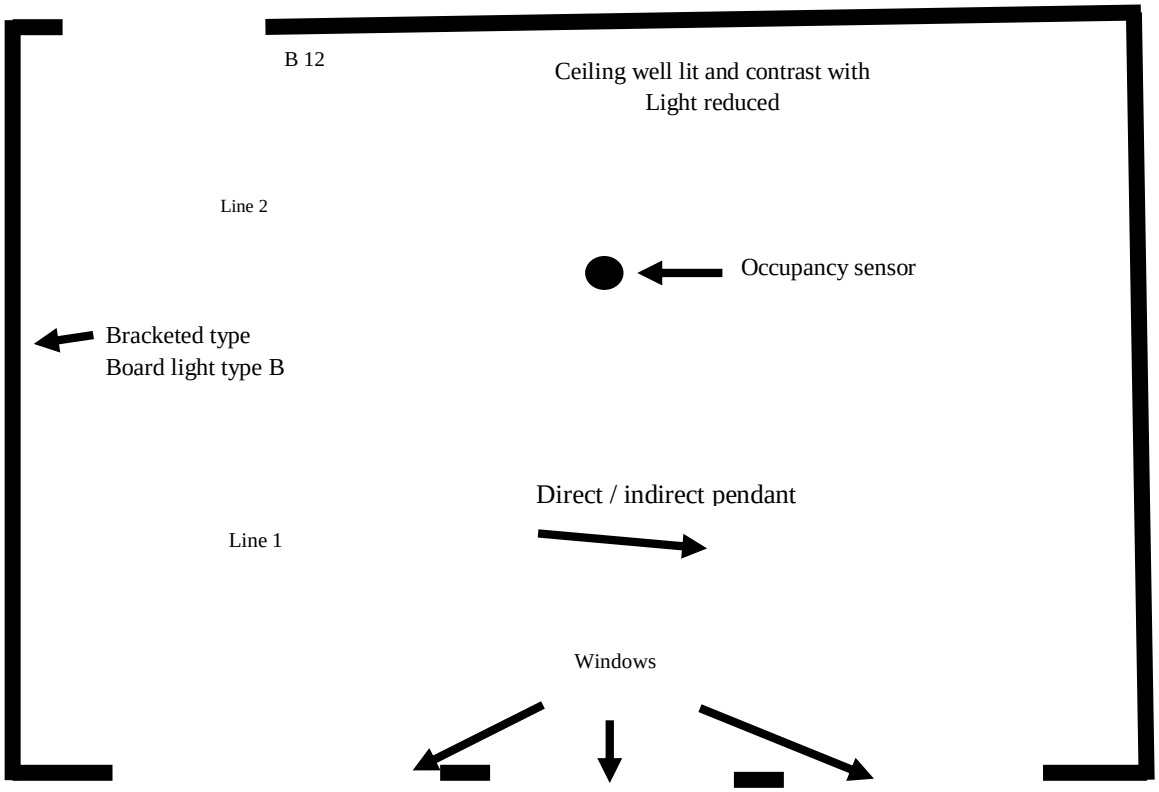


Figure 2.7 Classroom lighting system arrangement C plan (BRANZ, 2007)

Proposed classroom artificial lighting plan

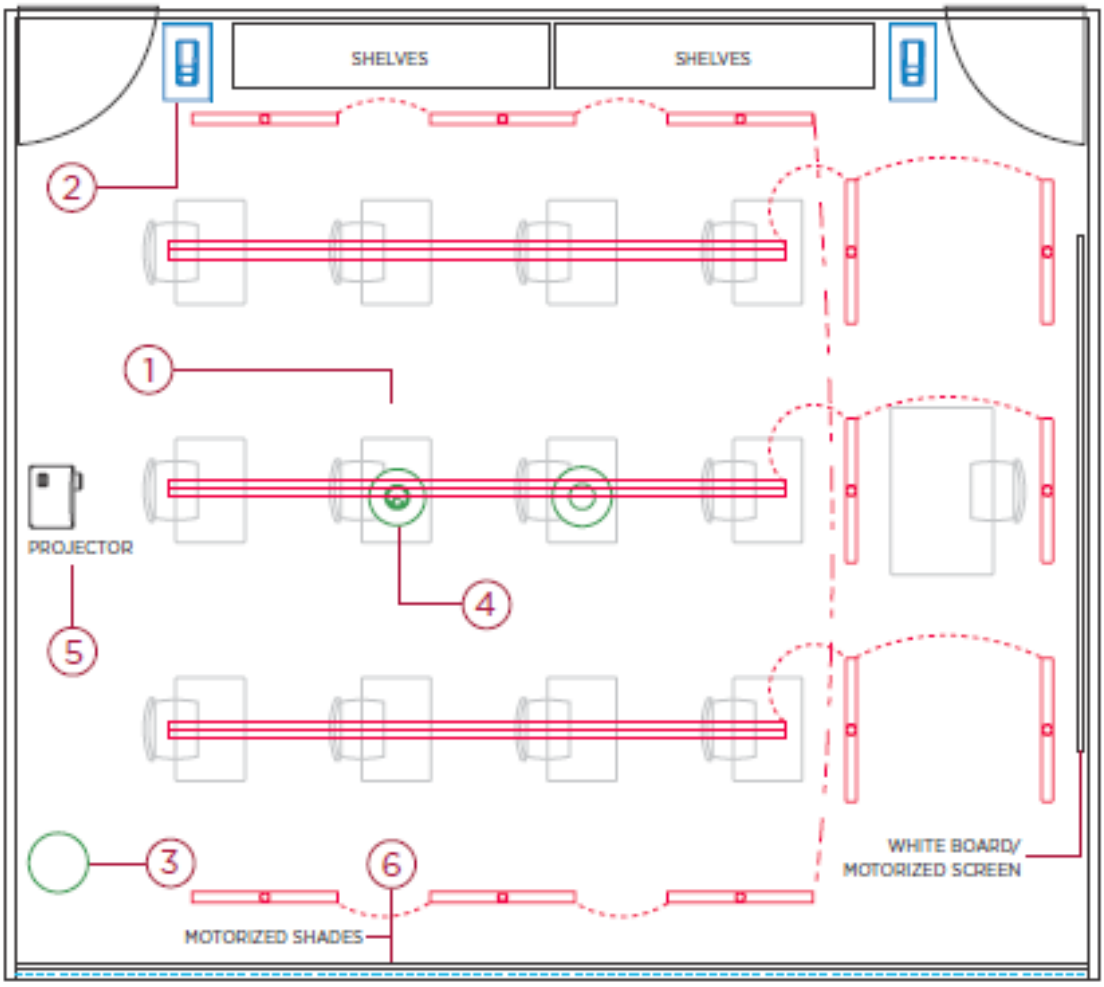


Figure 2.8 Classroom artificial lighting floor plan arrangement C (Vantage, 2013)

2.20 Lighting Controls

The phrase light control is often used to describe stand-alone control of light within a space (Helvar, 2007). According to Motzedian *et al*. (2016) defined a lighting control system an

intelligent programmed system that regulate illumination in a building. They reported that a lighting control system plays a key part in saving energy consumption of light without undermining the quality of light for any particular task. Uncontrolled artificial classroom lighting can cause irreversible damage to the students' eyes and permanently spoil their visual capabilities. Therefore controlled artificial classroom lighting is a preventive measure for students problems related to exposure to insufficient lighting. Lighting controls play an important role in artificial classroom lighting because they reduce power losses, and regulate the intensity of the light to the amount desirable for a learning task at a given period of time. The finest approach to regulate artificial classroom lighting is to simplify its installation. Automatic lighting control system should be integrated with a manual on/off switch to ensure that appropriate lighting is achieved (SEAI, 2010). This system would mean that the lights would have to be switched on and off manually and would automatically dim/stop based on signals from the automatic control system.

Table 2.20 Analysis of light controls

Light control	Characteristics
Install a power-saving regime and educate the users	• It may only work for a short time. • Is subject to misunderstanding and forgetfulness.
Switching lighting in groups	• Allow the lights to turn off or dim in the part of the room that has adequate lighting. • A bit more expensive in wiring groups of light to separate switches.
Manual control switches	• Saves electricity. • There is a possibility of leaving the lights on even during daylight.
Ability to reduce light output from dimming-systems	• This allows the level of illumination to be integrated with daylight. • Dim light uses less power. • Useful for reducing glare in specialist rooms such as computer rooms. • Useful in audio visual presentation room. • Moderately expensive
Occupancy sensors – turn off lights in occupied rooms	• Save energy • Permanent for most general learning places. • Combined with a manual switch to prevent activation when daylight is sufficient. • More sensitive but more expensive than infrared
Daylight sensor controls – automatically control lighting levels to integrate with available daylight	• Effective in controlling electricity usage. • Expensive to install. • Unfit to be cost-effective.

Source: Motzedian et al. (2016)

Lighting controls execute tasks such as switching on & off, time scheduling, dimming in response to the presence of natural lighting, lumen decrease and demand control (Tsangrassoulis and Synnefa, 2004). A characteristic design of automatic light control system is shown in figure 2.9.

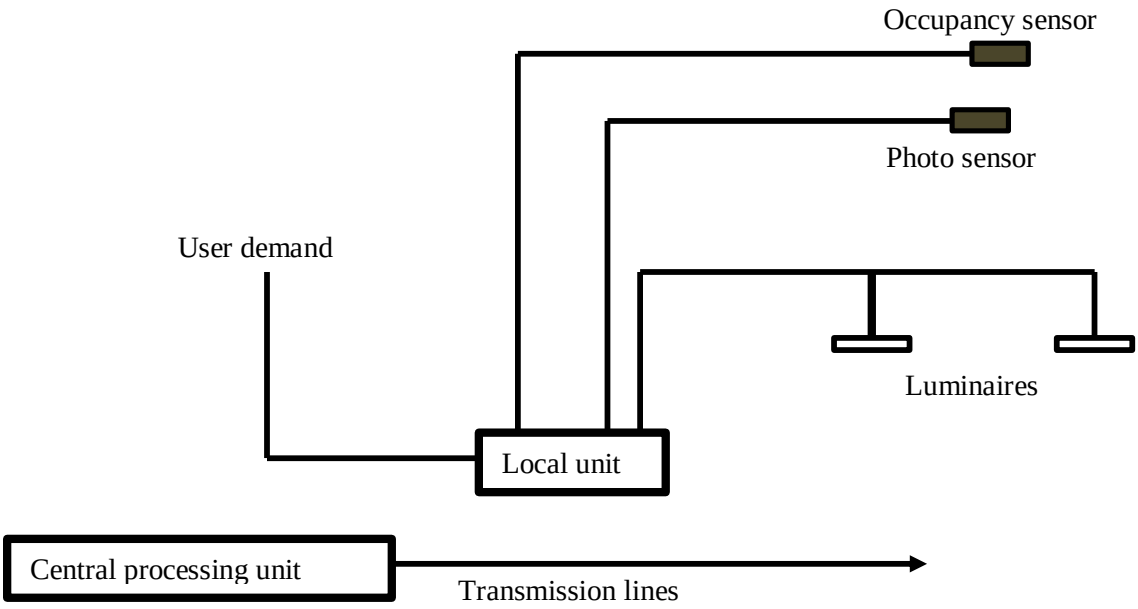


Figure 2.9 Layout of the control system for artificial lighting (Source: Motzedian et al., 2016)

The obective of the installing a lighting control system is to regulate lighting dynamically, in real-time, and allow for any divergence from the set comfort parameters in reference to the radiation data used for the design (Tsangrassoulis and Synnefa, 2004). The current technology offers two different control approaches:

- Control systems only for the lighting system.
- Building management systems with the ability to adjust the high voltage alternating current and the lighting system.

2.20.1 Controlled artificial lighting in the classroom

Uncontrolled artificial classroom lighting can cause irreversible damage to the students' eyes. Controlled artificial classroom lighting is a preventive measure for students' eye problems related to exposure to insufficient lighting. Controlled artificial classroom lighting is a key approach for ensuring that students learn in a conducive environment with lighting levels desirable for their learning tasks. A Classroom without a good management of artificial lighting negatively impact on students' academic achievement (Johnson, 2011). Samani and Samani (2012) reported that bright coloured lighting makes people joyful. They revealed that light creates visual massages which influence people's mood and incentive levels. Controlled artificial classroom lighting saves electric power. BRANZ (2007) revealed that teachers noted that it is essential to have suitable methods of controlling artificial classroom lighting especially for adjusting lighting at the chalk / whiteboard, dimming the room for projection visibility, adjusting lighting during special learning activities, and eliminating glare.

2.20.2 Automatic Lighting Controls

Manual control of artificial classroom lighting is a tedious process, therefore, automated controls are more suitable for controlling classroom lighting. An automatic lighting system

is an intelligent network based solution that includes communication between varied inputs and outputs with the help of central computing device(s) (Helvar, 2007). Automatic lighting control can significantly reduce electricity wastage by dimming artificial classroom lighting in response to the amount of natural light streaming into the classroom (Al-Mubayed, 2008). Under the latest standards, all classrooms must have occupant-sensing lighting controls that automatically shut lights off when the space is unoccupied (College and Oakland, 2013). Lutron (2011) reported that a wireless daylight sensor controls dimmers, switches and lighting control systems which switch off, dims or brighten artificial classroom illumination in response to the available amount of natural lighting in the classroom. Energy codes recommend the use of automatic controls to switch off lighting when there is no no occupant(s) in the classroom (McCowan *et al.*, 2017). Artificial classroom lighting automatic control saves energy costs, adjusts the lighting to the desired and preferred levels for a classroom learning task at hand.

2.20.3 Artificial classroom lighting control strategy

The essence of controlling artificial classroom lighting is to allow the users to regulate the lighting to the desired level for task they are engaged in. To regulate the intensity of artificial classroom lighting, the electric installation requires an electronic device to be installed that can be used to regulate lighting to a desired level. The classroom artificial lighting control system dims or brightens the artificial classroom lighting in reference to available amount of naural lighting and the overall set desirable classroom lighting (Tsangrassoulis and Synnefa, 2004). The main aim of using lighting control is to ensure

that the users of the classroom always have desirable artificial classroom lighting which will motivate them to spend more time reading without any lighting related distraction. Artificial classroom lighting can be controlled by using manual or automatic control strategies.

2.21 Color Rendering Index

The main aim of designing artificial classroom lighting is to create lighting that has adequate and favourable lighting levels for the learning environment. Color rendering index (CRI) is the ration of color of the surface lit by a given source of light and the colour of the same surface under a reference illuminating sourcer (natural light from the sun). Happek (2009) defined colour rendering index as the closeness in the surface color of an object illuminated by artificial lighting and the surface colour of the same object under natural light from the sun. He reported that high quality fluorescent lamps lighting attain a colour rendering index of about 90 which is believed to be outstanding. House *et al.* (2016) defined CRI as the colour appearanceof an object illuminated by a particular source of light in reference to the same object colour when illuminated by the natural light source from the sun. According to Konic Minolta (2018), CRI is the measure of the accuracy of color resemblance of the object under the assessment light source compared to the its actual colour appearance under sunlight which is measured by spectroradiometer. Using color in the learning environment can motivate students to learn better (Samani and Samnai, 2012). McCowan *et al*. (2017) asserted that an accurate CRI is a fundamental aspect in delivering suitable and desirable lighting levels for a learning environment. They suggested

that exact CRI delivers the visual distinction needed to carry out a task accurately. They recommended that modern artificial classroom lighting should have high color rendering, low glare, be efficient and meet the required energy codes standards. They however retorted that athough the correct CRI promote visual capabilities it is not the only element to consider in delivering adequate lighting in a learnig environment. The aim of any artificial classroom lighting design and installation is to ensure the classroom lighting is adequate and comfortable for learning. All classroom artificial lighting designs should ensure the correct colour rendering index is attained so that learners will have a conducive learning environment that will motivate them to learn and attain high academic performance.

Table 2.21 Lamp colour rendering index groups

Group	CRI groups	Typical use
1A	90 and over	Where high precision colour matching is essential
1B	80 -90	Where accurate colour judgment is required
2	60 – 80	Where moderate CRI is suitable

Source: McCowan et al. (2017)

Teachng and learning environments ought to have uniform lighting to overcome profound shades and robust conflicting arrays of light and darkness. Students devote

most of the time sitting in their desk where the rate of changing their head up, down and sideways position is influenced by the quality of lighting. This means that if lighting is not sufficient the rate of head adjustment will increase making them to be fatigued since they spend the energy required for leaning to adjust their heads to be able to see clearly what is project or written on the chalk /white board. The attention has to modify speedily for distance, angle, and lighting. Reducing profound shades and robust conflicting patterns of light and darkness will minimize students' fatigue and boost their academic perfromance (BRANZ, 2007).

2.22 Colour Temperature

Happek (2009) defined color temperature (CT) of a black object whose spectrum greatly look like that of a a reference light. He reported that incandescent lamps produce a colour temperature between 2600K – 3000 K, warm fluorescent lighting produce a colour temperature of 3000K, and a cool white light produces a colout temperature of 4200K. McCowan *et al*. (2017) revealed that numerous studies that have been financed by lamp manufacturers have found out that visual sharpness is enhanced by a particular range of colour temperature. They recommended a CT of around 5000K that is close to that of sunlight. Martel (2017) conducted a study on the impact of colour temperature on learners. The study revealed that cool white fluorescent bulbs installed in most classroom caused strain, nervousness, upset, fatigue and irritability that caused reduced concentration and low academic achievement. Samani and Samani (2012) lamented that many elements affect the learning environments, and the learning environments in return directly affect

students' academic achievementon. They revealed that well designed artificial lighting environment induce happiness in students and encourages them to carry out their learning tasks well. They concluded that a good artificial lighting of the environment has effect on users' feelings and outcomes. According to sleegers, *et al*. (2012) illuminance and correlated color temperatures (CCT) influence students' mood, level of alertness, effectiveness and the quality of sleep. Fluorescent lamp light source of about 17000 K CCT improve students' mental state, whereas inadequate artificial lighting CCT leads to common health issues like heart disorders, blood pressure, and circulatory issues (Silvester and Konstantinou, 2010).

2.23 Lighting Uniformity

Lighting uniformity on the walls, ceilings in relationship to the task area makes the learning environment conducive for learning. Lighting designs must meet uniformity requirements (Through Lighting, 2018). McCowan *et al*. (2017) reported that correct ligh distribution eliminates glare making the learning environment condusive for teaching and laerning. Uniform lighting is yearned in visual displays such as light cristal displat (LCD) backlights, and general illumination (Moreno, 2010). Classroom lighting uniformity makes the room favourable for learning and the application of modern teaching aids. This means that proper lighting design and choice of light fittings will create a good learning environment that will promote students' academic performance.

2.24 Wall Illumination

The choice of wall colour for a classroom is vital because it determines the quality of artificial classroom lighting. McCowan *et al*. (2017) suggeste that a modern classroom wall surfaces should redirect light to the task area. He reported that the light that falls on walls should be redirected to brighten the classroom. According to Pulay (2010), luminaries have an influence on classroom wall illumination levels. He reported that a well-lit classroom includes an accent in the focal wall. In the design of the classroom, artificial lighting wall colour should be given serious consideration because it is key to the quality of artificial classroom lighting. The classroom wall being a contributor to the quality of artificial classroom lighting it indirectly affects students' reading, health, and academic performance.

2.25 Lighting Levels

The variations of artificial classroom lighting are key for maintaining desirable lighting levels for different classroom tasks. Teachers prefer to have control over lighting levels (Mirrahimi *et al.*, 2012). Heschong *et al*. (2002) reported that increased light levels improve students' academic performance. McCowan *et a*l. (2017) argued that in lighting levels, the focus should be on adequate illumination. The lighting where students sit should be designed to meet students' needs while the lighting where the teacher stands to teach should be installed to meet the teacher's needs. In overall, artificial classroom lighting should be favourable to both the student and the teacher.

2.26 Lighting Power Density

Light power density should be of high concern in design and installation of artificial classroom lighting because it is a determinant in attaining quality artificial classroom lighting. McCowan *et al.* (2001) defined lighting power density as the maximum connected lighting points in a classroom of a specific dimension and size. One pont five (1.5) watts per square foot is the recommended power density threshold for a school for a total of all interior classroom space. In a research titled rethinking daylighting, Hans and Stanfield (2014) revealed that lighting power density for the classroom using T8 lamps is 0.8 W per square foot. They warned that incorporating LED in the classroom decreases the lighting power density. The power density in classroom has not been optimized because the current energy codes are outdated and therefore need to be revised to meet the current requirements.

2.27 Energy Codes and School Lighting

Energy codes used in artificial classroom lighting installation should be revised to match with current needs and demands of learning and teaching environment. Over the years enery codes have been introduced to regulate buildings energy and lighting requirements. McCowan *et al*. (2017) reported that energy codes regulate the maximum connected lighting loads for varous building space. Case studies of schools by Halonen *et al*. (2010) indicated that by use of the current technologies a normalized power density of of one hundred (100) lux two (2) watts per meter square can be attained. The specified energy

codes should ensure that artificial classroom lighting is adequate, comfortable, safe and positively influence students' academic performance.

2.28 Selecting Artificial Lighting Fixtures

The selection of artificial classroom lighting fixtures is key for a proper classroom installation that will optimize light and create a good learning environment.

2.28.1 Recessed fluorescent parabolic fixtures

PIER (2004) reported that information from many makers show that fixtures with recessed lenses or parabolic louvers have coefficients of utilization comparable to suspended direct – indirect systems usually within vary of 60% – 80% per classroom-sized areas. It discovered that recessed luminaires are able to provide power densities of about 0.9 W/square feet with acceptable uniformity of desktop luminaire. Parabolic fixtures, though less economical than their prismatic counterparts, provide dramatic reductions in sure sorts of glare (McCowan *et al*., 2017). Given correct fixture/computer terminal placement, incapacity glare encountered once wanting across space is reduced, as is mirrored glare on laptop screens. However, glare mirrored off a paper or alternative lit surfaces will truly be inflated with parabolic fixtures once the operating surface is directly below the fixture as a result of the operating surface is directly exposed to reveal lamp parabolic fixtures, particularly deep-cell versions. They have a big disadvantage for schoolroom lighting because the same "cut-off" feature that controls glare, additionally prevents lightweight from reaching the walls. Illuminating walls are extraordinarily vital in lecture rooms, each

for classwork show and also the overall feeling of brightness within the area. Pulay (2010) reported that recessed Accent Lighting is employed within the front of the schoolroom to produce the required (100 foot-candles on the focal wall. He, however, got wind that a PC area ought to avoid direct lighting and recessed fixture since each cause distinction and build viewing the PC troublesome. Recessed fluorescent parabolic fixtures achieve power densities of 0.9 watts per square feet and reduce glare.

2.28.2 Recessed direct/indirect fixtures

Recessed direct indirect fittings were used where ceiling height did not allow pendant fixtures. Recessed direct/indirect fixtures are notably common where they will substitute recessed troffers, and where available ceiling heights does not permit pendant direct/indirect fixtures installation (McCowan *et al*., 2017). Although recessed direct/indirect fixtures can offer similar energy levels and overall glare minimization like recessed parabolic fixtures, they are inferior to pendant direct /indirect fixtures because their illumination is supplied from a comparatively tiny reflective surface instead of from wide ceiling surface. Pranos *et al.* (2004) contended that recessed or surface mounted parabolic fixtures ought to be circumvented in most areas since they prevent light from reaching the higher part of the wall and ceiling creating undesirable shadows. The recessed direct / indirect fitting can only be used where it is difficult to install pendant fixtures, but pendant fixtures are the best choice of artificial classroom lighting installations.

2.28.3 Surface-mounted fixtures

The surface mount fixtures are the most inefficient fixtures in glare management. McCowan *et al*. (2017) reported that surface mounted fluorescent fixtures were widely used in classroom lighting before T-bar hanging ceilings became common. They warned that surface mount fixtures, even those with louvers were the most inefficient because they offered minimal glare management. However, T-5 lamps work well with low profile surface mounted fixtures in glare management (Mott *et al.*, 2012). The use of surface-mounted fixtures ought to be done away with because they provide low glare management.

2.28.4 Fluorescent wall washing fixtures

Incandescent wall washers are the most popular wall washing fixture. Lighting the walls is an essential feature in artificial classroom light design (McCowan *et al.*, 2017). Deep cell parabolic fixtures are incorporated with wall washing fixtures to reduce recessed glare sleegers *et al*., 2012). Linear parabolic louvered wall washing fixtures are efficienty in illuminating the walls (Samani and Samani, 2012). Wall washing parabolic fixtures provide uniform, efficient and low grare lighting.

2.28.4 Pendant indirect / direct luminaires

Pendant luminaires are the most suitable for teaching and learning space because they provide even spread lighting, a noble mix of indirect & direct illumination minimizes glare (BRANZ, 2007). Pendant luminaires spread light fairly on the ceiling, walls and floor (PIER, 2004). Pendant indirect / direct illumination reduces glare and reflection whih are

udesirable properties of light in a teaching and learning environment (McCowan *et al.*, 2017). Pendant fixture of at least 19 inches flom the ceiling sufface increases lighting uniformity and reduce reflection & glare. Suspended luminaires are the best choice for artificial classroom lighting because they uniformly distribute lighting and reduce glare.

Pendant fully indirect fixtures

Pendant luminaires provide a good balanced lighting and reduces glare & reflection. Pendant fully direct fixtures have replaced recessed fixtures because they make artificial classroom lighting levels adequate. Studies have shown that a hundred percent (100 %) installations of indirect lighting fixtures in the classrooms provides inadequate lighting for teaching and learnig processes.

2.29 Classroom wall, ceiling, and floor surfaces

Classroom wall, ceiling, and floor surfaces are key features of concern in designing and installing of artificial classroom lighting. Classroom wall texture and colour influence the type and quality of artificial classroom lighting installation. Classrooms with walls, ceilings and floor surfaces with high reflectance will help to distribute light evenly across the rooms (BRANZ, 2007). CPHI (2015) reported that good quality materials and appropriate walls and ceiling colors can provide good light distribution and a greater amount of reflective light. The choice of classroom wall, ceiling, and floor surface colour is a decisive aspect in artificial classroom lighting. The right choice of classroom wall

paint, ceiling, and floor surface colour can greatly improve the quality of artificial classroom lighting.

2.30 Task lighting

Special tasks require special lighting intensities. Some students learning tasks require specific task lighting. BRANZ (2007) reported that portable special task lighting luminaires should be used where background ambient light is not sufficient for a specific task area. He advised that where increased illumination is needed in only a small area, a strong directional lighting should be used. He concluded by pointing out that contrasted and higher lighting levels should be installed in a classroom for visual impaired students.

2.31 Selecting lamps

Lamp selection determines the outcome of artificial classroom lighting. Fluorescent lamps are the most suitable for classroom lighting, however, the choice of the fluorescent lamp fits a particular task should be carefully made. The choice of a lamp is determined by considering its efficiency, efficacy, cost, colour rendering, dimming ability, frequency, rating, and lifespan. T8 and T5 fluorescent lamps are the most suitable for a teaching and learning environment.

Table 2.31 Characteristic of T8 and T5 fluorescent lamps

Type	Characteristics
T8	• Long life. • High efficiency • Good colour rendering. • Low installations costs. • It can be dimmed.
T5	• More compact than T8. • Low-cost lamps and controls. • Low mercury content. • Can escape the quality of high-frequency management gear. • High effectualness

Source: BRANZ (2007)

Different tasks require different illuminations and lamp colours. Table 2.32 shows specific recommendations for a teaching space.

Table 2.32 Specific recommendations for various school tasks spaces

Type of space	Maintenance illumination lux	Lamp appearance group	Lamp colour rendering group	Maximum glare index	Comments
Multipurpose halls					
• General use	160	Warm intermediate	1B or 2	19	
• Social use • Examinations	80	Warm intermediate	1B or 2	19	
• Theatre use	240	Warm intermediate	1B or 2	19	
					Special requirements
Genera classrooms	240	Warm or intermediate	1B or 2	19	
Workshops	240				With task lighting
Artrooms	400 to 800	Warm or intermediate	1A	16	See specialist teaching spaces
Laboratories	320	Warm or intermediate	1A or 1B	19	
Music rooms	320	Warm or intermediate	1B or 2	19	
Textile craft rooms	320	Warm of intermediate	1B or 2	19	Task lighting
Gyms	320	Warm or intermediate	1B or 2	19	See specialist teaching spaces
Libraries	240	Warm or intermediate	1B or 2	19	See specialist teaching spaces

Source: McCowan et al. (2017)

2.32 The Melanopic Effect of Light

Artificial classroom lighting considerably affects body organs and physiology performance. Schlie-Roosen (2013) defined the melanotic effect of light as the non-visual effects facilitated by special photoreceptors containing photosensitive pigment melanopsin. He revealed that

melanotic effective lighting helps synchronize body processes with the environment. Light regulates circadian pulse which controls slumbering and waking up routines (Zumtobel, 2017). When blue light shines on the retina ganglion cells it inhibits the production of melatonon homorne which prevent learners from sleeping during the day (sleegers et a., 2012). The choice of design and installation of artificial classroom lighting should be done carefully to ensure that it positively influences the body organs and physiology. A good functioning of body organs and physiological performance will improve students' academic performance.

2.33 Human Centric Lighting

A well designed and installed artificial classroom lighting will promote emotional well-being, comfort, good health, and efficiency. Helvar (2007) defined human-centric lighting as the means by which the emotional well-being, comfort, health, and efficiency of individuals can be improved through correct control of lighting of the environment. He revealed that human centric lighting (HCL) enhances efficiency, concentration, health, mood and well-being (Zumtobel, 2017). HCL is a form of lighting in which the level, colour temperature and direction of light is designed to enhance visual acuity, productivity and relaxation (SLE, 2018). HCL lighting serves both the conscious and subconscious mind catering to both internal needs and aesthetic desires: influencing mood, behavior, sleep patterns, and general well-being, producing positive results (CPI, 2015). Lighting Europe (2018) reported that human-centric lighting increases the vision, performance, and well-being of people. Human-centric lighting promotes emotional wellbeing and human health which are the key factors in improving students' academic performance.

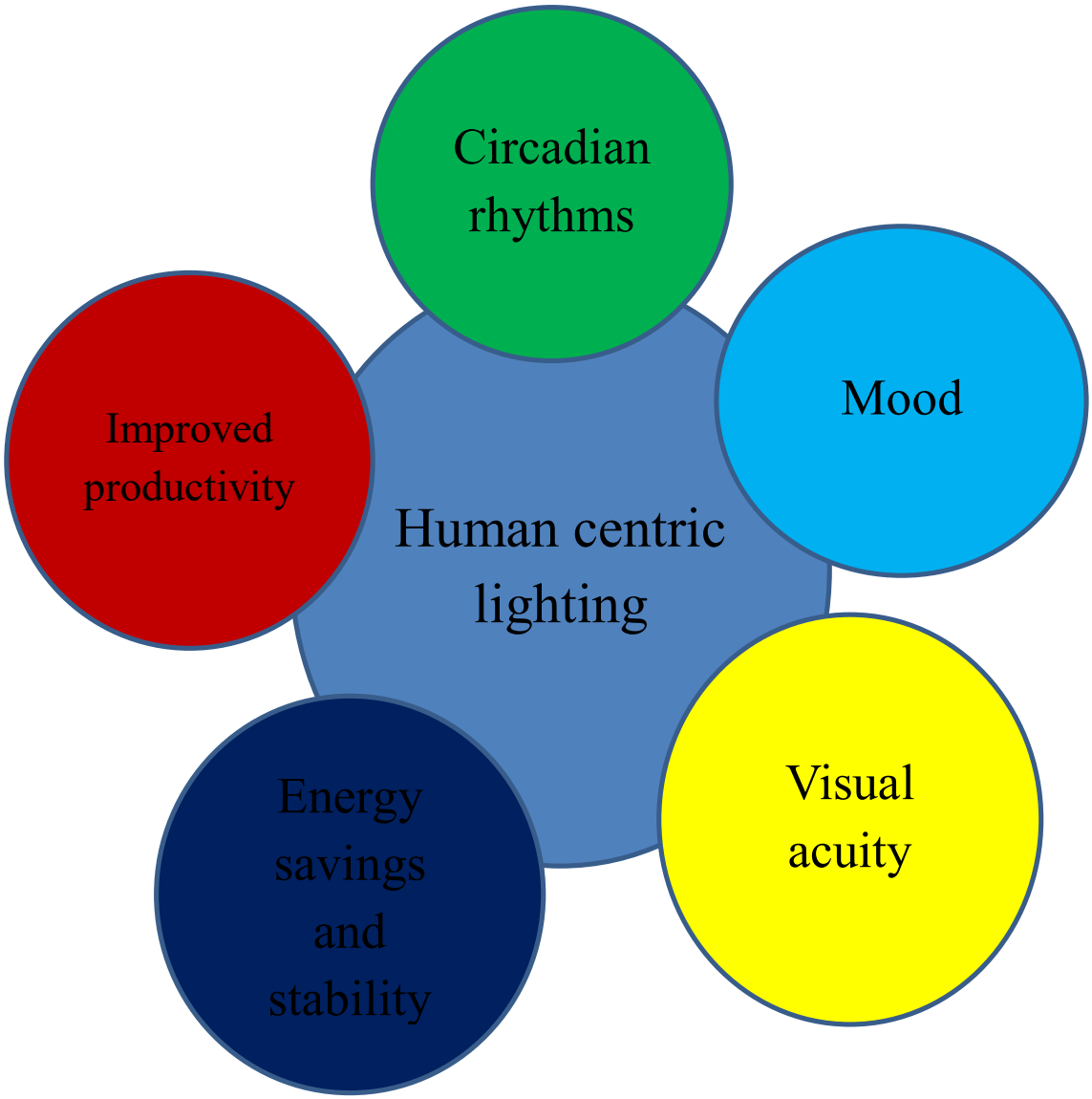


Figure 2.10 Human-centric lighting (Source: Schlie-Roosen, 2013)

2.34 Lighting Quality

A good quality artificial classroom lighting is focused, efficient, uniformly distributed, glare less and flicker less. Samani and Samani (2012) testified that the quality of artificial classroom lighting has a major impact on students' learning achievement. McCowan *et al*. (2017) warned that glare and uniformity are the major challenges in providing quality artificial lassroom lighting system. Sleegers *et al*. (2012) revealed that a good quality artificial classroom lighting positive influence learners' concentration. Mott *et al*. (2012) assessed the influence of focused and controlled artificial classroom lighting on students' oral reading fluency. The study found out that focused artificial classroom lighting increased students' oral reading fluency performance by thirty-six percent (36%) while cotrolled artificial classroom lighting increased students' oral reading fluency performance by seventeen percent (17%). They concluded that light is the only vision enabler; a regulator of the release of cortisol and melatonin hormones which control body processes like cognition, mood, sleep, rest and activity pattern. Finally, they concluded that lights of diverse wavelengths affect brain activity, rate of respiration, pulse rate and blood pressure. A good quality artificial classroom lighting increases students' reading fluency, visual performance, alertness, brain activity, and academic performance.

2.35 Dynamic lighting

Dynamic lighting provides good colour rendering, has a positive effect on students' visual performance, health, wellbeing and improves students' reading speed and academic performance. Different combinations, lighting settings, colour-correlated temperatures of dynamic lighting support mental alertness and relaxation. Sleegers *et al*. (2010) indicated that

dynamic lighting systems have positive effects on students' visual performance, arousal, and well-being. They testified that dynamic lighting enhance students' reading speed and aggressive behavior. Dynamic lighting is the best choice of artificial classroom lighting because it positively influences students' academic performance.

2.36 The effects of fluorescent lighting on boarding secondary school students' academic performance

The design and installation of fluorescent lamps in the classroom can influence positively or negatively students' academic performance. Energy Focus (2015) revealed that once fluorescent light bulb shatters, anyone within the locality will be exposed to the risks of mercury which is a health hazard. It warned that mercury gas in fluorescent bulbs produces high-frequency radiation that damages skin and eye tissues. Mercury gas eye tissue injury will interfering with the student's ability to see clearly which impacts negatively on student's academic achievement. Fluorescent lighting produces glare and flicker that causes discomfort, annoyance and may be dangerous with rotating machinery in the workshops (Branz (2007). This ultimately reduces the students learning morale which will lead to poor academic performance. Fluorescent lights with 100Hz frequency caused headache and impaired visual performance (Winterbottom and Wilkins, 2009). Cool white fluorescent lamp lighting cause strain, nervousness, disorder, fatigue, irritability, attention deficit and misery resulting in lack of concentration and hence poor academic achievement (Martel, 2017).

Hathaway (1993) reported that students who learned using full spectrum ultraviolet supplemented fluorescent lamps achieved high academic achievement. Electronic high-frequency ballasts operative fluorescent tubes overcome scientific instrument effects and eliminate glare on laptop screens. This will allow students to study for long hours which will greatly improve their academic performance. In comparison with other lamp varieties full-spectrum fluorescent lighting has been attributable to enhancement of vision and academic achievement (Veitch and McColl, 2001). The choice of fluorescent lamps and their installation technology should be done well to ensure that they positively influence students' academic performance.

2.37 The effects of bulb lighting onboarding secondary school students' academic performance

The choice of bulbs installation in public boarding secondary school classrooms can positively or negatively influence students' academic performance. Full-spectrum lamps usually embody additional blues and render colours well than customary cool white or heat white lamps (Boray, 1989). Cool-white fluorescent lamps cause strain, nervousness, upset, fatigue, irritability, devotion deficit and misery resulting in poor concentration and learning achievement (Martel, 2017). The choice of bulbs for artificial classroom lighting installation should be done carefully to ensure that they give a good quality lighting which will positively influence students' health and academic performance. Therefore, using full spectrum artificial classroom lighting will result in a good academic performance as compared to cool white or heat white lumans.

2.38 The effects of light-emitting diodes (LEDs) lighting onboarding secondary school students academic performance

Light emits diodes provides a safe, healthy, comfortable, green environment, eliminates glare and reflections. Kunz (2014) reported that LED lighting provides a harmless, desirable, comfortable, and condusive environment that supports students' learning. LED lights reduce udesirable lighting features which cause visual impairment (Energy Focus, 2015). Acuity Brands (2014) reported that light-emitting diode lighting blends well with the modern teaching aids by utilizing lighting management regulator to vary light inensity. It argued that Staple diode luminaire emits prolix, even, color steady, and glareless and flickerless lighting that is conducive for learning. LED lamps lighting has less biological effects on internal secretion suppression within the evening (Zumtobel, 2017). Suppression of melatonin reduces students' stress level allowing them to concentrate on their studies which will ultimately improve their academic performance. Installation of light-emitting diodes (LEDs) in the classroom works well with the modern technological instructional aids and improves students' academic achievememt.

2.39 Artificial classroom lighting illumination influence on boarding secondary school students' academic performance

The main objective of designing artificial classroom lighting is to ensure that an optimum illumination is achieved that facilitates good vision and comfort in a learning space. Ibanez *et al*. (2017) testified that adequately positioned luminaries improve the quality of artificial classroom lighting, and provide illumination on the work plane where the learning activity is performed. They reported that illumination levels between 300 to 500 lux are

suitable for classroom lighting. Mott *et al*. (2012) revealed that brighter light positively influences reading, writing and solving of mathematical problems. They also argued that illumination levels affect students' mood which in return affects students' academic performance. The bright light of illumination intensity between 300 – 500 lux positively influences students' health, reading, and academic performance.

2.40 Artificial classroom lighting colour influence students' learning and academic avhievement

Higher colour temperature enhances visual acuity and motivates students to read intensively. Precise rendering of colours is the basic part of providing sufficient and comfortable lighting planes (McCowan *et al*., 2017). A research by Katsuura (2005) on the impact of artificial lighting environment on humans established that color temperature condition accelerates sympathetic nervous activities. He disclosed that light of higher color temperature reduce the body temperature and have a tendency of hindering night-time secretion known as melatonin. Introducing colour in the classroom motivate students to learn better (Samani and Samnai, 2012). Mott *et al*. (2012) revealed that lighting of colour correlate temperature between 4000 K and 17000 K boosts students' alertness and academic. They revealed that girls perfrom well in warm white lighting environs whereas boys perform well in mental activities in cool white lighting. They concluded that color rendering, correlate color temperature, and luminous efficacy lighting diode enhance visibility creating a condusive learning environment. They reported that a selected relational unit of colour rendering and colour temperature enhance sight. In his study of

the effects of categories of lighting on children, Hathaway (1993) showed that Kolorite lamps which produce light closer to the natural light in spectral distribution give higher color qualities and provides a better degree of visual clarity than high efficacy lamps at equivalent illumination. They reported that full spectrum lights have a relatively high Colour Rendering Index that is tremendously necessary to vision processes. To enhance learners' visual and motivate them to study intensively artificial classroom lighting should be designed to provide higher colour temperatures preferably in the range of 400 K to 17,000 K.

2.41 Artificial classroom light distribution in learning task areas

Artificial classroom lighting should be distributed uniformly so that it can provide uniform illumination in the entire classroom. Loe *et al.* (1999) advised that library lighting installation should be harmonized to meet the needs of various task areas such as lighting for reading, lighting for surfing, all-purpose lighting and vertical book stacks lighting. They suggested that it's necessary for lighting to be stream lined to avoid interferrance between the appearance of the various features of the installation or distribution throughout the library. They counseled that attention should be given to artificial classroom lighting installation to avoid problems with flicker, gauze reflections, glare, and the use of visual display units. They suggested the use of pendant luminaires in general reading tables and browsing. They recommended the use of luminaries with assymetric distribution and special means to light vertical spines of books on the stacks.

2.42 Effects of light on the human eye

The eyes are the most affected body organs by ultraviolet radiation from artificial classroom lighting. Barbu (2015) researched on the consequences of radiation on the eye in an industrial setting and disclosed that anatomical effects of ultraviolet radiation from the human body are greater than simple heating effects. He warned that the eye is most sensitive to damage from ultraviolet rays of the lower band at 265–275 (nm) and the most common effects are photokeratitis, cataracts, pterygium, and pinguecula. He concluded that eye exposure to extreme UV will damage the retina. Wood (2014) reported that ultraviolet radiation destroy anterior tissues of the eye and short visible light radiation ("blue-light") destroys retinal structures. He discovered that UV-B radiation "causes" cortical cataracts. He further warned that stimulation of light-sensitive retinal ganglion tissues by blue coloured light will hinder sleep and keep one unnecessarily alert which is detrimental if one is aroused right before bedtime. A study on eye injury by the Victorian government (2010) revealed that a showy burn occurs once one is subjected to bright ultraviolet light and this will take place in all types of ultraviolet light. It indicated that showy burns cause throbbing inflammation of the clear tissue that covers the front of the eye and can affect both eyes.

2.43. The effect of artificial classroom lighting on instruction

Light is a key requirement in learning and instruction. The quality of artificial classroom lighting determines the effectiveness of instruction. Lighting affects the method the teacher adopts information communication technology in instruction (Buckley, 2014). BRANZ

(2007) advised that the majority teaching areas ought to have uniform light distribution to avid deep shadows and robust different patterns of darkness and light. It revealed that pendant luminaires provide good balance between direct and indirect lighting fixtures and it is the most suitable for instructional areas. Suleman and Hussein (2014) advised that suitable lighting systems ought to be guaranteed for effective learning and instruction to take place. A good quality artificial classroom lighting favours instruction and makes the learning space to be conducive for teaching and learning.

2.44. Effect of artificial classroom lighting on reading

Light is a great enabler of reading and most of the learning takes place through reading. Mott *et al*. (2012) revealed that lighting focus (6000 K – 100 FC average maintained) increases oral reading frequency. They reported that cool white fluorescent lamp lighting aid reading speed and accuracy. They concluded that bright light positively influences reading. Sleegers *et al*. (2012) reported that brighter lighting (500 lux) features a positive result on reading and dynamic lighting has been found to boost reading speed. In his study of the connection between the physical setting and educational achievement in public secondary schools in Nairobi County, Aloyo (2015) found out that scores in reading speed were considerably higher in well lit instruction environments. According to SEAI (2010), a minimum level of luminance with good uniformity is required in a reading task area. ZUMTOBEL (2017) revealed that good lighting conditions are more than just a basic prerequisite for concentrated reading. It reported that reading requires 681 lux illuminance and 0.422 uniformity. It concluded that supplementary luminaries are the ideal solution

for reading tasks. Therefore, dynamic fluorescent lighting with a minimum level of luminance improves oral reading fluency, speed, and accuracy.

2.45 Summary

This chapter reviewed preliminary, secondary, and primary empirical sources of literature related to artificial classroom lighting effects on students' academic performance with view of synthesizing existing resources. The literature reviewed reveals that lighting a learning environment is a major and crucial aspect in the teaching and learning process because it provides a well illuminated and safe working environment that provides learners with a feeling of well-being and allows them to perform their visual tasks well. It underscores that light is a powerful source of energy that orchestrates our endogenous daily trend setter with our surroundings and is a means for improving mental capabilities. It also testifies that natural daylight provides the best light for reading with a number of positive effects while artificial lighting pose undesirable challenges to the learners. The literature has also highlighted that lighting has psychological, physiological and biological effects on human beings. The literature has pointed out various lighting technologies which can improve the lighting and learning environment. Finally, the literature has emphasized lighting characteristics such as illumination, colour temperature, correlated colour index and colour can be adjusted so as to improve the quality of lighting. These literatures reviewed has shown that there is significant gap on the effects of artificial classroom lighting on students' academic performance. In the literature reviewed, there is no Kenya government or Kenya Ministry of Education Science and Technology policy guidelines document which provides

stardards and specification on lighting in schools. This silence may indicate a heap of reality of discrepancies in mediating factors that link artificial classroom lighting factors with students' academic performance. Therefore, this study endeavored to bridge the gap on artificial classroom lighting effects on student's lighting health related problems, reading, instruction environment and the application of instruction aids which collaboratively influence students' academic performance in boarding secondary schools.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.0 Introduction

This chapter presents the research philosophy, research designs, the rationale of the methodology, description of the research area, target population, sampling techniques, data collection procedure, materials and methods, statistical data treatment and data analysis that were adopted in the study.

3.1. Research Paradigm

The study adopted the pragmatic worldview that incorporates quantitative and qualitative approaches. Quantitative methods allowed for a simple collection and descriptive analysis of facts, data realities and evidences concerning the independent and dependent variables. The qualitative approach allowed for collection of comprehensive narrative explanation, analysis and explanation of data principally in form of words rather than figures. The interpretive assumption represents the world as having been socially created, multifaceted and always shifting with no single reality apart from our perceptions. Qualitative research views things in their ordinary situation while trying to make them seem sensible and to understand happening in terms of the meaning inhabitants convey.

3.1.1 Research Philosophy

This study adopted a Pragmatism analysis philosophy that was developed by James in 1907, Peirce in 1931, Dewey in 1931, Mead in 1938 and Goldkuh in 2004 (Singh, 2019). Pragmatism is a philosophical crusade that includes those who claim that a belief or a proposition is factual if it functions adequately, its meaning is to be found within the significance of acceptive it, and that ideas which are not practical should be rejected (McDermid, 2006). According to Reason (2003) pragmatism philosophy aims to expose practical knowledge that works in particular circumstances. Saunders *et al*. (2012) reported that pragmatism analysis philosophy assents that notions are appropriate when they sustain actions. They stressed that pragmatism acknowledges that there are many dissimilar ways of deciphering the world and conduct analysis. They contended that pragmatists believe that there are multiple realities and there is no single perception that can show the whole image of the world (Saunders *et al*., 2012). In practice pragmatists stresses the significance of carrying out a research that give practical solutions to the problem at hand and they prefer using both qualitative and quantitative information to solve a research problem (Creswel, 2007). Therefore, pragmatism advocates for the adoption of mixed ways analysis methodology. Pragmatism contends that a research question is main consideration in choosing a research philosopy to be adopted in a study. They also emphasize that one method may be better than another in addressing a specific research question. In a pragmatism world view one studies what interests him or her, and is importance to him or

her, studies it in several ways that he or she believes are suitable, and use the results in ways that can be of great benefits in his or her worth system.

Ralolo (2015) reported that pragmatism is an approach of transcending the irresolvable, philosophical and metaphysical dilemmas. He noted that pragmatism is categorized by its ability to embrace all well-constructed paradigms of scientific inquiry as valid when they are acceptable, i.e., where the character of studied reality is such the paradigm winds up in expedient results. He additionally stressed that pragmatism could be a duel with reality through actions as a principal supply of doubt, that successively feeds scientific curiosity and becomes the drive to inquire so as to settle the doubt. Pragmatism as a research philosophy accepts both singular and multiple truths in the world, setting itself towards solving practical programs in the physical world (Sofotho, 2015). The pragmatism philosophy gave the researcher a forum to analyze what people communicated, how they fulfilled their needs and got what they wanted. It was also a useful lens that helped the researcher to understand debates and discourses in complex situations.

3.1.2 Pragmatism Research ontology

Pragmatism research ontology states that research is external, multiple, and pragmatic views are the best answers to research questions and his research purpose (Ihuah and Eaton, 2013; Sounders *et al*., 2012). Pragmatism accepts both the existence of one reality and that individuals have multiple interpretations of this reality (Mogan, 2007). To conduct mixed research it is important to understand both objective and subjective views of reality.

Although it is important not to be biased or affect the phenomenon under investigation, it is also so important to understand the social actors point of view. A pragmatic researcher uses both the quantitative and qualitative ontological stances (Maarouf, 2019). Reality depends on the context to exist and continue existing, which means that changing the contexit changes the reality and the existence of multiple realities. Reality is perceived by humans or social acors differently, humans'peceptions of reality controls their behaviors, interactions among these behaviors constructs a new context over the time, and constructing a new context generates a new reality. The reality cycle assumptions allow the pragmatic researcher to switch between the two vies of one external reality and the multiple perceptions of reality in social actors' minds and thus between quantitative and qualitative research approaches and methods (Maarouf, 2019). Examining social actors perceptions will provide a deep understanding of the context generating the reality and help the researcher to develop a new theory or create major developments in the current one. Once rhe theory is developed the pragmatic researcher can switch back to one reality position and test the theory through quantitative research. Qualitative methods helped the researcher to gather information that he analyzed and got a deep understanding of the phenomenon and created a theory that he analyzed to get a deep understanding othe the phenomenon and create a theory that will be tested through quantitative research.

3.1.3 Pragmatism Research Epistemology

Pragmatic research epistemology employs both objective and subjective meanings, provides facts to research questions and lays stress on evaluation of different emerging views in the interpretation of information to providing workable solutions to problems (Ihuah and Eaton, 2013). Interpretivism belief that knowledge is acquired through an empathic understanding of participants' lived social truths, experiences, and understandings. Positivists believe that one will make a case for and forecast the outcomes within the social world by checking out patterns and relationships among the folks. They also suggest that a hypothesis is formulated and tested to answer pertinent research questions of a study. They conclude that knowledge is an accumulative process.

3.1.4 Pragmatism Axiology

Values perform a significant role to give an interpretation of the outcomes using objective and subjective rationales (Ihuah and Eaton, 2013). The pragmatic axiology in this study helped the research to explore both objective and subjective approach which gave the study a comprehensive interpretation of the effects of artificial classroom lighting on students academic performance.

3.2 Research Approach

This research applied deductive and inductive analysis strategies. This gave the research an opportunity of examining all aspects of artificial classroom lighting effects on students academic performance.

3.2.1 Inductive

The inductive research approach is one where the researcher moves from specific to general (Soiferman, 2010). It is a bottom-up approach where the researcher uses participants' views to create extensive themes and build a theory interdepending the themes. The deductive research approach enabled the researcher to develop a theoretical framework, identify variables for relevant constructs, enable respondents to give answers to specific questions and test the theories (Ali, 1998).

3.2.2 Deductive

In the deductive research approach, the researcher moves from the general and finishes with the specifics (Soiferman, 2010). This approach enabled the researcher to use existing theory and maximize attention given to the respondents perspectives (Ali, 1998).

3.3 Time Horizons

Time horizon refers to the period the research study was conducted to answer a question or address a problem being investigated. This research adopted a cross-sectional study

within which the research collected data on diverse cases during a single time period (Sounders *et al*., 2009).

3.4 Research Design

This research adopted a survey and experimental research designs. Survey research studies are those that are concerned with providing qualitative and numeric accounts of some part of the population (Kothari and Garg, 2014). According to Pinto (2015) survey research is a collection of data from a sample of personalities through their responses to questions. The survey analysis style enabled the researcher to contemplate considerations like the power to comprehend populations from portion of it, rapid data collection and economy of the design (Igo, 2007). It helped the researcher to carry out extensive research and obtain data about situations, views or practices at one opportune period of time in time through questionnaires or interviews schedules. It conjointly allowed the investigator to assess a spread of variables at just one occasion and collect information regarding the real-world milieu. Survey research eased the researcher's accessible information and provided an unbiased representation of the population under the study (Owens, 2002). Survey analysis style additionally permitted the researcher to collect data from a massive samples of the population; address issues that were raised; resolve issues that emerged or detected; evaluate requirements; appraise set goals; confirm whether particular set goals had been achieved; examine tendencies over time; and to explain quantity and context of what existed (Glasow, 2005). This study used a mixed analysis methodology. Since the set goals

of the research were varied, it created sense to use mixed methods since they complemented one another.

Experimental research design is a cautious harmonizing of several features including "power", generalizability, various forms of validity, practical and cost (Seltman, 2018). The basis of the experimental method is a test under controlled conditions that is done to exhibit a known reality or examine the legitimacy of a hypothesis (Muijs, 2010). The experiment design provided control over other external factors that allowed the researcher to make a stronger claim that determined causality than any other type of research. Experimental research design enabled the researcher to provide the strongest evidence about the existence of cause-and-effect relationship (Rumi, 1995). Also, the experimental research design enabled the researcher to shut out all extraneous influences (Glasow, 2005). This study used the normal experiment strategy that is refered to as pre-test-post-test management cluster styles. The materials and equipment used in the experiment were; lux meter, fluorescent lamb electric light fittings, wires, digital multimeter, fluorescent lambs, electrical wiring cables, camera, side cutter, priers, and a tape measure. The formulas in Appendix 30 were used in the experimental study to counter check various measured values. The researcher used procedures in Appendix 31 to conduct the experiment.

3.5 Description of the Research Area

The analysis was conducted in Nairobi County public boarding secondary schools. The county has a population of four million three hundred and ninty seven thousand and seventy three (4,397,073) which comprises of 2,192,452 males, 2,204,376 females, 245 intersex, it covers an area of 703.9 km²and has a population density of six thousand two hundred and forty seven(6,247) per square kilometers (KNBS, 2019). It has a total number of one million five hundredand six thousand eight hundred and eighty eight (1,506,888) households, seventeen (17) constituencies, eight-five (85) county wards and sixty (60) public boarding secondary schools (KNBS, 2019 and Sky Dat Lab, 2015). The total population of government secondary school students in Nairobi County is five thousand eighty hundred and eighty (5,880) of which two thousand and fifteen (2,015) are form three students (Ministry of Education, 2017). Nairobi County comprises Kenyas' capital city and its environs. Its experiences a minimum temperature of 10°C and a maximum of 24°C and it's 1,660 meters on top of the sea level. It receives a minimum of 500 mm and a maximum of 1,500 mm of rain fall annually. Nairobi county borders Kiambu County to the North, Kajiado County to the southwest and Machakos County to the Southeast. It is the largest commercial center, main national administrative unit, a cultural center and one of the expansive and fastest-growing cities in the continent of Africa.

The county is accessible by tarmac roads, railway lines, and international airports as means of transport. Nairobi city, the capital city of Kenya is also Nairobi County' headquarter. All regions in the entire county are served with electricity. Nairobi County was chosen for

the study because it is believed to be to have all kinds and classes of public secondary schools which can be used to determine the state of classroom artificial lighting technologies and find out their influence on secondary school students' academic performance.

3.6 Strategy of inquiry

The strategy of inquiry are models that specifically guides the procedure in study design. Others call them approaches (Creswell and Plano, 2017) or research methodologies (Mertens, 2010). Both qualitative and quantitative methodolies were utilized in this study. Qualitative methodology utilized interview schedules and observation methods whereas quantitative methodology utilized questionnaires and document analysis to to collect information regarding the characteristics of artificial classroom lighting on students' academic performance. A survey was adopted in this study because it allowed the inestigator to explain the result of artificial classroom lighting on students' academic perfroamce. Also an experiment was was carried out in order to give a strong evidence of the effect of artificial classroom lighting on students academic performance.

3.7 Population and Sampling Techniques

A population is a whole set of people, cases or objects with explicit observable characteristics, and sampling techniques amethod of selecting a sample for a study (Mugenda and Mugenda, 2005).

3.7.1 Target Population

The target population of this study comprised of all twenty-nine (29) public boarding secondary schools, twenty nine (29) principals, one thousand one hundred and twenty (1,120) teachers, twenty nine (29) nurses and two thousand and fifteen (2,015) students in Nairobi County public boarding secondary schools (see Appendix 24). Out of the tenty nine (29) public boarding secondary schools ten (10) were boys' schools, thirteen (13) were girls' schools and six (6) were mixed public boarding secondary schools. Makadara Sub County has two (2) boys' boarding and two (2) girls' boarding schools. Starehe Sub County has one (1) boys' boarding and one (1) girls' boarding schools. Dagoretti Sub County has three (3) boys' and three (3) girls' boarding schools. Westland Sub County has two (2) boys', five (5) girls' and three (3) mixed boarding secondary schools. Embakasi Sub County has one (1) girls' boarding school. Njiru Sub County has one (1) boys' and three (3) mixed boarding secondary school. Kamukunji Sub County has one (1) boys' boarding secondary school and Kasaran Sub County has one (1) girls boarding secondary school. The target population of public boarding secondary schools distribution is shown in Appendix 23.

Nairobi County is the most developed county in Kenya. It was therefore considerd appropriate for providing a focal point for the studying the effect of artificial classroom lighting on public boarding secondary school students' academic perfroamnce in Kenyan.

3.7.2. Sample Size and Sampling Technique

3.7.2.1 Sample Size of the study

Then the researcher adopted the research advisor (2006) developed table for determining sample size (Appendix 22) to determine the sample size. In this study, the level of significant testing was 0.05 hence the confidence level was 95% which is applicable to surveys in research (Dessel, 2013). Appendix 25 shows the sample sizes of the study. The sample size comprised of twenty (20) principals out of twenty-eight (28), two hundred (200) teachers out of one thousand one hundred and twenty (1,120), twenty (20) nurses out of twenty eight (28) and four hundred and thirty five (435) form three students out of two thousand and fifteen (2,015) form three students.

3.7.2.2 Sampling Technique

Purposive, stratified and simple random sampling techniques were implemented in this study. To select the sample, the researcher first used purposive sampling to pick the school which met the key focus of the study. To ensure all types of public boarding secondary schools were included in the study, the researcher stratified the schools into boys boarding, girls boarding and mixed public boarding secondary schools. Finally, the researcher used simple random sampling to select teachers and students who participated in the study. This was because there were many teachers and students in the selected school for the study.

3.7.2.2.1 Purposive Sampling Technique

In purposive sampling the researcher handpicked respondents to be incorporated in his sample on the grounds of his or her ruling of the required characteristics … (Cohen and Manion, 1992). Purposive sampling epitomizes a bunch of dissimilar non-probability sampling strategies and is also recognized as pejorative, discriminatory sampling (Plays, 2008). Therefore, purposive sampling depends on the verdict of the researcher when it comes to choosing the entities (e.g.; people, cases, organizations, events, and species of data) that will be researched. The researcher used purposive sampling because the sample of the secondary schools investigated was quite small (Mugenda and Mugenda, 2005). Purposive sampling enabled the researcher to deliberately choose schools with specific information-rich cases and qualities the study focused on (Etikan *et al*., 2016). Purposive sampling technique enabled the researcher to seek out respondents with specific characteristics, in regard to the requirements of developing analysis and emerging theory (Morse, 2004).

3.7.2.2.2 Stratified sampling Technique

The researcher adopted stratified sampling techniques to pick the school which participated within the study. This enabled the researcher to include respondents from various strata that were affected by the study (Onen and Oso, 2005). Stratified sampling provided more efficient estimates since variability within strata was considerably reduced and ensured there was little possibility of completely excluding any essential group of population. It

enabled the researcher to utilize available auxiliary information and ensure a better cross-section population representation of the entire population.

3.7.2.2.3 Simple Random Sampling Technique

Simple sampling is a method of sample choice that offers every potential sample combination equal chances of being seleted and every item in the whole population has equal probability of being incorporated in the sample (Kothari and Garg, 2014). In simple random sampling, an exhaustive list of elements is essential and elements are selected randomly (Du, 2018). The researcher made an exhaustive list of names of all students, allocated each name of a student a number, then used a computer-generated random table to select students who participated in the research. A simple random sampling technique enabled the researcher to omit the chances of systematic errors, sample biases and produce a representative sample (Alvi, 2016). Appendix 27 shows the sample size of the students who participated in the study.

3.8 Sampling frame

The study used four steps to determine the sample frame. First the researcher stratified the secondary schools in terms of gender; the boys', girls' and mixed schools. Secondly the research again stratified the school in terms of status; national, extra county, county and subcount schools, in the third step, the researcher further stratified the schools into geographical divisions that constituted the Nairobi Sub-Counties. finally, the researcher proportionately allocated the sample size to the selected schools. The distribution

comprised of nine girls' schools, eight boys' schools and three mixed schools as illustrated in Appendix 26.

In the fourth step, the researcher used systematic sampling and simple random sampling strategies to select participants of the study. Systematic sampling is as shown in Appendix 26 and the sample of the study is as shown in Appendix 28.

3.9 Research Instruments

This study used three questionnaires, two sets of interview schedules, observation method and document analysis to collect data. The researcher developed the research instruments and gave them to experts who ascertained their reliability and validity before they were applied in the study.

3.9.1. Questionnaire

The questionnaires were for the students, teachers, and nurses of the public boarding secondary schools that were selected for the study. The researcher designed three (3) sets of questionnaires that he used to gather information after they were valid. These questionnaires were developed from the literature reviewed to ensure that they covered all the required details. The first questionnaire was administered to students, the second to the teachers and the third to the nurses of the selected secondary schools to evaluate the impact of artificial classroom lighting on students' academic performance. The three (3) questionnaires were open and closed-ended and were designed to solicit information on the

impact of artificial classroom lighting on students' academic performance. The questionnaire specifically solicited information on the effects of artificial classroom lighting installation technology on public boarding secondary school students' reading, instruction, health, and academic performance. The questionnaires enabled the researcher to gather information from an expansive population in a short period of time, reduce the cost of research and draw inferences from data regarding existing relationships.

3.9.2. The Interview Schedule

The principals and teachers were interviewed through the guidelines of the interview schedule in order to get more input and verify the information obtained from the questionnaires. This helped the research to gather information that could not be put down in writing or observed.

3.9.3 Observation Method

Observation is a method of data collection in which researchers observe within a specific research field (Bryant, 2008). The researcher individually paid a visit the selected to observe the classroom lighting system in various learning task areas. This method helped the researcher to obtain information by direct observation without soliciting it from the respondents.

3.9.3.1. Observation checklist

The observation checklist was a guiding document on which the researcher recorded what he observed in the field. The observation checklist (Appendix 20) in this study was structured to observe the artificial classroom lighting installation, how they affect teachers' instruction modes; students' reading, health, and academic performance. The observation schedules were employed in assessing artificial classroom lighting installation technologies and discern how artificial classroom lighting affected the students.

3.9.4. Document analysis

Document analysis is a form of qualitative research in which documents are interpreted by the researcher to give voice and meaning around an assessment topic (Bowen, 2009). The researcher analyzed study related documents and secondary schools' end of term examination results to establish the impact of artificial classroom lighting on students' academic performance.

3.10 The validity of the Research Instruments

The study tools were evaluated and validated by professionals in the Department of Technology Education, University of Eldoret. The recommendations that were made by the professionals were incorporated by the researcher so as to ensure accurate and correct measurements were made.

3.11 Reliability of the Research Instruments

A pilot study was carried out in ten (10) public boarding secondary schools in Kiambu County. The researcher conducted a pilot study, tested and pretested the research tools to re-determine their validity and reliability. Ten (10) principals, forty (40) teachers, ten (10) nurses and two hundred (200) students in Kiambu County public boarding secondary schools were picked to take part in the pilot study. The data from the pilot study was used to determine the reliability of the research tools. A Cronbach alpha of 0.822 for the set of scores was obtained indicating that the test was 82 % reliable, and by extension that it was 12 % unreliable (100% - 82% = 12%). A minimum Cronbach Alpha Coefficient of 0.822 was well-thought-out to be appropriate for the study. This is in regard to George and Mallery (2011) who confirmed that a minimum Cronbach Alpha Coefficient of 0.75 was appropriate for a study.

To determine quality/dependability/rigor/trustworthiness and reliability of the interview schedule, the researcher subjected the interview schedule to credibility criterion, persistence observation, triangulation of information among different sources of data, and received feedback from informants (member check) and expert review (Simon, 2011).

3.12 Data Collection Procedures

The researcher requested for the introduction letter from the University of Eldoret Board of Graduate Studies to enable him to request for a research permit. The researcher requested for a research permit from the National Council for Science and Technology (NACOST)

to facilitate him to hold out the study. The researcher also sought permission from the Ministry of Education Science and Technology and the Nairobi County Government to allow him to gather information from the participants. The researcher in person visited the schools and farmiliarized himself with the principals and informed them of the importance of conducting the research.

3.12.1 Survey data collection

The researcher administered the questionnaires to the selected students, teachers, and nurses of the selected secondary schools. The researcher guided the principals and teachers through the interview as they responded to various questions.

3.12.2 Experimental data collection

An experiment is a means of collecting evidence to show the effect of one variable upon another (Herriot, 2005). The researcher made predition to be tested, selected appropriate experimental design and operationalized the experiment. The researcher conducted an experiment in six months (two terms) to assess the impact of artificial classroom lighting on students' academic perfromance. The investigator redesigned some classroom artificial lighting and assessed their effect on students' academic performance. The redesign of the classroom lighting was to confirm that there was adequate artificial lighting in the learners' learning environment for the experiment cluster.

The procedure of the experiment is as shown in Appendix 29. In the experiment, the students were placed into two groups, the experiment group, and the control group (see

Appendix 11). The students in the experiment group learned from an adequately designed artificial classroom lighting, while those in the control group learned in their normal artificial classroom lighting classroom. Both groups of students were examined (pre-tested) before the treatment was given to the experimental group only and then both groups were post-tested. The researcher personally visited the schools selected for the study, measured artificial classroom illumination and noted the end of term examination scores after and before treatments.

The researcher performed illumination measurements using HIOKI Lux Hi TESTER 3421 lux meter of 5% accuracy of reading, +10 digits calibrated in lamp and scales of 300, 1000 and 3,000. The researcher used a scale of 1,000 and the results of the experiment as shown in Appendices 31 and 32. The researcher recorded each student desk top illumination and end of term examination mean score values for analysis purposes. The pre-test and post-test illumination and end of term examination scores were recored as shown in Appendix 33 and Appendix 34.

3.12.3 Observation data collection

The researcher visited the schools selected for the study, observed the state of artificial classroom lighting installation technology and the behavior of students as they studied in their classroom. The researcher recorded the observed information in the personal observation checklist for data analysis process.

3.12.4 Document data collection

The researcher visited and collected documents with relevant information about schools lighting from the schools selected for the study; the Ministry of Education Science and Technology; and the Ministry of Infrastructure and Housing. The research went through the documents and recorded the data for analysis purpose.

3.13 Data Analysis

Data analysis is a methodology of consistently applying stastistical and or logical techniques to explain, illustrate, condense, recap and assess information (Shamoo and Resnik, 2003).

3.13.1 Survey data analysis

After collecting data by survey instruments, the data was entered into the Statistical Package for Social Scientists (SPSS) computer application for analysis. The descriptive statics was run to determine the normality of distribution and detect outliers. The research questionnaires were examined at 0.05 and 0.01 levels of significance. Pearson's product-moment correlation and t-test were used to establish the relationship between the variables. The interview and interview schedules were analyzed descriptively to see the result of artificial room lighting on students' achievements. In qualitative data analysis, the researcher transcribed data that was collected through interviews and observations; organized the transcribed data; familiarized himself with the data; coded the data; identified themes or emergent concepts; recoded to develop better well-defined categories for

analysis (Lacey and Luff, 2009). Inferential statistics assumed that the data that was collected was normally distributed (Mugenda and Mugenda, 2005). The Likert scale items resulted in data that was mathematically manipulated. The strength relied on the ability of the data to allow assessment of the relationship among variables. The data was additionally regressed to yield expected variance in dependent variable that was explained by independent variables.

3.13.2 Experimental data analysis

The illumination measuremts for pre-test and post-test for both experimental group and control group were codded and entered in SPSS data file that was created for analysis purposes. Both descriptively and inferentially statistic were used to analyze the experiment data. After post-test, statistical analysis was carried out to see whether the treatment had had an effect.

3.13.3 Observation data analysis

The researcher selected units of analysis, carried out a thematic analysis of information gathered, conducted data content analysis and reviewed observation videos. The researcher analyzed the observed data by describing what he observed. The researcher also coded observed data anay analyzed it using SPSS computer program software.

3.13.4 Interview data analysis

The researcher transcribed, logged, prepared anecdotes and vignetted the interviews. Then, the researcher coded the interview information, entered it in SPSS computer program and analyzed it descriptively.

3.13.4 Document data analysis

Document analysis is a form of qualitative research in which documents are interpreted by the researcher to give voice and meaning around an assessment topic (Bowen, 2009). The researcher evaluated the documents for completeness and originality of their purpose; skimmed the documents to get overview; read the documents to identify relevant categories for the overal set of documents and interpreted the forms of the documents. The researchen then examined the data and interpreted it in oder to elicity meaning, gain understanding and develop imperical knowledge. Finally, the researcher collated the documents, coded them into themes and analyzed them using SPSS computer software.

3.14 Statistical Treatment of Data

Descriptive and inferential statistics were used to analyze the information during this study. Descriptive statistics were used to analyze information that was collected through the questionnaires. The descriptive statistics that were utilized in the information analysis were frequencies, percentages, means, standard deviations and variance. The inferential statistics that were used in the data analysis were a correlation, a student's T-test and Chi-Square Tests of Goodness of Fit. The results that were obtained from the analyzed

knowledge were conferred in sort of tables, charts, and graphs. The information that was obtained from the analyzed data was used to verify the findings, and from the findings, conclusions were drawn and recommendations made.

3.15 Ethical Considerations

In this study, thought was given to obliging with moral measures within the course of conducting the analysis. to make sure their safety and rights, the respondents were briefed concerning the present moral thought, for instance, consent, rights of the respondents, voluntary participation, anonymity, and confidentiality. The researcher obtained consent from every respondent. The consent was obtained orally once the participant had had the chance to rigorously think about the risks and edges and asked any pertinent questions about the study. Privacy and confidentiality issues got merited thought (Onen and Oso, 2005). The ethical principle refers to the duty on the a part of the scientist to respect every respondent as an individual capable of constructing associate enlightened call concerning participation within the analysis study. The researcher ensured that the participants received full revealing of the character of the study, benefits, and alternatives, with associate extended chance to raise queries.

3.16 Summary

This study investigated the effects of artificial classroom lighting on public boarding secondary students' academic performance in Nairobi County of Kenya. The study adopted a pragmatism paradigm, philosophy, ontology, epistemology and axiology. it employed a

survey and experimental research designs. Questionnaires, interview schedules, observation methods, and document analysis were used to collect data for the study. The study used purposive, stratified and simple random sampling techniques. The instruments used in the study were first examined and validated by the University of Eldoret professionals before they were used in the study. A research permit was obtained that allowed the researcher to collect data. A pilot study was conducted in ten public boarding secondary schools in Kiambu County of Kenya and a minimum Cronbach Alpha Coefficient of 0.85 was obtained which was considered appropriate. The Statistical Package for Social Sciences (SPSS) computer software was used to analyze the data. The analyzed data was interpreted and presented in tables, charts, and graphs. The result of the study was used to draw conclusions and make recommendations.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS, INTERPRETATION, AND DISCUSSION

4.0 Introduction

This part gives a synthesis of information gathered in the study using tools discussed in chapter three. It constitutes five key parts. It starts with a in depth synthesis, interpretation and discussion of data on general information on the characteristics of schools and respondents. The second part part provides an in depth analysis, interpretation and discussion of data on the effect of artificial classroom lighting on reading that affect students' academic performance in Nairobi County Public Boarding Secondary Schools. The The third part provides an in depth analysis, interpretation and discussion of data on the effects of artificial classroom lighting on instruction that affect students' academic performance in Nairobi County Public Boarding Secondary Schools. The fourth part gives an in depth analysis, interpretation and discussion of data on the effects of artificial classroom lighting on students 'health that affect students' academic performance in Nairobi County Public Boarding Secondary Schools. The fifth part gives an in depth analysis, interpretation and discussion of data on artificial classroom lighting installation technology that affect students' academic performance in Nairobi County Public Secondary Schools.

4.1 General information

The sample frame of the research was the public boarding secondary school in Nairobi County of Kenya. Nairobi County consists of eleven sub-counties that the study recognized as devolved units carrying out education administration. In the sample frame, therefore, eleven sub-counties forming Nairobi County formed the stratified samples for the study. The students provided a unit sample for the study. Others were the staff personnel classified as principals, teachers, and nurses. The study recognized the principals who are the heads of the public secondary school, teachers who taught the students and the nurses who provided medical services to the students. Twenty schools drawn from the eleven sub-counties participated in the study.

Out of two hundred (200) questionnaires that were given to the teachers, one hundred and ninety-eight (198) 99 % were received back and one hundred and ninety-five (195) 98 % were found to be valid responses. The teachers were found to be conversant with artificial classroom effects on students' academic performance and gave relevant responses. Out of twenty (20) questionnaires that were given to the nurses, nineteen (19) 95% of the questionnaires were received back and found to be valid responses. The nurses were found to be acquainted with students' artificial classroom lighting health-related problems. Out of four hundred and thirty-five questionnaires that were given to the students, four hundred and twenty (420) 94% were received back of which four hundred and nine (409) 92% were found to be valid responses.

In general, therefore, the complete responses received back were slightly above 95% and those were found to meet the threshold for the survey. This complete questionnaire responses percentage was found adequate for the findings of the research to be generalized. The response rate of the survey is very important to the credibility of the research results. Scholars have held varied response rates. However, the response rate of 60% has been found adequate in most of the studies. Baruch (1999) settled for 60 ± 20 % among the population of employees, managers, and professionals as an acceptable response rate. Fincham (2008) and Johnson & Owens (2013) agreed that an average response rate of 60% is adequate for the surveys.

4.1.1 Sample size classification

The study involved respondents of varying categories and responsibilities and, therefore, it was necessary to classify respondents in accordance with their respective categories and roles. The sampling size varied depending on the respective categories involved in the study. Table 4.1.1 shows the distribution of questionnaires among the teachers, nurses and students.

Table 4.1.1 Different questionnaires distribution

Category	Number of questionnaires
Teachers	200
Nurses	20
Students	435
Total	**655**

Table 4.1.1 shows a total of six hundred and fifty-five respondents participated in the research. Teachers were involved because they carry out the instruction activities which determined students' academic performance that was affected by classroom artificial lighting. The nurses were selected because they were the ones who handled students' health problems related to artificial classroom lighting. The students were selected because they were the key informants on how artificial classroom lighting affected their reading, learning, health, and academic performance.

4.1.2 The sample size

This part provides the sample size classification based on the replied questionnaires received by the researcher. The responses of the questionnaires received were the ones involved in data analysis. Table 4.1.2 provides a summary of the questionnaires replied and received by the researcher. This was for the questionnaires distributed, those received back and those found to be complete responses. The complete response questionnaires were used for analysis.

Table 4.1.2 Summary of questionnaires distributed, received and with complete responses

Party	**Teachers**	**Nurses**	**Students**	**Total**
Distributed	200	20	435	**655**
Received	198	19	420	**637**
Coplete responses	195	19	409	**623**
% Received	99	95	96	**97**
% Complete responses	**98**	**95**	**94**	**95**

Table 4.1.2 shows how the six hundred and fifty-five (655) questionnaires were carefully distributed to achieve the target of collecting relevant data for the study. Two hundred (200) questionnaires were given to the teachers, twenty (20) questionnaires were given to the nurses and four hundred and thirty-five (435) questionnaires were given to the students. Each respondent was given one hour to respond to the questionnaires. Six hundred and thirty-seven (637) 97% of the questionnaires were received back and six hundred and twenty-three (623) representing 95% were found to have complete responses. The response is above the acceptable rate of at least 50% (Creswell, 2009). This was therefore found to be adequate for the analysis process.

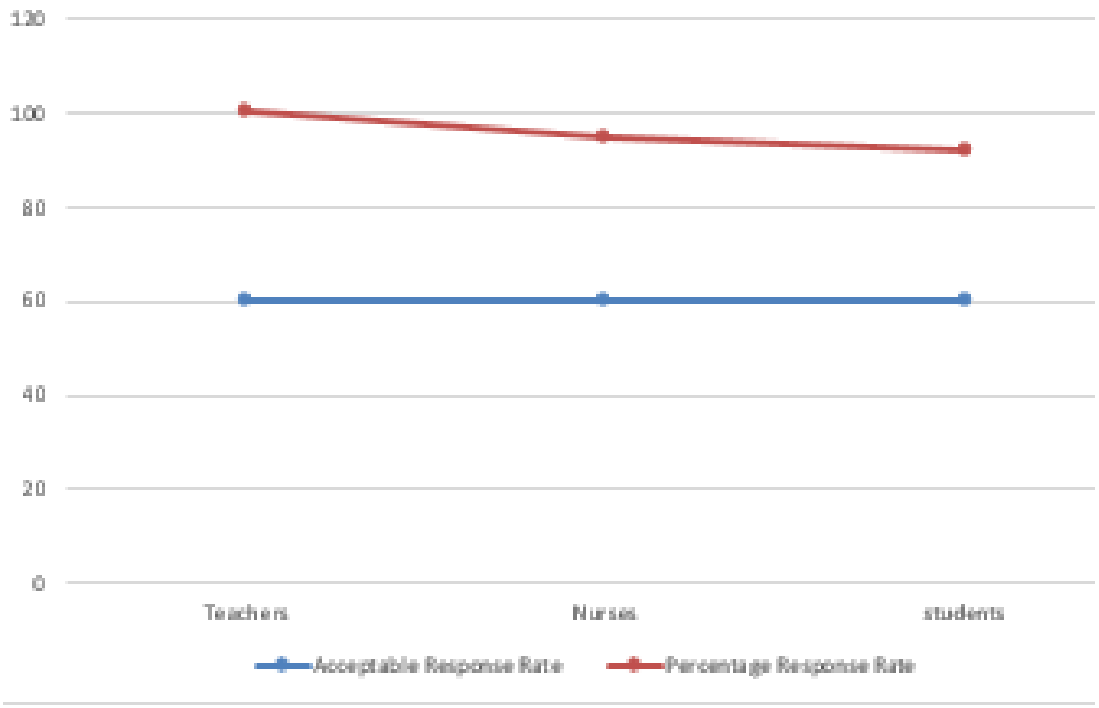


Figure 4.1 Respondents rate of response

4.2 Survey Data Presentation, Analysis, Interpretation, and Discussion

4.2.1 Demographic statistics

4.2.1.1 Gender

4.2.1.1.1 Students gender

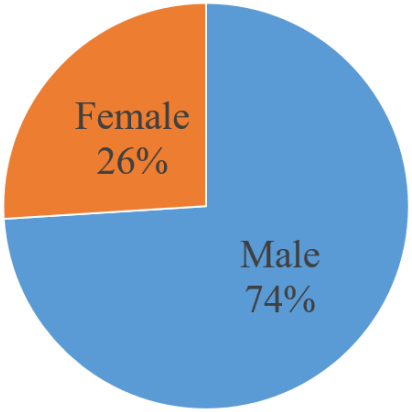


Figure 4.2 Students gender

Three hundred and four students (74%) were male and one hundred and five respondents (26%) were female.

Table 4.2.1.1 T-test Results of differences analysis of artificial classroom lighting distribution uniformity and students' gender

Students' Gender	N	Mean	SD	t	Degree of freedom	Sig. P-value 2 tailed
Boys	304	1.1678	0.374227	1.801	407	0.072
Girls	105	1.0952	0.29495			
	409	2.2630	0.66922			

Table 4.2.1.1 T-test results showed that there was a significant difference in the influence of students' gender on the perception of artificial classroom light distribution uniformity, $t(407) = 1.801$, $P < 0.05$. The t-test scores suggested that boys had a more perception of artificial classroom lighting uniformity than girls at the 0.5 significant level.

4.2.1.1.2 Nurses gender

Eighteen (18) 90% of the nurses were female while two (2) 10 % were males.

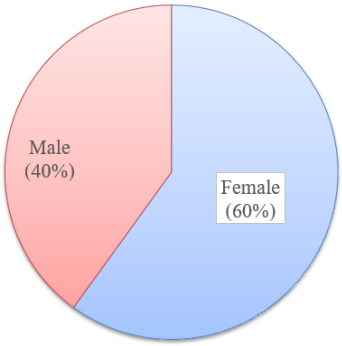


Figure 4.3 Nurses gender

Majority of nurses were wome.

4.2.1.1.3 Teachers gender

One hundred and twenty(120) 60% of teachers were male while eighty (80) 40% were female.

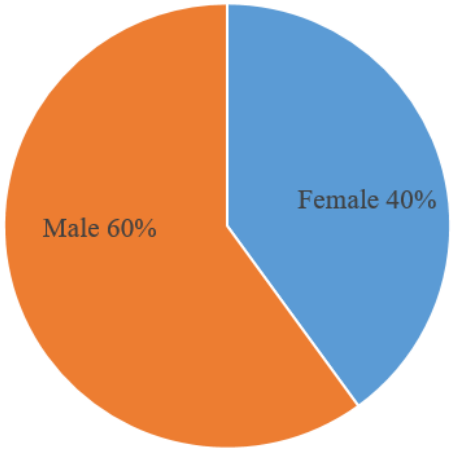


Figure 4.4 Teachers gender

4.2.2 Academic qualification

4.2.2.1 Nurses academic qualification

Table 4.2.2.1 Nurses academic qualification

Academic achievement	F	Percentage (%)
Certificate	5	25 %
Diploma	8	40%
Bachelors Degree	7	35 %
Total	**20**	**100 %**

Seven (7) 35% of the nurses were bachelor degree holders, eight (8) 40 % were diploma holders, and five (5) 25% were certificate holders. These medical practitioners were qualified and able to diagnose artificial classroom lighting health-related problems.

4.2.2.2 Teachers educational qualification

Table 4.2.2.2 Teachers academic qualification

Academic achievement	F	Percentage (%)
Bachelors Degree	123	61.5 %
Masters Degree	76	38%
Doctor(PHD)	1	0.5 %
Total	**200**	**100 %**

All teachers had the qualifications to teach well and enable students to attain good academic performance.

4.2.3 Work experience

4.2.3.1 Nurses work experience

Table 4.2.3.1 Nurses professional experience

Number of years worked	F	Percentage
1	1	5 %
2	2	10 %
3	4	20 %
4	2	10 %
5	4	20 %
Over 5	7	35 %
Total	**19**	**100 %**

Majority of the nurses had the professional experience required to establish artificial classroom lighting health-related problems. Only 15 % of the nurses had worked for 2 and 1 years.

4.2.3.2 Teachers professional experience

Table 4.2.3.2 Teachers professional experience

Number of years worked	F	Percentage (%)
1	10	5 %
2	20	10 %
3 - 5	40	20 %
6 – 10	60	30 %
11 – 20	30	15 %
Over 20	10	5 %

Ten (10) 5 % of teachers had worked over 20 years, 30 (15%) had worked 11 – 20 years, 60 (30 %) had worked 6 – 10 years, 40 (20%) had worked 3 - 5 years, 20 (10%) had worked 2 years, and 10 (5%) had worked for one year. This confirms that teachers had the expertise required to apply correct teaching approaches to enable students to attain high academic performance.

4.2.4 Type of Schools

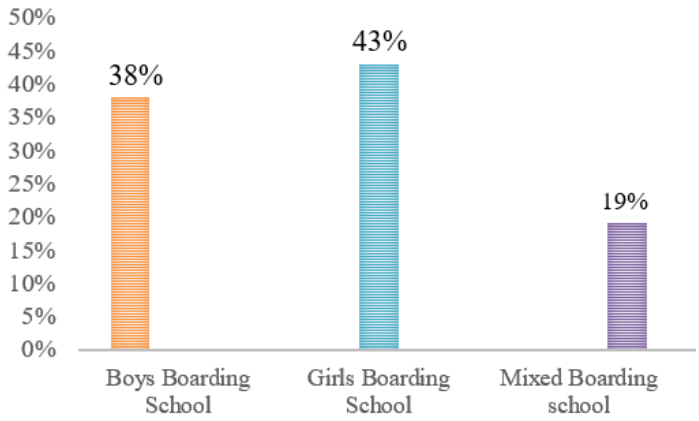


Figure 4.5 Types of schools

The majority of the schools were single sex boarding institutions with only 19% being mixed boarding secondary schools.

4.2.5 School Classification

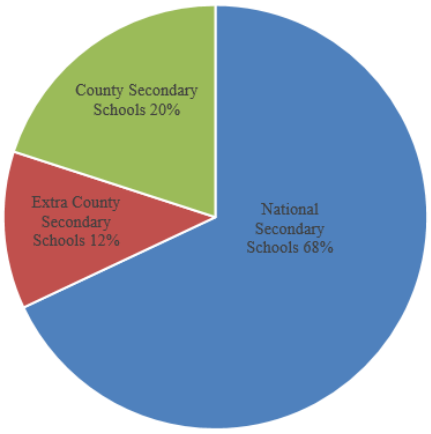


Figure 4.6 Classification of schools

Two hundred and seventy-eight respondents (68%) were from national secondary schools, 49(12%) were from extra county secondary schools and 82 (20%) were from county secondary schools.

4.2.6 Students reading light preferences

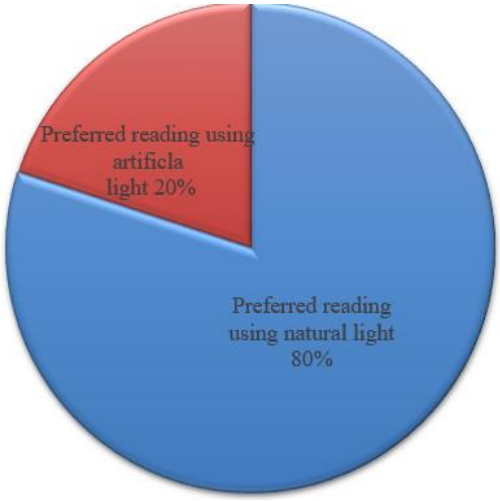


Figure 4.7 Students reading light preferences

The majority of the students preferred reading using natural light while only 36 (20%) preferred reading using artificial classroom lighting. This indicates that artificial classroom lighting in Nairobi County public boarding secondary schools was not desirable for reading as compared to natural light.

4.2.7 Students using spectacles

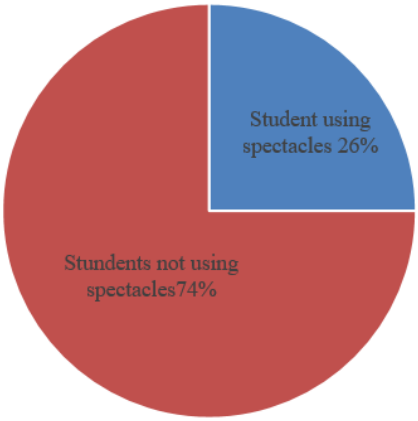


Figure 4.8 Students use of spectacles

Only 25 % of the students used spectacles to be read.

Table 4.2.7 Time students started using spectacles

Time students started using spectacles	Frequency	Percentage (%)
Before joining school	10	9
Form 1	33	30
Form 2	30	28
Form 3	35	32
Total	**108**	**100**

Table 4.2.7 indicates that ten (9%) of the respondents started using spectacles before joining the school, 33 (30%) in form 1, 30(28%) in form 2, and 35(32%) in form three. This indicates that the number of students using spectacles kept on rising every year of

their secondary school education. This shows that 98 (90.7 %) of the students started using spectacles after joining form one an indication that artificial classroom lighting might have been one of the cause of students wearing spectacles to be able see clearly. This may have been due to the effect of insufficient classroom lighting.

4.3 Artificial classroom lighting effects on students reading which affect students' academic performance in Nairobi County public boarding secondary schools

In this section, respondents were requested to indicate the effect of artificial classroom lighting on their reading. The rating was on a four-point Likert scale with agreeing (4), tend to agree (3), tend to disaree (2) and disagree (1). Table 4.3.1 shows the respondents' responses.

Table 4.3.1 The effects of artificial classroom lighting on students' reading

Item	Response								Total (N)	
	Disagree(D)		*Tend to disagree (TD)*		*Tend to Agree (TA)*		*Agree (A)*			
	f	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**
Light in the classroom sometimes flickers	104	25	0	0	0	0	305	75	195	100
Fluorescent make buzzing noise disturbing reading	104	25	0	0	0	0	305	75	195	100
Student skip lines when they read	104	25	0	0	305	75	0	0	195	100
Students skip some words when they read	0	0	104	25	305	75	0	0	195	100
Could not read what was written on the chalk / white board	23	12	14	7	49	25	109	56	195	100

Table 4.3.1 reveals that most of the respondents agreed while only 25 % disagreed that artificial classroom lighting sometimes flickered, made a disturbing buzzing noise and that they skipped words and lines when they read using artificial classroom lighting. Many respondents agreed while only 19 %) disagreed that they were not able to read small letters displayed on the chalk/whiteboard when artificial classroom lighting was on. These ripostes from the respondents reveal that the artificial classroom lighting in Nairobi County had a negative effect on the learners' reading because some lights flickered, some lights buzzed, and could not give sufficient lighting making the learners skip some lines and words as they read in the classroom. This is in agreement with Sleegers *et al*. (2012).

H_{01}: There is no significant relationship between the effect of artificial classroom lighting and students reading which affects students academic performance in public boarding secondary schools in Nairobi County.

Table 4.3.2 Ranking of top five effects of artificial classroom lighting on reading

Effects	Mean	SD	N
I skip lines when I read	2.4914	0.87198	409
I skip words when I read	2.4914	0.87198	409
I find It difficult to read letters on chalk/whiteboard	2.4156	0.83920	409
Fluorescent lamb buzzing noise disturbs reading concentration	1.2543	0.43599	409
Light flickering makes students uncomfortable to read	1.2298	0.42124	409

As reported in table 4.3.2 above, artificial classroom lighting factors relating to "skipping of words" (M=2.4914, SD = 0.87198) and "skipping of letters" (M=2.4914, SD = 0.87198) were the most prevalent effects of artificial classroom lighting on students reading.

The artificial classroom lighting factors relating to "difficulty to read letters on chalk/whiteboard" (M=2.4156, SD = 0.83920) was a more prevalent artificial classroom lighting effect on students reading.

The artificial classroom lighting factors relating to "fluorescent buzzing noise disturbing reading concentration" (M=1.2543, SD = 0.43599) was a lesser prevalent artificial classroom lighting effect on students reading.

The artificial classroom lighting factors relating to “light flickering “(M=1.2298, SD = 0.42124) was the least prevalent effect of artificial classroom lighting on students reading. To assess the impact of artificial classroom lighting on students reading, the chi-square goodness-of-fit was applied to the scores obtained from the questionnaires. From the scores, the researcher tested whether artificial classroom lighting had an effect on students reading. The research claim was that the artificial classroom lighting had an effect on students reading that was observed against expected checklist. At $\alpha = 0.90$, the claim was tested. The critical value was determined at the degree of freedom of $5 - 1 = 4$ and $\alpha = 0.90$ the critical value was 1.064 (Chi-square distribution table- Appendix 21).

Table 4.3.3 The Chi-Square source table of the results of the level of relationship between artificial classroom lighting and students' reading

df	Item	Observed	Expected	O-E	$(() - E)^2$	$\frac{(O-E)^2}{E}$
1	Light flickering	327	309	18	324	1.049
2	Fluorescent buzzing	305	309	-4	16	0.052
3	Section of the room darker than others	303	309	6	36	0.117
4	Students skip line when reading	305	309	-4	16	0.052
5	Students skip words when reading	305	309	-4	16	0.052
Total						**1.322**

(Source: Field Survey 2019)

Decision: The decision rejected that claim since 1.322 > 1.064. From the test results, there was enough evidence to reject that claim that there is no significant relationship between artificial classroom lighting and students' reading. Therefore, there is a significant relationship between artificial classroom lighting and students' reading. This is in agreement with Barret *et al*. (2015) and Wilkins (2009).

Figure 4.9 shows the observed graph is very much below the expected. The gap between the two graphs shows how the results of the Chi-squares test for goodness-of-fit-test is not a good fit.

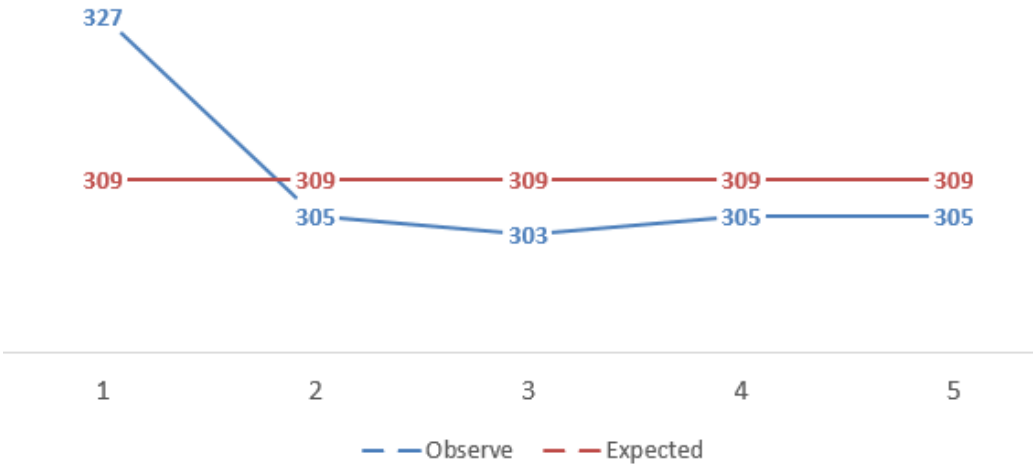


Figure 4.9: Results of the Goodness-of-fit for effect of the artificial classroom on students reading

NOT GOOD FIT

Table 4.3.4 The effects of reading on students' academic performance

Effects	End of the term mean score	SD	Variance	N
skipping of lines	50.1705	8.12152	65.959	88
Some section of classroom darker than others	49.5556	7.99313	63.890	90
Difficulty to read small letters on the chalk/whiteboard	48.2472	7.39054	54.620	89
Fluorescent lamp buzzing noise	46.1778	7.19016	51.698	90
Skipping of words	45.4231	5.93212	35.190	52
Total				**409**

(Source: Author, 2019)

Table 4.3.4 shows that students who skipped lines when reading scored a mean of 50.17 in end of term examination, those who indicated that some sections of the classroom were darker than others scored a mean of 49.56 in end of term examination, those who had difficulties to read small letters on the chalk/whiteboard scored a mean of 48.25 in end of term examination, those who were disturbed by classroom fluorescent lamp buzzing noise scored a mean of 46.18 in end of term examination and those who skipped words when they were reading scored a mean of 45.42 in end of term examination. Most of these students scored below average at the end of term examination indicating that reading related factors made the student score low in their academic performance.

The students who complained of not being able to see letters on the chalk/whiteboard, fluorescent lamps buzzing disturbing noise and skipping of words as they read were the most affected with artificial classroom lighting installation technology because their mean scores were very low. This is in agreement with Samani and Samani (2012) and sleegers *et al*. (2012).

4.4 Artificial classroom lighting effects on instruction which affect students' academic performance in Nairobi County public boarding secondary schools

In this part, respondents were requested to evaluate the effect of artificial classroom lighting on teaching. The responses were ranked on a four-point Likert scale with agreeing (4), tend to agree (3), tend to disaree (2) and disagree (1). Tables 4.4.1 and Table 4.4.2 give a picture of their rejoinders.

Analysis of teachers' questionnaire

Table 4.4.1 Teachers' perception of artificial classroom lighting effects on instruction

Item	Response								Total (N)	
	Disagree (D)		*Tend to disagree(TD)*		*Tend to Agree (TA)*		*Agree(A)*			
	f	%	f	%	f	%	f	%	F	%
Some students not able to see clearly diagrams on classroom projector screen when electric light is on	31	15	16	8	59	30	89	46	195	100
Students were not able to read letters displayed on computer screen	37	19	20	10	68	35	70	36	195	100
Student were not able to see small writing on the chalk / white board	23	12	14	7	49	25	109	56	195	100
Some students look sleepy when learning using artificial classroom lighting	17	9	12	6	82	42	84	43	195	100

Table 4.4.1 reveals that most of the teachers agreed while 23 % disagreed that the students could not clearly see diagrams on the classroom projector screen when artificial classroom lighting was on. Many teachers and students agreed while only 29% disagreed that the sudents were not able to read letters displayed on the computer screen when artificial classroom lighting was on. Many teachers agreed while only 19 % disagreed that the

students were not able to read small letters displayed on the chalk/whiteboard when artificial classroom lighting was on. Many teachers agreed while only 15 % disagreed that some students appeared to be sleepy as they learning using artificial classroom lighting. This indicates that artificial classroom lighting in Nairobi County public boarding secondary schools made the students not to be able to read small letters displayed on the chalk/whiteboard, see clearly diagrams on the classroom projector screen, and read letters displayed on the computer screen. This is in line with Wall (2016), Buckley (2014) and Gill (2014).

Analysis of students' questionnaire

Table 4.4.2 Artificial classroom lighting effects on instruction

Item	Responses						Total	
	Disagree (D)		*Tend to disagree (TD)*		*Tend to Agree (TA)*		*(N)*	
	f	%	f	%	f	%	f	%
Students not able to see clearly diagrams on classroom projector screen when electric light is on	104	25	33	8	272	67	409	100
Students not able to read letters displayed on computer screen	92	23	84	21	233	57	409	100
Student were not able to see small writing on the chalk / white board	104	25	0	0	305	75	409	100
Some students look sleepy when learning using artificial classroom lighting	20	10	20	10	160	80	409	100

Table 4.4.2 reveals that most of the respondents agreed while only 33 disagreed that they could not clearly see diagrams on the classroom projector screen when artificial classroom lighting was on. Many agreed while 43 % disagreed that they were not able to read letters displayed on the computer screen when they were using artificial classroom lighting. Many respondents agreed while only 25 % disagreed that they were not able to see clearly small writings on the teacher's board when artificial classroom lighting was on. The majority of

the respondents agreed whily only 20 % disagreed that some students appeared sleepy in the classroom as they were being taught when artificial classroom lighting was on. This is in agreement with Gill (2014), Wall (2016) and Buckley (2014).

Table 4.4.3 Comparison of teachers and students' opinion on how artificial classroom lighting affect instruction in Nairobi County of Kenya public boarding secondary schools

		Responses				*Total*	
		Disagree (D)		*Agree (A)*		*(N)*	
Item	**Respondents**	**f**	**%**	**f**	**%**	**f**	**%**
The student was not able to see small writing on the chalk/whiteboard	Teachers	37	19	158	81	195	100
	Students	104	25	305	75	409	100
Some students not able to see clearly diagrams on the classroom projector screen when electric light is on	Teachers	47	24	148	76	195	100
	Students	137	33	272	67	409	100
Students not able to see clearly letters displayed on the computer screen	Teachers	57	29	138	71	195	
	Students	104	25	305	75	409	100

Table 4.4.3 shows that many teachers and students agreed that artificial classroom lighting made students unable to see small writings on the chalk/whiteboard, see clearly diagrams on the projector screen and read letter displayed on the computer screen. This suggests beyond a reasonable doubt that artificial classroom lighting in Nairobi County public boarding secondary schools hampered instruction activities such as seeing clearing what is written on chalk/whiteboard, projections on the projector screen and displayed on the computer screen. This is in line with Buckley (2014), Wall (2016) and Gill, 2014).

H_{02}: There is no significant relationship between the effects of artificial classroom lighting and instruction which affect students academic performance in public boarding secondary schools in Nairobi County.

Table 4.4.4 Ranking of the effects of artificial classroom lighting on instruction

Effects	Mean	SD	N
Difficulty to see clearly writings on chalk/whiteboard	1.7946	0.51151	409
Some classroom sections are slightly darker than others	1.2543	0.43599	409
Light sometimes flickers	1.2005	0.40086	409

As reported in table 4.4.4 above, artificial classroom lighting factors relating to "difficulty to see clearly what is written on the chalk/whiteboard" (M=1.7946, SD = 0.51151) were the most prevalent effects of artificial classroom lighting on students instruction.

The artificial classroom lighting factors relating to "some classroom sections being slightly darker than others" (M=10254, SD = 0.43599) was a more prevalent artificial classroom lighting effect of on students' instruction.

The artificial classroom lighting factors relating to "light sometimes flickers" (M=1.2005, SD = 0.40086) were the least prevalent effect of artificial classroom lighting on students' instruction.

Table 4.4.5 The Chi-Square source table of the results of the level of relationship between artificial classroom lighting and instruction

df	Item	Observed	Expected	O-E	$(() - E)^2$	$\frac{(O-E)^2}{E}$
1	Some students not able to see clearly diagrams on the classroom projector screen when electric light is on	272	246	26	676	2.748
2	Difficulty to see writing on chalk / white board	305	246	59	3481	14.150
3	Students appearing sleepy in classroom	160	246	-85	7396	30.065
Total						**46.963**

(Source: Author, 2019)

Decision: The decision rejected that claim since 46.963 > 0.211. From the test results, there was enough evidence to reject that claim that there is no significant relationship between artificial classroom lighting and instruction. Therefore, there is a significant effect of artificial classroom lighting technology on instruction.

Figure 4.10 shows the observed graph is very much below the expected. The gap between the two graphs shows how the results of the Chi-squares test for goodness-of-fit-test is not a good fit.

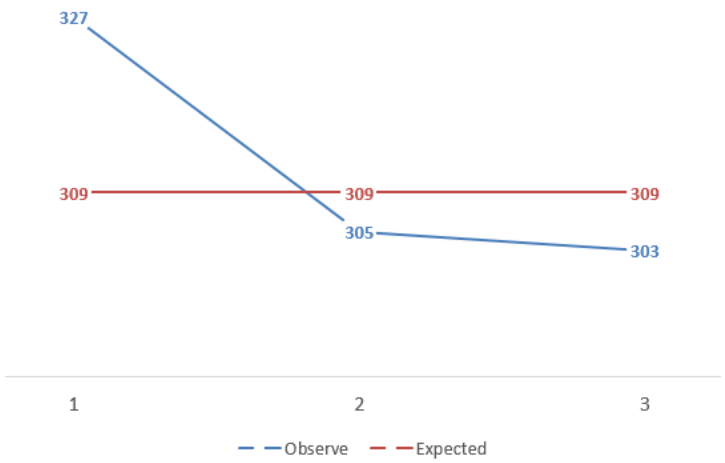


Figure 4.10: Results of the Goodness-of-fit for artificial classroom lighting on instruction

NOT GOOD FIT

Instructional factors effect on students' academic performance

Table 4.4.6 Instruction effects on students' academic performance

Effects	Student end of the term mean score	SD	Variance	N
Difficulty to see clearly what is displayed on the projector screen	48.3942	7.83373	61.367	104
Light flickering	48.3441	7.99116	63.859	93
Difficult to see clearly writing on chalk/whiteboard	48.2381	7.56577	57.241	105
Some sections of the classroom slightly darker than others	47.5981	7.33930	53.865	107
Total				**409**

(Source: Author, 2019)

Table 4.4.6 shows that students who reported that they had difficulties to see clearly what was displayed on the projector screen scored a mean of 48.39 in end of term examination, those who indicated that some lighting flickered scored a mean of 48.34 in end of term examination, those who had some difficulties to read letters on the chalk/whiteboard scored a mean of 48.23 in end of term exams and those who said that some sections of the classroom were darker than others scored a mean of 47.60 in end of term examination. All students who were affected by artificial classroom lighting effects on instruction scored below average at the end of term examination indicating that

instructional related challengs made the student score below average in their academic performance.

The students who complained of having difficulties in seeing clearly what was written on the chalk/whiteboard and some sections of the room being darker than the others were the most affected by artificial classroom lighting because they had very low mean scores. This is in line with Samani and Samani (2012) and Sleegers *et a*l. (2012).

4.5 Artificial classroom lighting effects on students' health which affect students' academic performance in public boarding secondary school in Nairobi County

In this section, respondents were requested to indicate their agreement with varied statements that described the factors. The nature of agreement was varied on a four-point Likert scale with agreeing (4), tend to agree (3), tend to disaree (2) and disagree (1). The analysis of frequencies, means and percentages of the disagree, tend to disagree, tend to agree and agree responses provided a better picture of how classroom artificial lighting affected secondary school students' health in Nairobi County of Kenya. The state of health was characterized by headache, impaired visual performance, eye aches, and eye strains. Tables 4.5.1 and 4.5.2 below shows the nurses and students' opinion in regard to how artificial classroom lighting affect students health.

Analysis of the Nurses Questionnaire

Table 4.5.1 Nurses opinion on the effect of artificial classroom lighting on secondary school students health in Nairobi County of Kenya public boarding secondary schools

Item	**Response**				***Total***	
	Tend to Agree(TA)		***Agree(A)***		***(N)***	
	f	**%**	**f**	**%**	**f**	**%**
Student experience eye strain when they read using artificial classroom lighting	5	26	14	74	19	100
Students eyes itched when they read using artificial classroom lighting	3	16	16	84	19	100
Students visited hospital for artificial classroom lighting related eye problems	2	11	17	91	19	100
Some students had visual impairment	3	16	16	84	19	100
Students experienced headache when they read using classroom artificial light	5	26	14	74	19	100
Students' eyes felt dry when they read using classroom artificial light	2	11	17	91	19	100

Table 4.5.1 shows that many respondents agreed that some students experienced eye strain, eyes itch, headache, visited the hospital complaining of artificial classroom lighting-related eye problems, had visual impairment, and eyes felt dry when they read using classroom artificial lighting.

Analysis of the students' Questionnaire

Table 4.5.2 Students' opinion on how artificial classroom lighting affect their health in Nairobi County of Kenya public boarding secondary schools

	Response								*Total*	
	Disagree(D)		*Tend to disagree(TD)*		*Tend to Agree(TA)*		*Agree(A)*		*(N)*	
Item		%	f	%	f	%	f	%	f	%
Artificial classroom lighting not enough for students eyes at night.	64	16	43	11	272	67	30	7	409	100
Artificial classroom light colour not desirable for students' eyes.	104	25	33	8	272	67	0	0	409	100
Student experience eye strain when they read using artificial classroom lighting.	104	25	33	8	272	67	0	0	409	100
Students eyes itched when they read using artificial classroom lighting.	104	25	33	8	272	67	0	0	409	100
Students visited hospital for artificial classroom lighting related eye problems.	94	23	33	8	272	67	10	2	409	100
Students experienced visual impairment.	261	64	43	10	12	3	93	23	409	100
Students experienced headache when they read using classroom artificial light.	94	23	84	21	221	54	10	2	409	100
Students' eye felt dry when they read using classroom artificial light.	104	25	254	62	51	13	0	0	409	100
Students used spectacles to read	316	77	0	0	93	23	0	0	409	100

Table 4.5.2 illustrates that the majority of the respondents agreed while 36 % disagreed disareed that artificial classroom lighting was not enough for their eyes at night. Many

respondents agreed while 33 % disagreed that artificial classroom light colour was not desirable for their eyes, they experienced eye strain, their eyes itched and they visited the hospital for eye problems when the read using artificial classroom lighting. Many respondents disagreed while only 26 % agreed that they had visual impairment. Many respondents agreed while 44 % disagreed that they experienced headache when they read using classroom artificial lighting. Many respondents disagreed while 13% agreed that their eyes felt dry when they read using classroom artificial lighting. Many respondents disagreed while 23 % agreed that the used spectacles when they read using classroom artificial lighting. Many respondents agreed while 40 % disagreed that they complained of eye aches when they read using classroom artificial lighting.

Table 4.5.3 below shows a comparison between nurses and students' opinion on how artificial classroom lighting affect students' health in Nairobi County public boarding secondary schools.

Table 4.5.3 Comparison of nurses and students' opinion on how artificial classroom lighting affect students' health in Nairobi County of Kenya public boarding secondary schools

Item	Respondents	Total		Responses			
		(N)		*Disagree(D)*		*Agree(A)*	
		f	%	f	%	f	%
Student experience eye strain when they read using artificial classroom lighting	Nurses	**19**	100	0	0	19	100
	Students	409	100	136	33	272	67
Students eyes itched when they read using artificial classroom lighting	Nurses	**19**	100	0	0	19	100
	Students	409	100	136	33	272	67
Students visited hospital for artificial classroom lighting related eye problems	Nurses	**19**	100	0	0	19	100
	Students	409	100	127	31	282	69
Some students had visual impairment	Nurses	**19**	100	0	0	19	100
	Students	409	100	304	74	105	26
Students experienced a headache when they read using classroom artificial light	Nurses	**19**	100	0	0	19	100
	Students	409	100	178	44	231	56
Students' eyes felt dry when they read using classroom artificial light	Nurses	**19**	100	0	0	19	100
	Students	409	100	358	87	51	13

Table 4.5.3 shows that all nurses and many students agreed that artificial classroom lighting made students experience strain, eye itch, visual impairment, headache, dry eyes and visit the hospital for eye-related problems. This suggests beyond a reasonable doubt that

artificial classroom lighting in Nairobi County caused students health problems such as eye strain, eye itching, visual impairment, headache, and dry eyes. This is in agreement with Miriahim *et al*. (2012) and Morrow, Sanakri (2018) and Kappel & Alanoly (2018).

H_{03}: There is no significant relationship between the effects of artificial classroom lighting and students' health which affects students'academic performance in public boarding secondary schools in Nairobi County.

Table 4.5.4 Ranking of top nine (9) effects of artificial classroom lighting on health

Item	N	Mean	SD
Students experience visit hospital due to eyes problems	409	2.4841	0.87187
Light colour not desirable for eyes at night	409	2.4108	0.86743
Students experience eye strain	409	2.4108	0.86743
Students experience eyes itch	409	2.4108	0.86743
Students experience a headache when reading using electric light	409	2.0244	0.73056
Eyes feel dry reading in the electric light classroom	409	1.8704	0.60255
Classroom sections slightly darker than others	409	1.2543	0.43599
Light sometimes flickers	409	1.2005	0.40086
Light distributed uniformly appropriately spread	409	1.1491	0.35667

As shown in table 4.5.4 above, artificial classroom lighting factors relating to “hospital visit due to eye problems “(M=2.4841, SD = 0.87187) were the most prevalent artificial classroom lighting effects on students health.

The artificial classroom lighting factors relating to “lighting colour not being desirable for the eyes” (M=2.4108, SD = 0.86743), “eye strain” (M=2.4108, SD = 0.86743), and “eye itch” (M=2.4108, SD = 0.86743) were more prevalent artificial classroom lighting effects on students health.

The artificial classroom lighting factors relating to “experiencing headache” (M=2.0244, SD = 0.73056) were the next prevalent artificial classroom lighting effects on students health.

The artificial classroom lighting factors relating to the “feel of a dry eye” (M=1.8704, SD = 0.60255) was the next prevalent artificial classroom lighting effects on students health.

The artificial classroom factors relating to “classroom sections slightly darker than others” (M=1.2543, SD = 0.43599) was the next prevalent artificial classroom lighting effects on students health.

The artificial classroom lighting factors relating to “lights sometimes flickering” (M=1.2005, SD = 0.40086) was the least prevalent artificial classroom lighting effects on students health.

To examine the effect of artificial classroom lighting on students’ health, the chi-square goodness-of-fit was applied to the scores obtained from the questionnaires. From the scores, the researcher tested whether artificial classroom lighting had an effect on student’s

health. The research claim was that the artificial classroom lighting had an effect on students' health that was observed against expected checklist. At $\alpha = 0.90$, the claim was tested. The critical value was determined at the degree of freedom of $5 - 1 = 4$ and $\alpha = 0.90$ the critical value was 1.064 (Chi-square distribution table- Appendix 21).

. At $\alpha = 0.90$, the claim was tested. The critical value was determined at the degree of freedom of $7 - 1 = 6$ and $\alpha = 0.90$ the critical value was 2.204 (Chi-square distribution table- Appendix 21).

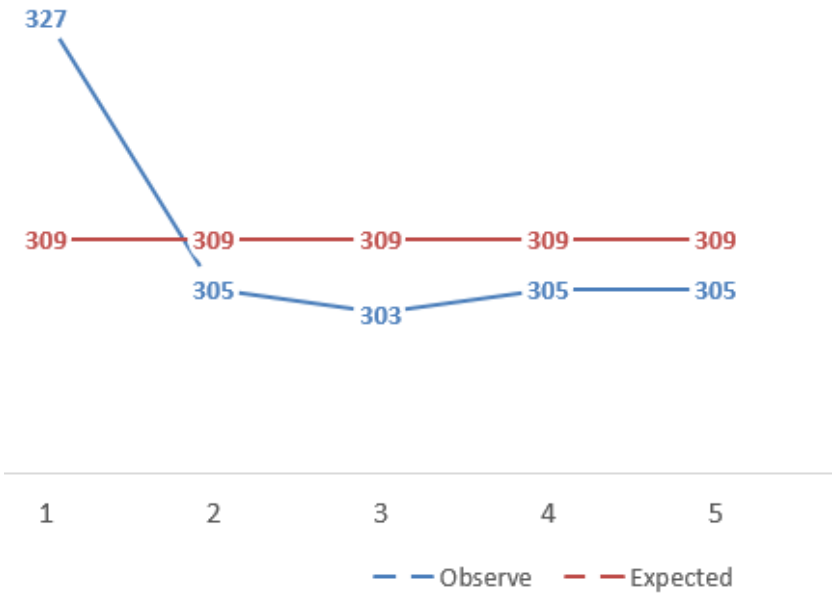
Table 4.5.5 The Chi-Square source table of the results of the level of relationship between artificial classroom lighting and students' health

df	Item	Observed	Expected	O-E	$(() - E)^2$	$\frac{(O-E)^2}{E}$
1	Experience eye strain	272	185	87	7569	40.91
2	Experience eye itch	272	185	87	7569	40.91
3	Visited hospital	272	185	87	7569	40.91
4	Had visual impairment	105	185	-80	6400	34.60
5	Experienced headache	231	185	46	2116	11.44
6	Eye felt dry	51	185	-134	17956	97.06
7	Used spectacles	93	185	-92	8464	45.75
Total		**1,296**				**311.58**

(Source: Author, 2019)

Decision: The decision rejected that claim since 311.58 > 2.204. From the test results, there was enough evidence to reject that claim that there is no significant relationship between artificial classroom lighting and students' health. Therefore, there was a significant effect of artificial classroom lighting on students' health in Nairobi County public boarding secondary schools. This is in agreement with Inger *et al*. (2014).

Figure 4.11 shows the observed graph is very much below the expected. The gap between the two graphs shows how the results of the Chi-squares test for goodness-of-fit-test is not a good fit.



NOT GOOD FIT

Figure 4.11: Results of the Goodness-of-fit for artificial classroom lighting effect on students' health.

The effects of health on students' academic performance

Table 4.5.6 Health effects on students' academic performance

Effects	Mean	SD	Variance	N
Students visit hospital for eye problems	49.0169	7.82236	61.189	59
Students experience eye itch	48.9688	8.00787	64.126	64
Students experience headache	48.5000	7.41260	54.947	76
Students experience eye strain	47.6892	7.86169	61.806	74
Light not desirable for eyes at night	46.7377	7.38219	54.497	61
Total				**334**

Table 4.5.6 shows that students who visited hospital for eye problems scored a mean of 49.02 in end of term examination, those who suffered from eye itching scored a mean of 48.97 in end of term examination, those who suffered headaches scored a mean of 48.51in end of term examination, those who suffered from eye strain scored a mean of 47.69 in end of term examination and those who said light was not desirable for their eyes scored a mean of 46.50 in end of term examination.. All students who were affected by artificial classroom lighting effects on health scored very low means at the end of term examination indicating that health-related factors made the student score below average in their academic performance.

The students who complained of experiencing headaches, eye strain and light not desirable for their eyes were the most affected by the classroom artificial classroom lighting because they had very low mean scores. This is in line with Hopper (2017) and Boyce & Wilkins (2017).

4.6 Artificial classroom lighting installation technology effect on Nairobi County public boarding secondary school students' academic performance

In this part, the researcher used a questionnaires to gather information from the respondents and carried out an experiment to determine the effect of artificial classroom lighting installation technology on student's academic performance. Through the questionnaire the researcher requested the students to rate the number of artificial classroom lighting points. The researcher compared the students' rating of their classroom lighting points with their individual end of term examination scores. The following was the analysis and interpretation.

Table 4.6.1 The effect of the number of lighting points on students' academic performance

	End of term mean score			
Number of lighting points		**SD**	**Variance**	**N**
12 lighting points	68.2500	5.50925	30.352	20
8 lighting points	60.7500	5.50925	30.352	250
6 lighting points	59.8000	7.64315	58.418	80
4 lighting points	52.8000	7.86104	61.796	50
2 lighting points	46.5517	3.45983	11.970	29

Table 4.6.1 shows that students who learned in a classroom with twelve (12) lighting points scored a mean of 68.25 in end of term examination, (8) lighting points scored a mean of 60.75 in end of term examination, six (6) lighting points scored a mean of 59.80 in end of term examination, four (4) lighting points scored a mean of 52.80 in end of term examination and two (2) lighting points scored a mean of 46.55 in end of term examination. The students who learned in a classroom with twelve (12) lighting points scored the highest mean score, followed with eight (8) lighting points, six (6) lighting points, four (4) lighting points, and two (2) lighting points respectively. This is in agreement with NAO (2019) and Mott *et al.* (2012).

4.6.2 Experiment Data Presentation, Analysis, Interpretation and Discussion

4.6.2.1 Introduction

To have control over other external factors and make a stronger claim that determined the causality of artificial classroom lighting installation technology on students' academic performance, the researcher carried out an experiment. In the experiment, the respondents were placed into two groups, the experiment group, and the control group. Both groups of students were examined (pre-test) before the treatment of the experimental group and after treatment of the experimental group. The researcher re-designed one classroom artificial lighting technology for the experiment group to meet the required artificial lighting installation technology standards and assessed its impact on students' academic performance. The students in the experiment group learned from an adequately designed artificial lighting classroom, while those in the control group learned in their normal

artificial lighting classroom. The experiment was conducte in a period of six months (two terms). The following hypothesis was tested.

H_{04}: There is no significant relationship between artificial classroom lighting technology and public boarding secondary schools the students academic performance.

This hypothesis was tested by conducting an experiment.

4.6.2.2 The experiment results

The data for the experiment were analyzed and the results are as recorded in appendix 33 and appendix 34.

In Appendix 33, the control group experiment shows that the mean score dropped by 9.98%, while Appendix 34 shows that the mean score increased by 8.67%. This indicated that adequate artificial classroom lighting improved students' test scores by ten percent (10%). Figure 4.12 below shows variations in illumination and students' academic performance.

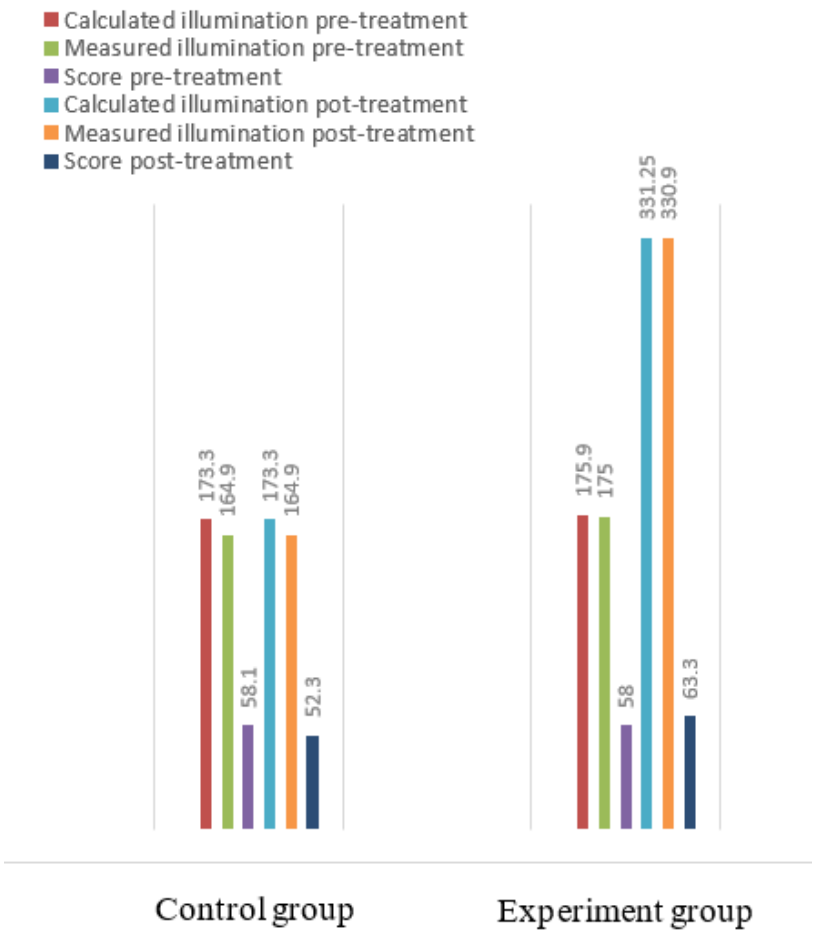


Figure 4.12 Control group versus Experiment group means

Figure 4.12 shows that the control group test means score dropped by approximately ten percent (10%) while the experiment group test means score increase by approximately eleven percent (11%). This indicates that insufficient artificial classroom negatively influences students' academic performance while sufficient artificial classroom lighting positive influences students' academic performance.

Table 4.6.2.2 Pearson's correlation coefficient results on the relationship between artificial classroom installation illumination and students' end of term examination scores

Variable	N	Mean	Std.	Minimum	Maximum	Possible	r
Illumination	20	3.06	1.35	28	363	240 - 500	0.275*
Test Scores	20	2.91	0.83	31	87	0 - 100	

*P < 0.001).

As a result in table 4.6.2.2. indicates, the Pearson Product Moment Correlation Statistical analysis resulted in a significant positive correlation, $r = 0.275$ ($p < 0.001$). This indicates that there was a positive significant relationship between students academic pefromance and artificial classroom lighting. This is in line with Mott *et al.* (2013) and Arora (2014).

From the experimental group results of illumination measurements, the researcher tested whether there was evidence of signs of improved quality of artificial classroom lighting. The claim was that there was no evidence of signs of the quality of artificial classroom lighting illumination that was observed against the expected checklist. At $\alpha = 0.90$, the claim was tested. The critical value was determined at the degree of freedom of $20 - 1 = 19$ and $\alpha = 0.90$ the critical value was 11.651 (Chi-square distribution table- Appendix 21).

Table 4.6.2.3 The Chi-Square source table of the results of the level of relationship between artificial classroom lighting installation illumination and students' academic performance

Station	df	Observed(O)	Expected(E)	O-E	$(() - E)^2$	$\frac{(O-E)^2}{E}$
1	1	321	330	-9	81	0.246
2	2	351	330	21	441	1.336
3	3	339	330	9	81	0.246
4	4	300	330	-30	900	2.727
5	5	337	330	7	49	0.149
6	6	359	330	29	841	2.47
7	7	321	330	-9	81	0.246
8	8	317	330	-13	169	0.512
9	9	319	330	-11	121	0.367
10	10	329	330	-1	1	0.003
11	11	350	330	20	400	1.212
12	12	339	330	9	81	0.246
13	13	334	330	4	16	0.049
14	14	311	330	-19	361	1.093
15	15	356	330	26	676	2.049
16	16	338	330	8	16	0.049
17	17	316	330	-14	196	0.593
18	19	310	330	-20	400	1.212
19	20	330	330	0	0	0
20	19	320	330	-10	100	0.303
Total		**6,597**				**12.489**

(Source: Author, 2019)

Decision: The decision rejected that claim since 12.489 > 11.651. From the test results, there was enough evidence to reject that claim that there is no significant relationship between artificial classroom lighting installation illumination and students' academic

performance. Therefore, there was a significant relationship between artificial classroom lighting installation illumination and students' academic performance. This is in agreement with Gilavanda *et al*. (2012).

Figure 4.13 shows the observed graph is very much below the expected. The gap between the two graphs shows how the results of the Chi-squares test for goodness-of-fit-test is not a good fit.

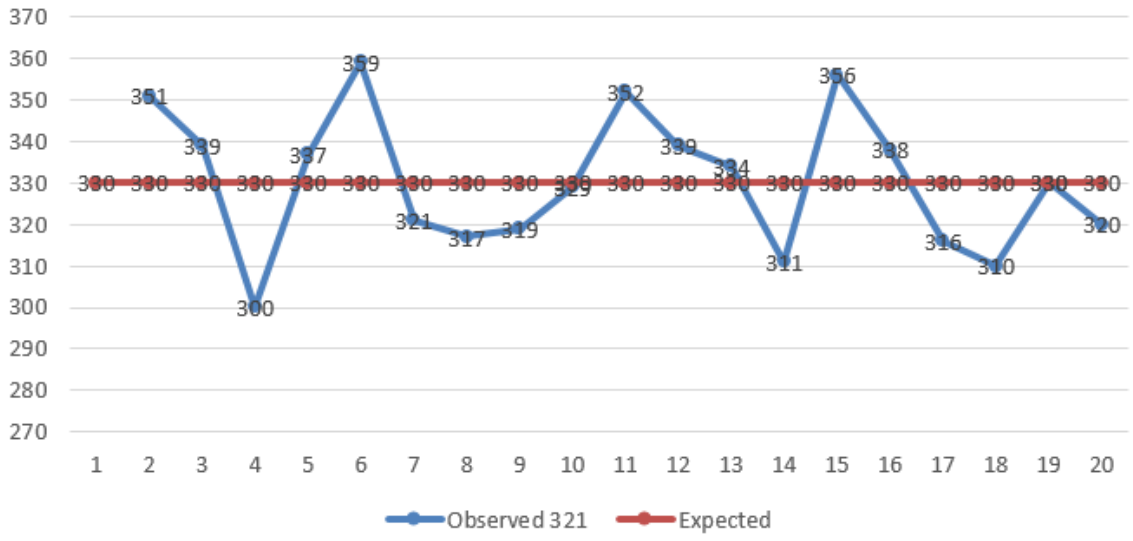


Figure 4.13: Results of the Goodness-of-fit for artificial classroom illumination

NOT GOOD FIT

4.7 Interview Schedules Data Presentation, Analysis, Interpretation and Discussion

From both the principals' and teachers' interview schedule it was found that;

1. The principals appeared not to be sure if artificial classroom lighting affected students' academic performance.
2. Most teachers were not aware of the technology of artificial classroom lighting installed in the classrooms.
3. Teachers said that when artificial classroom lighting was put on made some students not see clearly what was written on the chalk/whiteboard, projector screen, and computer screen.
4. The teachers recommended artificial classroom lighting to be installed in such a way that it can enable them to successfully use teaching aids in instruction.

4.8 Observation Data Presentation, Analysis, Interpretation and Discussion

From the observation checklist analysis, it was observed that in all public boarding secondary schools classrooms only T8 fluorescent lamp lighting fittings were installed directly on the ceiling surface without luminaries. Some classrooms had eight, some six, some four and some two lighting points. The illumination at students' desktop ranged between 60 lux to 230 lux during the day and 40 lux to 190 lux at the night which was not sufficient for a reading and learning space.

4.9 Documents Data Presentation, Analysis, Interpretation and Discussion

From the document analyze the researche found out that;

1. The government of Kenya, the Mnistry of Education Science and Technology and the Ministry of Infrastrucure and House lay down guidelines on artificial classroom lighting were outdated.
2. The developed world documents guidelines on artificial classroom lighting were current and offered some solutions to issues that affected the effect of artificial classroom lighting on students academic performance.

4.10 Summary

Nairobi County public boarding secondary schools students who learned using more lighting points posted higher mean scores in end of term examination as compare to those who learned using fewer lighting points. Artificial classroom lighting in Nairobi County public boarding secondary schools made students experience health problems like dry eyes, headache and visual impairment which made them to score below average in their end of term examinations; have difficulties in reading which made them attain low mean scores in their end of term examinations; and made it hard for teachers to instruct students which made students to score low means in the end of term examinations.

CHAPTER FIVE

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

5.0 Introduction

This chapter presents the findings of the research in the sequence of summary of findings, the effect of artificial classroom light installation technology on public boarding secondary schools students' academic performance, the effect of artificial classroom lighting on students' reading, instruction and health. Subsequently, the conclusions of the study, recommendations and suggestions for futher study.

5.1 Summary

This study sought to establish the effect of artificial classroom lighting on reading, instruction, health and students' academic performance. In all public boarding secondary school classrooms, only T8 fluorescent lamp lighting fittings were installed directly on the ceiling surface. Some classrooms had eight, some six, some four and some two lighting points. The illumination at students' desktop ranged between 60 lux to 230 lux during the day and 40 lux to 190 lux at the night which was not sufficient for a reading and learning space. The artificial classroom lighting negatively affected students' reading, instruction, health and academic performance in Nairobi County public boarding secondary school. It made the students skip words and lines when they read a text, made a buzzing noise which disturbed the students when they were reading, glared on the chalk/whiteboard making it hard for some students to read what the teacher wrote. It also caused reflection which made it impossible for the students to see clearly what was displayed on the projector and

computer screens. It made students feel sleepy when they were reading. It also made the students experience eye strain, eye itch, headache, develop visual impairment and their eyes to feel dry.

5.2.1 The effect of artificial classroom lighting technology on public boarding secondary schools students' academic performance

1. Artificial classroom lighting in Nairobi County public boarding secondary schools negatively affected students' academic performance.

2. The students who learned in a classroom with twelve (12) lighting points comparatively scored a higher mean score followed with eight (8) lighting points, six (6) lighting points, four (4) lighting points and two (2) lighting points respectively.

3. There was a significant positive relationship ($r = 0.275$ ($p < 0.05$)) between artificial classroom lighting and learners' academic performance.

5.2.2 The effect of artificial classroom lighting on students' reading which affects students' academic performance in Nairobi County public boarding secondary schools

1. Artificial classroom lighting in Nairobi County public boarding secondary schools had a negative effect on the learners' reading.

2. Some artificial classroom lighting in Nairobi County public boarding secondary schools flickered, made a buzzing noise that disturbed students the students when they were reading.

3. Artificial classroom lighting in Nairobi County public boarding secondary schools made students skip words or lines when they read in their classrooms.

4. Artificial classroom lighting in Nairobi County public boarding secondary schools made it difficult for the students to read clearly what was written on the chalk/whiteboard.

5. There was a positive significant relationship between artificial classroom lighting illumination and students' reading.

6. Students who complained of not being able to read letters on the chalk/whiteboard, fluorescent lamps disturbing buzzing noise and skipping of words or lines had low mean scores at the end of term examinations.

5.2.3 The effect of artificial classroom lighting on instruction which affects students' academic performance in Nairobi County public boarding secondary schools

1. Artificial classroom lighting in public boarding secondary schools in Nairobi County negatively affected instruction.

2. Artificial classroom lighting in public boarding secondary schools in Nairobi County made it hard for the students to see clearly diagrams on the classroom projector screen, letters displayed on the computer screen and what was written on the chalk/whiteboard.

3. All students who were affected by artificial classroom lighting effects on instruction scored below average at the end of term examination.

4. There was a significant relationship between artificial classroom lighting illumination and instruction.

5.2.4 The effect of artificial classroom lighting on students' health which affected students' academic performance in Nairobi Count public secondary schools

1. Artificial classroom lighting in Nairobi County caused students health problems such as eye strain, eye itching, visual impairment, headache, and dry eyes.

2. Artificial classroom lighting in public boarding secondary schools in Nairobi County made the learners experience eye strain, eyes itch, dry eye, headache and develop visual impairment.

3. There was a positive significant relationship between artificial classroom lighting and students' health in Nairobi County public boarding secondary schools.

4. All students who were affected by artificial classroom lighting effects on health scored very low means at the end of term examination indicating that health-related factors made the student score below average in their academic performance.

5.3 Findings

1. Nairobi County public boarding secondary schools students who learned using more lighting points posted higher mean scores in end of term examination as compare to those who learned using fewer lighting points.

2. Artificial classroom lighting in Nairobi County public boarding secondary schools made students experience health problems like dry eyes, headache and visual impairment which made them to score below average in their end of term examinations.

3. Artificial classroom lighting in Nairobi County public boarding secondary schools made students have difficulties in reading which made them attain low mean scores in their end of term examinations.

4. Artificial classroom lighting in Nairobi County public boarding secondary schools made it hard for teachers to instruct students which made students to score low means in the end of term examinations.

5.4 Conclusions

From the study findings, it was concluded that:

1. Artificial classroom lighting technologies installed in many public boarding secondary schools in Nairobi County were insufficient.

2. Artificial classroom lighting in Nairobi County public secondary schools negatively affected students' reading, instruction, health, and academic performance.

3. Artificial classroom lighting in Nairobi County public boarding secondary schools hampered instruction activities such as seeing clearing what was written on chalk/whiteboard, projections on the projector screen and display on the computer screen.

4. Artificial classroom lighting in public boarding secondary schools in Nairobi County of Kenya caused reflections or glare on the projector screen, computers display and the chalk/whiteboard which made it difficult for the students to see clearly what was displayed on the projector screen, displayed on computer screen and what was written on the chalk/whiteboard.

5. Artificial classroom lighting in Nairobi County public boarding secondary schools was not sufficient because it made students experience health problems such as eye strain, eye itching, visual impairment, headache, and dry eyes.

6. Increase in the number of lighting points in the classroom will increase illumination that will create a conducive learning environment that will motivate students to concentrate in learning and achieve high academic performance.

7. Reduced numbers of lighting points in the classroom will reduce illumination that will create undesirable learning conditions that will cause visual impairment, eye strain and other insufficient lighting health-related problems that will make it difficult for students to concentrate in learning and achieve high academic performance.

8. Artificial classroom illumination that ranges between 300 lux and 500 lux is sufficient and good enough for a teaching and learning space because it eliminates glare, flicker, and reflections which are the main undesirable characteristics of artificial classroom lighting.

5.5 Recommendations

This study, therefore, made the following recommendations:

1. The school management should install artificial classroom lighting of a white cool fluorescent lamp fitting with a high-efficiency control gear that provides dynamic and focused lighting in boys schools and warm white fluorescent lamp fitting with a high-efficiency control gear that provides dynamic and focused lighting in girls schools.

2. The government should enforce the installation of quality and standardized artificial classroom lighting in all public schools to help students have a conducive learning environment that will help them to attain high academic performance.

3. The government should make a policy document that will ensure the installation of T8 LED fluorescent lamb A of 300lux – 500 lux maintained illuminance, 80+ Ra colour rendering and 3,000 – 4,000 K colour temperature to reduce electric power consumption and provide the best illumination in the teaching and learning environment.

4. School management should install Pendant luminaires in secondary schools classroom lighting because they distribute light well in the learning environment.

5.6 Suggestions for Future Research

The current research assessed the effect of artificial classroom lighting on students' academic performance and found out that artificial classroom lighting in Nairobi County of Kenya was insufficient and negatively impacted on students' academic performance.

The study, therefore, recommends some future research that could address the limitations of this study.

1. A study should be done on the effects of artificial classroom lighting colour temperature and colour rendering index on secondary school student's academic performance.

2. A study should be done on factors such as artificial classroom lighting radiations and gases emission on students' academic achievement.

3. A study should be done on artificial classroom lighting installation special education needs.

4. Since the study was concentrated in Nairobi County public boarding secondary schools future researchers should consider widening the scope of the population in other schools and colleges that were not covered in this study.

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APPENDICIES

APPENDIX I DOCUMENT ANALYSIS FORM

No.	Adm. No.	Sex	School type	Name of school	End of term I score	End of term II score
1.						
2.						
3.						
4.						
5.						
6.						
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36.						
37.						
38.						
39.						
40.						
41.						

APPENDIX II USEFUL FORMULAS FOR EXPERIMENTAL STUDY

Candela $= {}^{1}/_{60^{\text{th}}}$ of the luminous intensity per cm^2 of black body radiation at the the temperature of solidification of platinum (2045^0k)

Total flux emitted by candle (cd) all-round is 4πX 1= 4π lumen.

$$I = {}^{L_i C_u I_{LF}}/_{A_i}$$

Where I = Illumination (lux, lumen/m^2).

L_i = Lumens per lamp (lumen)

C_u = Coefficient of utilization

L_{LF} = Light loss factor

Ai = Area per lamp (m^2).

Illumination can be calculated as (NOAO, 2019);

$$I = L_i C_u \, {}^{I_{LF}}/_{A_i}$$

Where:

I = Illumination (lux, lumen / m^2

L_i = lumens per lamp (lumen)

C_u = coefficient of utilization

L_{LF} = Light loss factor

A_i = Area per lamp

1 Lux = 1 lumen / square meters =0.0001 phot = 0.0929 foot candles (ftcd, fcd)

1 phot = 1 lumen / square centimeter = 10,000 lumens / square meter = 10,000 lux.

1 foot candle (ftcd, fcd) = 1 lumen / square foot = 10.752 lux.

Illuminance or illumination $E = \frac{\delta\varphi}{\delta A} = \frac{\varphi}{A}\, lm/_{m^2}$ or lux or meter-candle (mcd).

The luminance of the source element $L = \frac{\Delta I}{\Delta A Cos\varphi} = \frac{AI}{\Delta A'}\, cl/_{m^2}$

= area of source element projected onto a plane perpendicular to a specific direction.

$$E = \frac{I\ Cos\theta}{d^2}\, or\ \Delta E = \frac{\Delta I}{d^2} cos\theta$$

Where $d\omega = {\Delta A'}/_{d^2}\ steradian$

$$E = \int LCos\theta . d\omega = L \int Cos\theta . d\omega$$

APPENDIX III THE TARGET POPULATION

Item Description	**Target Population**
Principles	28
Teachers	1120
Nurses	28
Students	2015
Total	**3,191**

APPENDIX IV TARGET POPULATION OF PUBLIC BOARDING SECONDARY SCHOOLS IN NAIROBI COUNTY

No.	Sub County	Boys' Boarding Secondary School	Girls' Boarding Secondary School	Mixed Boarding Secondary School	Total
1.	Langata	0	0	0	0
2.	Kibra	0	0	0	0
3.	Dagoretti	3	3	0	6
4.	Embakasi	0	1	0	1
5.	Kamkunji	1	0	0	1
6.	Kasarani	0	1	0	1
7.	Starehe	1	1	0	2
8.	Mathare	0	0	0	0
9,	Njiru	1	0	3	4
10.	Makadara	2	2	0	4
11.	Westland	2	5	3	10
	Total	***10***	***13***	***5***	***28***
	Percentage (%)	**36 %**	**46 %**	**18 %**	**100 %**

Source: (Author, 2018)

APPENDIX V: THE SAMPLE DISTRIBUTION TABLE

Required Sample Size†

Population Size	Confidence = 95% Margin of Error				Confidence = 99% Margin of Error			
	5.0%	3.5%	2.5%	1.0%	5.0%	3.5%	2.5%	1.0%
10	10	10	10	10	10	10	10	10
20	19	20	20	20	19	20	20	20
30	28	29	29	30	29	29	30	30
50	44	47	48	50	47	48	49	50
75	63	69	72	74	67	71	73	75
100	80	89	94	99	87	93	96	99
150	108	126	137	148	122	135	142	149
200	132	160	177	196	154	174	186	198
250	152	190	215	244	182	211	229	246
300	169	217	251	291	207	246	270	295
400	196	265	318	384	250	309	348	391
500	217	306	377	475	285	365	421	485
600	234	340	432	565	315	416	490	579
700	248	370	481	653	341	462	554	672
800	260	396	526	739	363	503	615	763
1,000	278	440	606	906	399	575	727	943
1,200	291	474	674	1067	427	636	827	1119
1,500	306	515	759	1297	460	712	959	1376
2,000	322	563	869	1655	498	808	1141	1785
2,500	333	597	952	1984	524	879	1288	2173
3,500	346	641	1068	2565	558	977	1510	2890
5,000	357	678	1176	3288	586	1066	1734	3842
7,500	365	710	1275	4211	610	1147	1960	5165
10,000	370	727	1332	4899	622	1193	2098	6239
25,000	378	760	1448	6939	646	1285	2399	9972
50,000	381	772	1491	8056	655	1318	2520	12455
75,000	382	776	1506	8514	658	1330	2563	13583
100,000	383	778	1513	8762	659	1336	2585	14227
250,000	384	782	1527	9248	662	1347	2626	15555
500,000	384	783	1532	9423	663	1350	2640	16055
1,000,000	384	783	1534	9512	663	1352	2647	16317
2,500,000	384	784	1536	9567	663	1353	2651	16478
10,000,000	384	784	1536	9594	663	1354	2653	16560
100,000,000	384	784	1537	9603	663	1354	2654	16584
300,000,000	384	784	1537	9603	663	1354	2654	16586

Research Advisor (2006)

APPENDIX VI THE STUDY SAMPLE SIZE

Item Description	**Sample Size**
Principles	20
Teachers	200
Nurses	20
Students	435
Total	**675**

APPENDIX VII SELECTED SCHOOLS USING SYSTEMATIC AND RANDOM SAMPLING TECHNIQUES

Sub County	No.	School	Type	No.	Sample
Dagoretti	1.	Dagoretti High School	BBS	1.	Upper Hill School (BBS)
	2.	Upper Hill School	BBS	2.	Lenana High School (BBS)
	3.	Lenana High School	BBS	3.	Precious Blood School Riruta (GBS)
	4.	Moi Girls School Nairobi	GBS		
	5.	Precious Blood School Riruta	GBS		
	6.	Nembu Girls High School	GBS		
Embakasi	7.	Embakasi Girls Secondary School	GBS	4.	Embakasi Girls Secondary School (GBS)
Kamkunji	8.	Moi Forces Academy	BBS	5.	Moi Forces Academy (BBS)
Kasarani	9.	Starehe Girls School	GBS	6.	Starehe Girls School (GBS)
Starehe	10.	Pumwani Secondary School	BBS	7.	Pumwani Secondary School (BBS)
	11.	Ngal Girls High School	GBS	8.	Ngara Girls High School (GBS)
Njiru	12.	Muiruri Muchiri Boys High	BBS	9.	Muiruri Muchiri Boys High School
	13.	School	GBS	10.	(BBS)
	14.	Jehova Jire Secondary School	MBS	11.	Jehova Jire Secondary School (GBS)
	15.	Drumvale Secondary School	MBS		ST. George Athi Secondary School
		ST. George Athi Secondary School			(MBS)
Makadara	16.	Aquinas High School	BBS	12.	Aquinas High School (BBS)
	17.	Ofafa Jericho High School	BBS	13.	Buruburu Girls Secondary school
	18.	Buruburu Girls Secondary	GBS	14.	(GBS)
	19.	school	GBS		OLM Shauri Moyo Secondary School
		OLM Shauri Moyo Girls Secondary School			(GBS)
Westland	20.	Nairobi School	BBS	15.	Nairobi School (BBS)
	21.	Kangemi High School	BBS	16.	Kangemi High School (BBS)
	22.	Parkland Girls High School	GBS	17.	State House Girls High School (GBS)
	23.	State House Girls High School	GBS	18.	ST. Georges Girls Secondary School
	24.	SF, Georges Girls Secondary	GBS	19.	(GBS)
	25.	School	GBS	20.	Hospital Hill School (MBS)
	26.	Kenya High	MBS		Highridge Mixed Secondary School
	27.	Hospital Hill High School	MBS		(MBS)
	28.	Lavington Mixed Secondary School	MBS		
		Highridge Mixed Secondary School			

Source: (Field survey, 2018)

APPENDIX VIII SAMPLING FRAME

No.	Sub County	Boys' Boarding Secondary School	Girls' Boarding Secondary School	Mixed Boarding Secondary School	Total
1.	Langata	0	0	0	0
2.	Kibra	0	0	0	0
3.	Dagoretti	3	3	0	6
4.	Embakasi	0	1	0	1
5.	Kamkunji	1	0	0	1
6.	Kasarani	0	1	0	1
7.	Starehe	1	1	0	2
8.	Mathare	0	0	0	0
9.	Njiru	1	0	2	4
10.	Makadara	2	2	0	4
11.	Westland	2	5	3	10
	Total	**10**	**13**	**5**	**28**
	Proportion allocation of Schools	***8***	***9***	***3***	***20***

Source: (Field survey, 2018)

APPENDIX IX SAMPLE SIZE FOR THE STUDENTS WHO WILL PARTICIPATE IN THE STUDY

No.	Schools	Type	Classes	No. of students	Sample
1.	Lenana High School	BBS	Form 3	120	21
2.	Upper Hill	BBS	Form 3	122	22
3.	Precious Blood School Riruta	GBS	Form 3	118	25
4.	Embakasi Girls Secondary School	GBS	Form 3	80	29
5.	Moi Forces Academy	BBS	Form 3	120	21
6.	Starehe Girls School	GBS	Form 3	60	18
7.	Pumwani secondary School	BBS	Form 3	85	28
8.	Ngala Girls High School	GBS	Form 3	117	25
9.	Muiruri Muchiri Boys High School	BBS	Form 3	87	30
10.	Jehova Jire Secondary School	GBS	Form 3	65	11
11.	St. George Athi River Secondary School	MBS	Form 3	85	25
12.	Aquinas High School	BBS	Form 3	128	44
13.	Buruburu Girls Secondary School	GBS	Form 3	112	17
14.	OLM Shauri Moyo Secondary School	GBS	Form 3	58	9
15.	Nairobi School	BBS	Form 3	80	13
16.	Kangemi High School	BBS	Form 3	60	12
17.	State House Girls High School	GBS	Form 3	152	28
18.	SF Georges Girls Secondary School	GBS	Form 3	78	12
19.	Hospital Hill School	MBS	Form 3	73	11
20.	Highridge Mixed Secondary School	MBS	Form 3	65	10
Total				**2,015**	**435**

APPENDIX X: PERSONAL OBSERVATION CHECKLIST

Name of the school:……

Date:……

Below is a list of artificial classroom lighting infrastructure and activities that took place which is likely to affect students' academic performance.

No.	Observations	Available	Unavailable	Yes	No	RMKS
1.	Only fluorescent lamps installed					
2.	T8 fluorescent lamps available					
3.	T5 Fluorescent lamps available					
4.	Luminaries					
5.	Pendant					
6.	Recessed					
7.	Students concentrating when reading					
8.	Only bulbs lighting installed					
9.	Lighting installed on to of chalk/whiteboard					
10.	LEDs installed in the classroom					
11.	Recessed luminaires installed in the classroom					
12.	Pendant luminaires installed in the classroom					
13.	Light fitting installed flat on the ceiling room					
14.	12 lighting points installed					
15.	8 lighting points installed					
16.	6 lighting points installed					
17.	4 lighting points installed					
18.	2 lighting points installed					
19.	Glare on the chalk/whiteboard					
20.	Glare on the white paper of reading task area					
21.	Students desktop illumination (lux) during the day (12:00) noon					
22.	Students desktop illumination (lux) during night preps (8:00 pm)					

APPENDIX XI EXPERIMENT SEQUENCE

Group	Pre-test	Treatment	Post-test
Experimental group	X	X	X
Control group	X		X

APPENDIX XII: EXPERIMENT GROUP AND CONTROL GROUP SAMPLES

GROUP	SAMPLE
Experimental	20
Control	20
Total	40

APPENDIX XIII CONTROL GROUP ILLUMINATION MEASUREMENTS AND STUDENTS END OF TERM EXAMINATION SCORES

The control group light illumination (lux)

	TERM I			TERM II		
Student	**Calculated Illumination(lux) Pre-treatment**	**Measured Illumination(lux) Pre-treatment**	**End of term examination Score Pre-treatment**	**Calculated Illumination(lux) Post-treatment**	**Measured Illumination(lux) Post-treatment**	**End of term examination Score Post-treatment**
X1	148	150	61	148	150	52
X2	118	120	68	118	120	57
X3	138	140	57	138	140	45
X4	147	145	59	147	145	49
X5	159	161	47	159	161	58
X6	118	122	51	118	122	53
X7	98	100	59	18198	100	54
X8	208	210	55	208	210	59
X9	243	247	58	243	247	63
X10	118	121	52	118	121	60
X11	221	223	56	221	223	40
X12	302	300	60	302	300	51
X13	179	181	62	179	181	62
X14	158	156	57	158	156	60
X15	222	220	64	222	220	52
X16	151	152	42	151	152	57
X17	179	181	51	179	181	58
X18	222	28	76	222	28	59
X19	158	160	65	158	160	57
X20	179	181	62	179	181	62
AVG.	**173..3**	**164.9**	**58.1**	**173.3**	**164.9**	**52.3**

(Source: Author, 2019)

APPENDIX XIV EXPERIMENTAL GROUP ILLUMINATION MEASUREMENTS VERSUS STUDENTS END OF TERM SCORES

The experimental group illumination (lux)

	TERM I			TERM II		
Student	Calculated Illumination(lux) Pre-treatment	Measured Illumination(lux) Pre-treatment	End of term examination Score Pre-treatment	Calculated Illumination(lux) Post-treatment	Measured Illumination(lux) Post-treatment	End of term examination Score Post-treatment
X1	179	180	63	327	321	65
X2	151	150	57	355	351	74
X3	222	200	65	342	339	80
X4	158	160	42	295	300	60
X5	179	180	51	336	337	76
X6	302	300	76	361	359	75
X7	221	220	65	318	321	68
X8	118	120	61	344	347	83
X9	242	240	69	317	319	59
X10	208	210	57	328	329	76
X11	98	100	59	355	350	80
X12	118	120	47	342	339	65
X13	159	160	51	332	334	68
X14	218	210	60	309	311	56
X15	147	150	55	351	356	70
X16	138	140	58	343	338	58
X17	176	180	52	318	316	56
X18	118	120	57	315	310	78
X19	148	150	60	328	330	69
X20	218	210	60	309	311	70
AVG.	**175.9**	**175**	**58.25**	**331.25**	**330.9**	**68.25**

(Source: Author, 2019)

APPENDIX XV: CHI-SQUARE DISTRIBUTION TABLE

df	$\chi^2_{.995}$	$\chi^2_{.990}$	$\chi^2_{.975}$	$\chi^2_{.960}$	$\chi^2_{.900}$	$\chi^2_{.100}$	$\chi^2_{.050}$	$\chi^2_{.025}$	$\chi^2_{.010}$	$\chi^2_{.005}$
1	0.000	0.000	0.001	0.004	0.016	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	9.236	11.070	12.833	15.086	16.750
6	0.676	0.872	1.237	1.635	2.204	10.645	12.592	14.449	16.812	18.548
7	0.989	1.239	1.690	2.167	2.833	12.017	14.067	16.013	18.475	20.278
8	1.344	1.646	2.180	2.733	3.490	13.362	15.507	17.535	20.090	21.955
9	1.735	2.088	2.700	3.325	4.168	14.684	16.919	19.023	21.666	23.589
10	2.156	2.558	3.247	3.940	4.865	15.987	18.307	20.483	23.209	25.188
11	2.603	3.053	3.816	4.575	5.578	17.275	19.675	21.920	24.725	26.757
12	3.074	3.571	4.404	5.226	6.304	18.549	21.026	23.337	26.217	28.300
13	3.565	4.107	5.009	5.892	7.042	19.812	22.362	24.736	27.688	29.819
14	4.075	4.660	5.629	6.571	7.790	21.064	23.685	26.119	29.141	31.319
15	4.601	5.229	6.262	7.261	8.547	22.307	24.996	27.488	30.578	32.801
16	5.142	5.812	6.908	7.962	9.312	23.542	26.296	28.845	32.000	34.267
17	5.697	6.408	7.564	8.672	10.085	24.769	27.587	30.191	33.409	35.718
18	6.265	7.015	8.231	9.390	10.865	25.989	28.869	31.526	34.805	37.156
19	6.844	7.633	8.907	10.117	11.651	27.204	30.144	32.852	36.191	38.582
20	7.434	8.260	9.591	10.851	12.443	28.412	31.410	34.170	37.566	39.997
21	8.034	8.897	10.283	11.591	13.240	29.615	32.671	35.479	38.932	41.401
22	8.643	9.542	10.982	12.338	14.041	30.813	33.924	36.781	40.289	42.796
23	9.260	10.196	11.689	13.091	14.848	32.007	35.172	38.076	41.638	44.181
24	9.886	10.856	12.401	13.848	15.659	33.196	36.415	39.364	42.980	45.559
25	10.520	11.524	13.120	14.611	16.473	34.382	37.652	40.646	44.314	46.928
26	11.160	12.198	13.844	15.379	17.292	35.563	38.885	41.923	45.642	48.290
27	11.808	12.879	14.573	16.151	18.114	36.741	40.113	43.195	46.963	49.645
28	12.461	13.565	15.308	16.928	18.939	37.916	41.337	44.461	48.278	50.993
29	13.121	14.256	16.047	17.708	19.768	39.087	42.557	45.722	49.588	52.336
30	13.787	14.953	16.791	18.493	20.599	40.256	43.773	46.979	50.892	53.672
40	20.707	22.164	24.433	26.509	29.051	51.805	55.758	59.342	63.691	66.766
50	27.991	29.707	32.357	34.764	37.689	63.167	67.505	71.420	76.154	79.490
60	35.534	37.485	40.482	43.188	46.459	74.397	79.082	83.298	88.379	91.952
70	43.275	45.442	48.758	51.739	55.329	85.527	90.531	95.023	100.425	104.215
80	51.172	53.540	57.153	60.391	64.278	96.578	101.879	106.629	112.329	116.321
90	59.196	61.754	65.647	69.126	73.291	107.565	113.145	118.136	124.116	128.299
100	67.328	70.065	74.222	77.929	82.358	118.498	124.342	129.561	135.807	140.169

APPENDIX XVI: QUESTIONNAIRE FOR SECONDARY SCHOOL STUDENTS

School: _____

Student Admission No.: _____

May, 2018.

Dear Student,

The researcher is a Doctor of Philosophy (PhD) student. He is conducting a research on "artificial lighting in the classrooms in Kenya secondary schools." The researcher is kindly requesting you to participate in this study by answering all questions that focus on the following areas: your school's background information, artificial lighting technologies in your school classrooms, classroom artificial lighting effects on you as students, The influence of the artificial lighting on the your concentration and academic performance, and the degree of comfort as you use the classroom artificial lighting. You will need around 40 minutes to complete all the questions. There are NO right or wrong answers. Please do this on your own and answer honestly, just indicating whatever you think is right. Your participation is very important in this study. Your opinion will help in determining whether there is a need to improve the classroom artificial lighting in your school to facilitate your concentration and improve academic performance in your school.

All the information and answers you give will be treated confidentially. Please do not write your name. You will not be identified or mentioned in any report. I appreciate your help in giving your opinion about the questions below so that the results of this study can be useful to schools, families, communities, planners and government policymakers.

Thank you very much for your help.

SECTION A: BACKGROUND INFORMATION

Sex: □1 Male □2 Female

Type of school accommodation: □1 Boys Boarding School □2 Girls Boarding School

□3 Mixed Boarding School

School classification: □1 Sub-county school □2 County school

□3 Extra County school □4 National school

Sponsorship: □1 Government □2 Church

□3 Company □4 Sole proprietor

Do you put on spectacles so as to see well or read well? □1 Yes □2 No

If yes, at what time did you first start using spectacles? □1 Before joining form one □2 Form One

□3 Form Two □4 Form three

What is the size of your classroom windows? □1 Very small □2 Small

□3 Medium □4 Large □5 Extra large

SECTION B: INFORMATION RELATED TO CLASSROOM ARTIFICIAL LIGHTING TECHNOLOGY

INSTRUCTIONS:

On this questionnaire, please indicate your level of agreement with each of the statements below by circling the appropriate number.

KEY

1 = Yes
2 = No

Example: If my answer is No, then I show this by circling 2 representing “No”

QUESTION-X. At this school—	YES	NO
Our school classroom is lit using light-emitting diodes	1	(2)

No.	STATEMENT	YES	NO
	Lighting Installation		
1.	Light distribution in our classroom is appropriately and uniformly spread	1	2
2.	Only fluorescent lamps are installed in our classroom	1	2
3.	Only bulbs are installed in our classroom	1	2
4.	Only Light Emitting Diodes are installed in our classroom	1	2
5.	A mixture of fluorescent lamps and Light-emitting diodes are installed in our classroom	1	2
6.	A mixture of bulbs and Light-emitting diodes are installed in our classroom	1	2
7.	A mixture of fluorescent lamps, bulbs, and light-emitting diodes are installed in our classroom	1	2
8.	A mixture of fluorescent lamps and bulbs are installed in our classroom	1	2
	Nature of light		
9.	The lighting in our classroom is bright white	1	2
10.	The lighting in our classroom is bright red	1	2
11.	Some sections of the class are slightly darker than the others	1	2
12.	Light in this classroom sometimes flickers (goes on and off rapidly)	1	2
13.	Flickering of lights makes me uncomfortable when I read in this classroom	1	2
14.	The lighting in our classroom have reflectors	1	2
15.	I sit directly in a window	1	2
16	The windows in our classroom allow enough natural light into the classroom	1	2
	Lighting Technology		
16.	The lights in our classroom are installed right on the surface of the ceiling	1	2
17.	The lights in our classroom are installed right on the surface of timber traces	1	2
18.	The lights in our classroom are installed in the depression made on the classroom ceiling	1	2
19.	Light luminaries are installed in the classroom	1	2
20.	There is only one lighting point in our classroom	1	2
21.	There are two lighting points in our classroom	1	2
22.	There are three lighting points in our classroom	1	2
23.	There are four lighting points in our classroom	1	2
24.	There are five lighting points in our classroom	1	2
25.	There are six lighting points in our classroom	1	2

26.	There are eight lighting points in our classroom	1	2
27.	There is light installed on top of the teachers writing board	1	2
28.	Fluorescent lighting in this classroom makes buzzing noise which is disturbing when I read in this classroom.	1	2

KEY

1 = Yes
2 = No

Example: If my answer is No, then I show this by circling 2 representing "No"

QUESTION-X. At this school—	YES	NO
Our school classroom is lit using light-emitting diodes	1	(2)

No.	STATEMENT	YES	NO
22.	Do you have a visual impairment	1	2
23.	Some of the lighting points do not come on	1	2
24.	Lighting intensity in this classroom can be increased or decreased by use of a switch	1	2
25.	The lighting in this class can dim or brighten automatically	1	2
26.	I like the light in this classroom	1	2
27.	Light is uniformly distributed in this classroom at night	1	2
28.	I prefer reading in sunlight as compared to electricity light	1	2
29.	I prefer reading in electric lighting as compared to sunlight	1	2

SECTION C: ARTIFICIAL CLASSROOM LIGHTING COMFORT

INSTRUCTIONS:

On this questionnaire, I need your opinion about whatever you know, think or feel about your classroom artificial lighting. Please indicate your level of agreement with each of the statements below by circling the appropriate number.

KEY

1 = Strongly Disagree
2 = Disagree
3 = Agree
4=Strongly Agree

Example:

Example: If I tend to disagree with the following statement, then I show this by circling 2 representing 'Tend to Disagree'

QUESTION-X. At this school—	Disagree	Tend to Disagree	Tend to agree	Agree
Alternative sources of electricity are not necessary	1	(2)	3	4

No.	STATEMENT	Disagree	Tend to disagree	Tend to agree	Agree
	Health				
1.	At night the colour of light in this classroom is not desirable to my eyes	1	2	3	4
2.	I experience a headache when I read using the lighting in this classroom	1	2	3	4
3.	Studying in our classroom during night preps makes me have a sense of wellbeing	1	2	3	4
4.	I visit the hospital often because of eye problems	1	2	3	4
5.	My eyes feel dry when I read in this classroom lighting	1	2	3	4
6.	The light in our classroom makes my eyes behave abnormally at night	1	2	3	4
7.	I feel eye strain when I read in this classroom electric lights at night	1	2	3	4
8.	I feel eyes strain when I read in this classroom lighting	1	2	3	4
9.	I put spectacles in order to see what I read	1	2	3	4
	Lighting quality				
10.	The classroom ceiling is adequately brightened by the electric lighting of this classroom at night	1	2	3	4
11.	The electric light in our classroom is bright	1	2	3	4
12.	Other students give me good attention when I ask them anything when we study in our classroom at night.	1	2	3	4
13.	The lighting in this classroom is not enough for my eyes for reading at night	1	2	3	4
14.	My eyes itch when I read using our classroom artificial lighting at night	1	2	3	4
	Instruction				
15.	My eyes cannot see what the projector displays on the screen when the classroom electric light is on	1	2	3	4
16.	It is not possible to see small writings on the board in this classroom when electric lights are on	1	2	3	4
17.	I find it difficult to read letters on a computer screen in this classroom when electric lights are on	1	2	3	4
18.	I have problems in see what is written on the board even when electric lights are switched on	1	2	3	4
19.	The light in our classroom makes my eyes not to able to see clearly at night	1	2	3	4
20.	I have difficulties in seeing objects on the screen of this classroom when electric lights are on	1	2	3	4
	Reading				
21.	Sometimes I skip a line when I read in our classroom in the evening preps	1	2	3	4
22.	Sometimes I skip some words when I read in our classroom in the evening preps	1	2	3	4
23.	I am motivated to read using our classroom artificial lighting	1	2	3	4
24.	I remain alert when I read using our classroom artificial lighting	1	2	3	4
25.	I prefer reading in a room with some blue color lighting	1	2	3	4
26.	I prefer reading in a room with red color lighting	1	2	3	4
27.	I prefer reading in a room with yellow color lighting	1	2	3	4

APPENDIX XVII: TEACHERS' QUESTIONNAIRE

School:
……

May 2018.

Dear Teacher,

The researcher is a Doctor of Philosophy student. He is conducting research on "artificial lighting in the classrooms in Kenya secondary schools." The researcher is kindly requesting you to participate in this study by answering all questions that focus on the following areas: your school's background information, artificial lighting in your school classrooms, classroom artificial lighting effects on students, The influence of the artificial lighting on the students' concentration and academic performance, and the students' level of comfort as they use the classroom artificial lighting. You will need around 40 minutes to complete all the questions. There are NO right or wrong answers. Please do this on your own and answer honestly, just indicating whatever you think is right. Your participation is very important in this study. Your opinion will help in determining whether there is a need to improve the classroom artificial lighting in your school to facilitate the students' concentration and improve academic performance in your school.

All the information and answers you give will be treated confidentially. Please do not write your name. You will not be identified or mentioned in any report. I appreciate your help in giving your opinion about the questions below so that the results of this study can be useful to schools, families, communities, planners and government policymakers.

Thank you very much for your help.

SECTION A: BACKGROUND INFORMATION

Sex:	□1 Male	□2 Female
Academic qualification:	□1 Diploma	□2 Bachelor's degree
	□3 Master's degree	□4 PhD
Type of school:	□1 Boys boarding school	□2 Girls boarding school
	□3 Mixed boarding school	
School classification:	□1 Sub-county school	□2 County school
	□3 Extra County school	□4 National school
Sponsorship:	□1 Government	□2 Church
	□3 Company	□4 Sole proprietor

SECTION B: INFORMATION RELATED TO CLASSROOM ARTIFICIAL LIGHTING TECHNOLOGY

INSTRUCTIONS:

On this questionnaire, I need your opinion about whatever you know, think or feel about your classroom artificial lighting. Please indicate your level of agreement with each of the statements below by circling the appropriate number.

KEY

1 = Strongly Disagree
2 = Disagree
3 = Agree
4=Strongly Agree

Example: If I tend to disagree with the following statement, then I show this by circling 2 representing

'Tend to Disagree'.

QUESTION-X. At this school—	Disagree	Tend to Disagree	Tend to agree	Agree
Alternative sources of electricity are not necessary	1	(2)	3	4

No.	STATEMENT	Disagree	Tend to disagree	Tend to agree	Agree
	Instruction				
1.	The lighting in the classroom is sufficient for the learners	1	2	3	4
2.	The students strain to see what is written on the classroom board	1	2	3	4
3.	The students have a problem to see clearly what is projected on the screen with a projector	1	2	3	4
4.	Some students keep on fidgeting when they are learning	1	2	3	4
5.	Some students look sleepy when learning	1	2	3	4
6.	The light in this classroom is comfortable for teaching	1	2	3	4
7.	The electric lighting in the classroom makes the student have physical comfort	1	2	3	4
8.	Students give me good attention when I teach them				
	Health	1	2	3	4
9.	Students visit the hospital often because of eye problems	1	2	3	4
10.	I put spectacles in order to see what I read	1	2	3	4
11.	Some students have tears flowing from their eyes when they are not crying	1	2	3	4
12.	Some students complain of eye aches	1	2	3	4
13.	Some students eyes look red or bloodshot	1	2	3	4
14.	Some students have some unusual emissions from their eyes when they visit the school dispensary	1	2	3	4
15.	Students visiting the dispensary with eye problems have watery eyes.	1	2	3	4
	Reading				
16.	The lighting in this classroom is not enough for reading at night	1	2	3	4
18.	The light in this classroom is comfortable for reading				
19.	Some students put on spectacles in order to see what they read	1	2	3	4
20.	Some students cannot see or read what the projector displays on the screen when the classroom electric light is on.	1	2	3	4
21.	Some students find it difficult to read letters on a computer screen in this classroom when electric lights are on.	1	2	3	4
	Academic performance				
22.	Students who put on spectacles normally register a low academic performance.	1	2	3	4
23.	Students who skip lines when the read normally register low academic performance.	1	2	3	4
24.	A student who registers a lot of absences because of eye problems normally registers a low academic performance.	1	2	3	4
25.	A student who finds difficult to see what is written on the board normally registers low academic performance.	1	2	3	4
26.	Students who study in the classroom with electric light which is not enough normally register low academic performance.	1	2	3	4

APPENDIX XVIII: SCHOOL NURSE QUESTIONNAIRE

School: _____

May 2018.

Dear Nurse / Clinical Office / Doctor,

The researcher is a Doctor of Philosophy student. He is conducting research on "artificial lighting in the classrooms in Kenya secondary schools." The researcher is kindly requesting you to participate in this study by answering all questions that focus on the following areas: the school's background information, artificial lighting in the school classrooms, classroom artificial lighting effects on students, The influence of the artificial lighting on the students' concentration and academic performance, and the students' level of comfort as they use the classroom artificial lighting. You will need around 40 minutes to complete all the questions. There are NO right or wrong answers. Please do this on your own and answer honestly, just indicating whatever you think is right. Your participation is very important in this study. Your opinion will help in determining whether there is a need to improve the classroom artificial lighting in your school to facilitate the students' concentration and improve academic performance in your school.

All the information and answers you give will be treated confidentially. Please do not write your name. You will not be identified or mentioned in any report. I appreciate your help in giving your opinion about the questions below so that the results of this study can be useful to schools, families, communities, planners and government policymakers.

Thank you very much for your help.

SECTION A: BACKGROUND INFORMATION

Sex:	□1 Male	□2 Female
Academic qualification:	□1 Certificate	□2 Diploma
	□3 Bachelor's degree	□4 Master's degree
Type of school:	□1 Boys boarding school	□2 Girls boarding school
	□3 Mixed boarding school	
School classification:	□1 Sub-county school	□2 County school
	□3 Extra County school	□4 National school
Sponsorship:	□1 Government	□2 Church
	□3 Company	□4 Sole proprietor

SECTION B: INFORMATION RELATED TO CLASSROOM ARTIFICIAL LIGHTING TECHNOLOGY

INSTRUCTIONS:

On this questionnaire, I need your opinion about whatever you know, think or feel about your classroom artificial lighting. Please indicate your level of agreement with each of the statements below by circling the appropriate number.

KEY

1 = Strongly Disagree
2 = Disagree
3 = Agree
4=Strongly Agree

Example:

Example: If I tend to disagree with the following statement, then I show this by circling 2 representing

'Tend to Disagree'.

QUESTION-X. At this school—	Disagree	Tend to Disagree	Tend to agree	Agree
Alternative sources of electricity are not necessary	1	(2)	3	4

No.	STATEMENT	Disagree	Tend to disagree	Tend to agree	Agree
	Health				
1.	There is a problem with artificial lighting in classrooms in this school.	1	2	3	4
2.	The students report that they strain to see what is written on the classroom board	1	2	3	4
3.	The students complain that they have a problem to see clearly what is projected on the screen with a projector	1	2	3	4
4.	Some students complain of eye aches	1	2	3	4
5.	Some students eyes look red or bloodshot	1	2	3	4
6.	Some students have tears flowing from their eyes even when they are not crying	1	2	3	4
7.	Some students put on spectacles in order to see what they read	1	2	3	4
8.	Some students have some unusual emissions from their eyes as they seek treatment at the school dispensary	1	2	3	4
9.	Some students have been diagnosed with a musculoskeletal disorder	1	2	3	4
10.	The students complain that electric light in their classroom is too bright.	1	2	3	4
11.	The students complain that the lighting in their classroom is not enough for their my eyes for reading at night	1	2	3	4
12.	Students report that they find it difficult to read letters on a computer screen in their classroom when electric lights are on	1	2	3	4
13.	Some students complain of eye pain that may be mild to very severe.	1	2	3	4
14.	Some students report being sensitive to light.	1	2	3	4
15.	Students visiting the dispensary with eye problems have watery eyes.	1	2	3	4
16.	Some students report having blurred vision.	1	2	3	4

APPENDIX XIX: SCHOOL PRINCIPALS INTERVIEW SCHEDULE

Guiding questions

1. What lighting technologies are installed in your school classrooms?
2. What problem do learners experience when they read and learn using the artificial lights installed in the classrooms?
3. What is kind of lighting technologies do you recommend to be installed in the classrooms?
4. What do you think can be done to improve the artificial classroom lightings in your institutions?
5. What drawbacks or hindrances do you know that affect the installation of appropriate lighting technologies in your institution's classrooms?
6. What are your plans for the future installation of artificial classroom lighting technologies?
7. What advice would you give concerning the installation of artificial lighting in your institution's classrooms?
8. Do you think that inadequate artificial classroom lighting can influence learners' academic performance negatively?

APPENDIX XX: TEACHERS INTERVIEW SCHEDULE

Guiding questions

1. What lighting technologies are installed in classrooms?
2. What problem do learners experience when they read and learn using the artificial lights installed in the classrooms?
3. What is kind of lighting technologies do you recommend to be installed in the classrooms?
4. What do you think can be done to improve the artificial classroom lightings in your institutions?
5. What drawbacks or hindrances do you know that affect the installation of appropriate lighting technologies in your institution's classrooms?
6. What do you suggest to be done in the future installation of artificial classroom lighting technologies?
7. What advice would you give concerning the installation of artificial lighting in your institution's classrooms?
8. Is it likely that an inadequate artificial classroom is likely to negatively influence learners' academic performance?

APPENDIX XXI: PUBLIC SECONDARY SCHOOLS IN NAIROBI COUNTY

1. 20401001 AQUINAS HIGH SCHOOL – Boys Boarding

2. 20401002 HIGHWAY SECONDARY SCHOOL – Boys Day

3. 20401003 HURUMA GIRLS' HIGH SCHOOL – Girls Day & Boarding

4. 20401004 OUR LADY OF MERCY SECONDARY SCHOOL SOUTH B-Girls Day

5. 20401005 OFAFA JERICHO HIGH SCHOOL – Boys Boarding

6. 20401006 NILE ROAD SECONDARY – Girls Day

7. 20401008 ST. TERESA'S BOYS SECONDARY SCHOOL – Boys Day

8. 20401008 MAKONGENI SECONDARY SCHOOL – Mixed Day

9. 20401081 RUARAKA HIGH SCHOOL – Mixed Day

10. 20401084 BURUBURU GIRLS SECONDARY SCHOOL – Girls Boarding

11. 20401088 OUR LADY OF FATIMA SECONDARY SCHOOL – Mixed Day

12. 20401233 BABA DOGO SECONDARY SCHOOL – Mixed Day

13. 20401258 C.G.H.U SECONDARY SCHOOL – Mixed Day

14. 20402001 EASTLEIGH HIGH SCHOOL – Boys Day

15. 20402003 MAINA WANJIGI SECONDARY SCHOOL – Mixed Day

16. 20402004 UHURU SECONDARY SCHOOL – Boys Day

17. 20402005 KAMUKUNJI SECONDARY SCHOOL – Mixed Day

18. 20402006 O.L.M SHAURI MOYO GIRLS SEC. SCHOOL – Girls Boarding

19. 20403001 JAMHURI HIGH SCHOOL – Boys Day

20. 20403002 PARKLANDS SECONDARY SCHOOL – Boys Day

21. 20403003 PUMWANI SECONDARY SCHOOL – Boys Boarding

22. 20403004 NGARA GIRLS' HIGH SCHOOL – Girls Boarding

23. 20403005 ST TERESA'S GIRLS SECONDARY SCHOOL – Girls Day

24. 20403019 NDURURUNO SECONDARY SCHOOL – Mixed Day

25. 20403024 MURANG'A ROAD MIXED DAY SECONDARY SCHOOL – Mixed Day
26. 20403026 PUMWANI GIRLS SECONDARY SCHOOL – Girls Day
27. 20404001 LANG'ATA HIGH SCHOOL – Mixed Day
28. 20404022 KAREN ' C ' SECONDARY SCHOOL. – Mixed Day
29. 20404024 OLYMPIC HIGH SCHOOL – Mixed Day
30. 20404025 RAILA EDUCATIONAL CENTRE – Mixed Day
31. 20405001 DAGORETTI HIGH SCHOOL – Boys Boarding
32. 20405002 UPPER HILL SCHOOL – Boys Boarding
33. 20405003 MOI GIRLS' SCHOOL NAIROBI – Girls Boarding
34. 20405004 PRECIOUS BLOOD RIRUTA – Girls Boarding
35. 20405005 MUTUINI HIGH SCHOOL – Boys Day
36. 20405006 RUTHIMITU SECONDARY SCHOOL – Mixed Day
37. 20405007 NEMBU GIRLS HIGH SCHOOL – Girls Boarding
38. 20405008 RUTHIMITU GIRLS SEC SCHOOL – Girls Day
39. 20405009 DAGORETTI MIXED SEC SCHOOL – Mixed Day
40. 20406001 PARKLANDS ARYA GIRLS HIGH SCHOOL – Girls Boarding
41. 20406002 STATEHOUSE GIRLS H. SCH – Girls Boarding
42. 20406007 KANGEMI HIGH SCHOOL – Boys Boarding
43. 20406009 HOSPITAL HILL HIGH SCHOOL – Mixed Boarding
44. 20406011 ST. GEORGE'S GIRLS' SECONDARY SCHOOL – Girls Boarding
45. 20406012 NAIROBI MILIMANI SECONDARY SCHOOL – Boys Day
46. 20406018 LAVINGTON MIXED SECONDARY SCHOOL – Mixed Boarding
47. 20406019 HIGH RIDGE MIXED SECONDARY SCHOOL – Mixed Boarding
48. 20407002 KAHAWA GARRISON SECONDARY SCHOOL – Mixed Day
49. 20407004 KAMITI SECONDARY SCHOOL – Mixed Day
50. 20408001 KAYOLE SECONDARY SCHOOL – Mixed Day

51. 20408007 EMBAKASI GIRLS SECONDARY SCHOOL – Girls Boarding

52. 20408014 PETER KIBUKOSYA SECONDARY SCHOOL – Mixed Day

53. 20408015 KAYOLE SOUTH SECONDARY SCHOOL – Mixed Day

54. 20409001 DANDORA SECONDARY SCHOOL – Mixed Day

55. 20409002 MUHURI MUCHIRI BOYS HIGH SCHOOL – Boys Boarding

56. 20409003 HON. DR. MWENJE SECONDARY SCHOOL – Mixed Day

57. 20409004 USHIRIKA SECONDARY SCHOOL – Mixed Day

58. 20409005 JEHOVA JIRE SECONDARY SCHOOL – Mixed Boarding

59. 20409006 DRUMVALE SECONDARY SCHOOL – Mixed Boarding

60. 20409007 ST. GEORGE ATHI SECONDARY SCHOOL – Mixed Boarding

APPENDIX XXII: LIGHTING REQUIREMENTS FOR SCHOOL AREAS

Area	Maintained illuminance (lux)	Colour rendering (Ra)	Colour temperature (K)	Recommended lamp
General classrooms/Teaching spaces	300	80+	3,000 – 4,000	A
Computer rooms	300	80	3,500 – 4,000	A
Specialist subject rooms	500	80+	3,000 – 4,000	A
Book shelves/Library areas	300	80	3,500 – 4,000	A
Gen. purpose/Assembly hall	300	80	3,500 – 4,000	A
Sports halls	400[1]	80	3,500 – 4,000	A
Corridors/Stairs/Circulation areas/Waiting rooms	120[2]	80	3,500 – 4,000	A B

(Energy Focus, 2015)

APPENDIX XXIII: LAMP COMPARISON CHART

The best light sources for schools are highlighted in green in the table below.

Lamp type	Efficacy (lumens per watt)	Colour rendering (Ra)	Colour temperature (K)	Lamp life (Hours)
Daylight		100	5,500 – 8,500	
Tungsten Mains Voltage	12	100	2,600 – 2,700	1,000 – 2,000
Tungsten Halogen Mains Voltage	18	100	3,000	2,000 – 8,000
Compact Fluorescent	45 - 60	85	2,700 – 4,000	8,000+
T8 (26mm dia.) Halophosphor Fluorescent Tubes	37 - 68	58	2,700 – 4,000	6,000+
T8 (26mm dia.) Triphosphor Fluorescent Tubes	71 - 92	80±	2,700 – 6,000	20,000 – 60,000
T5 (16mm dia.) High Efficiency Fluorescent Tubes	66 - 82	80±	2,700 – 6,500	20,000
T5 (16mm dia.) High Output Fluorescent Tubes	62 - 76	80±	2,700 – 6,500	20,000

(Energy Focus, 2015)

APPENDIX XXIV: THE EXPERIMENT GUIDE SHEET

Objectives:

To assess the effect of artificial classroom lighting on students' academic performance (achievement).

Materials and equipment:

Lux meter, Electric light fittings, wires, Digital multimeter, Digital lux meter, Camera, Picturant 3.2 software, Rad display software, Side cutter, priers, Tape measure, and Ultraviolet rays measuring tool.

Procedure:

1. The research will first measure the initial classroom illumination per student siting station.

2. The research will record the end of Term I examination scores and record.

2. The researcher will re-design adequate artificial electric lighting for the classrooms.

3. The researcher will install electric light fittings in the classroom as per the re-design.

4. The researcher will measure the illumination of the re-designed classroom artificial lighting and record.

5. The researcher will allow the students to do their studies in the re-designed artificial classroom lighting during Term II, record end of Term II examination scores and compare it with the end of Term I examination scores.

Results:

Observations:

Conclusion:

Remarks and comments:

APPENDIX XXV: MESH POINTS FOR THE MEASUREMENT OF ILLUMINANCE

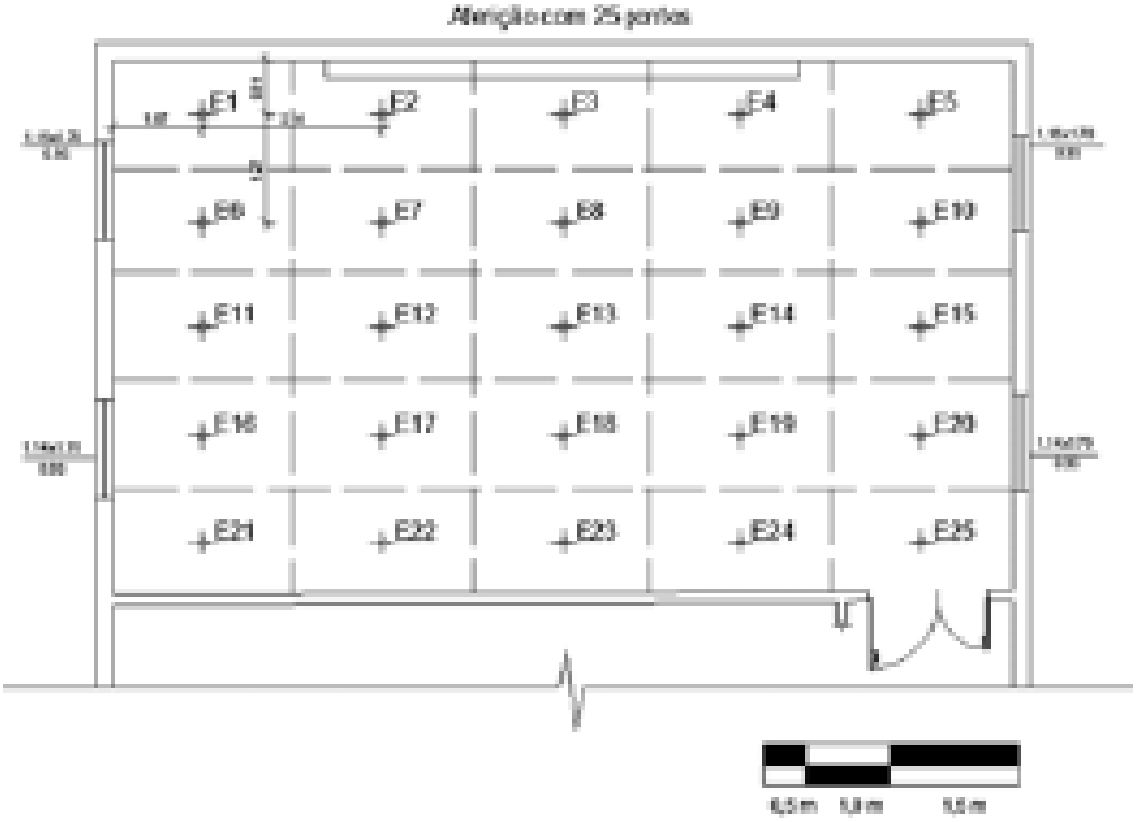


Figure 7.1 Mesh points for the measurement of illuminance (Ibanez et al., 2017)

APPENDIX XXVI: EXPERIMENT GROUP WORKSHEET

Experiment Illumination data table

				Illumination		Test Score
				Calculated	Measured	
Lighting Point	Power Rating	Station	X			
L1		Height				
		Length				
		Hyp				
		Θ				
L2		Height				
		Length				
		Hyp				
		Θ				
L3		Height				
		Length				
		Hyp				
		Θ				
L4		Height				
		Length				
		Hyp				
		Θ				
L5		Height				
		Length				
		Hyp				
		Θ				
L6		Height				
		Length				
		Hyp				
		Θ				
L7		Height				
		Length				
		Hyp				
		Θ				
L8		Height				
		Length				
		Hyp				
		Θ				
L9		Height				
		Length				
		Hyp				
		Θ				
L10		Height				
		Length				
		Hyp				
		Θ				
L11		Height				
		Length				
		Hyp				
		Θ				

APPENDIX XXVII: EXPERIMENT ON THE IMPACT OF ARTIFICIAL CLASSROOM LIGHTING ON STUDENTS'ACADEMIC ACHIEVEMENT

Objectives:

To assess the impact of artificial classroom lighting on academic achievement.

Materials and equipment:

Lux meter, Electric light fittings, wires, Digital multimeter, Digital lux meter, Camera, Picturant 3.2 software, Rad display software, Side cutter, priers, Tape measure, and Ultraviolet rays measuring tool.

Procedure:

1. The researcher will design adequate artificial electric lighting for the classrooms.
2. The researcher will install electric light fittings in the classroom as per the design.
3. The researcher will measure the illumination of classroom artificial lighting and record.

4. The researcher will allow the students to do their studies in the classroom for one term and sit tor the end term examination which he will compare with the previous terms end term examination performance before the classroom adequate lighting was installed.

Results:

Observations:

Conclusion:

Remarks and comments:

APPENDIX XXVIII: CORRESPONCENCES

UNIVERSITY OF ELDORET RESEARCH LETTER OF INTRODUCTION

University of Eldoret

P.O. Box 1125-30100,
ELDORET, Kenya
Tel: 053-2063111 Ext. 242
Fax No. 20-2141257

Our Ref: UOE/SEDU/TED/13

11th September, 2018

The Executive Secretary,
National Council for Science Technology & Innovation
P.O. BOX 30623-00100,
NAIROBI.

Dear Sir/Madam,

SUBJECT: RESEARCH PERMIT FOR- ORIBO CALLEB MAGUTU
EDU/PHD/TE/001/15

This is to confirm that the above named Post Graduate Student has completed Course work of his Doctor of Philosophy in Technology Education.

He is currently preparing for a field research work on his thesis entitled: ***"The Effects of Artificial Classroom Lighting on Reading, Instruction, Health and Ultimate Influence on Students' Academic Performance in Kenya." A Case of Nairobi County Public Boarding Secondary Schools.*** The proposal has been approved by this Institution.

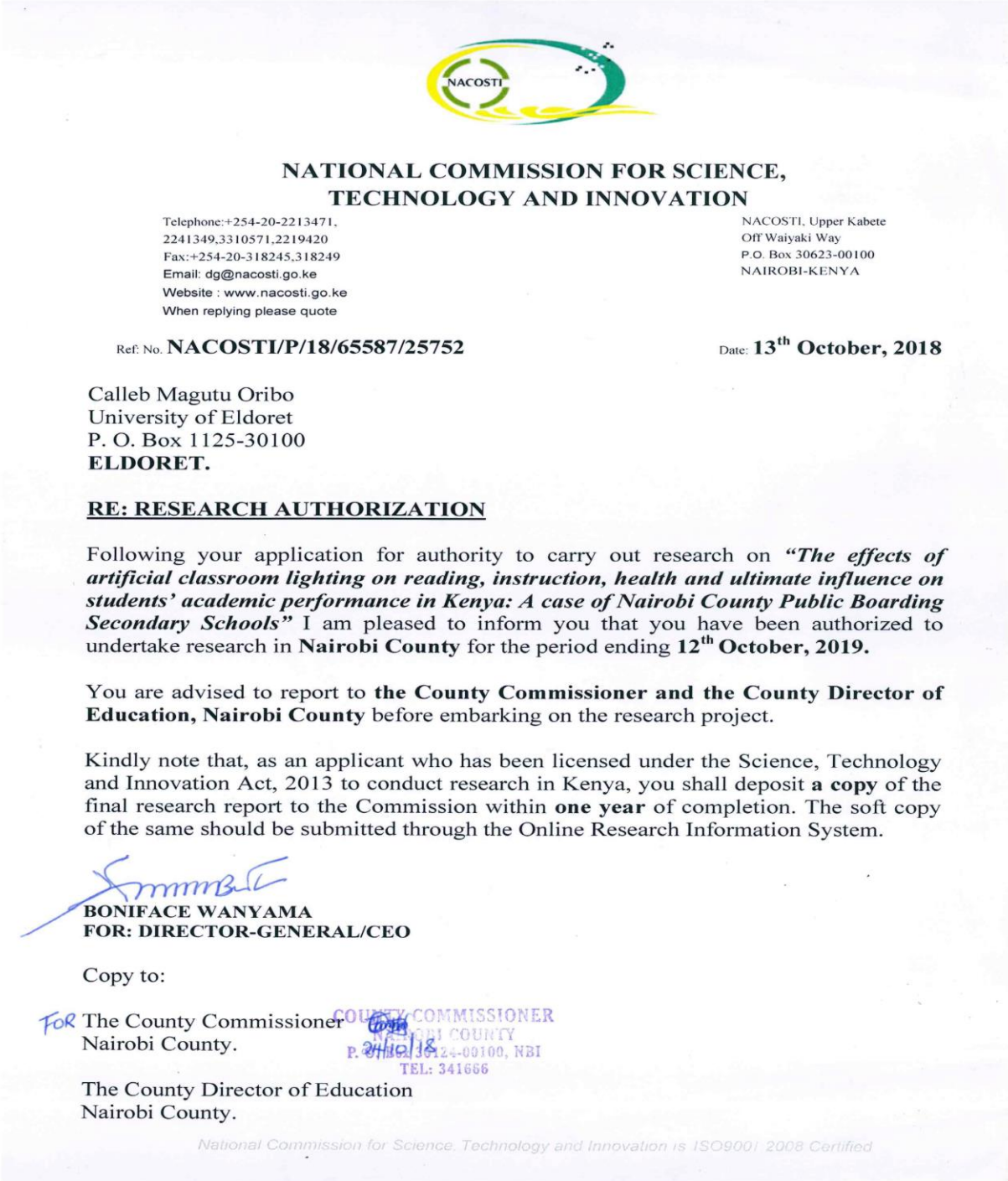
Any assistance accorded him to facilitate successful conduct of the research and the publication will be highly appreciated.

Yours faithfully,

DR. S. WANAMI
AG. HEAD, TECHNOLOGY EDUCATION DEPARTMENT

Copy to: Permanent Secretary,
Ministry of Higher Education, Science & Technology,
P.O. Box 9583-00200,
NAIROBI.

NACOSTI RESEARCH AUTHORIZATION LETTER



NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/18/65587/25752**

Date: **13th October, 2018**

Calleb Magutu Oribo
University of Eldoret
P. O. Box 1125-30100
ELDORET.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"The effects of artificial classroom lighting on reading, instruction, health and ultimate influence on students' academic performance in Kenya: A case of Nairobi County Public Boarding Secondary Schools"*** I am pleased to inform you that you have been authorized to undertake research in **Nairobi County** for the period ending **12th October, 2019.**

You are advised to report to **the County Commissioner and the County Director of Education, Nairobi County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

BONIFACE WANYAMA
FOR: DIRECTOR-GENERAL/CEO

Copy to:

FOR The County Commissioner
Nairobi County.

COUNTY COMMISSIONER
NAIROBI COUNTY
P. 30124-00100, NBI
TEL: 341666
24/10/18

The County Director of Education
Nairobi County.

National Commission for Science, Technology and Innovation is ISO9001: 2008 Certified

RESEARCH AUTHORIZATION LETTER FROM THE MINISTRY OF EDUCATION

Republic of Kenya

MINISTRY OF EDUCATION

STATE DEPARTMENT OF EARLY LEARNING & BASIC EDUCATION

Telegrams: "SCHOOLING", Nairobi
Telephone; Nairobi 020 2453699
Email: rcenairobi@gmail.com
cdenairobi@gmail.com

When replying please quote

REGIONAL COORDINATOR OF EDUCATION
NAIROBI REGION
NYAYO HOUSE
P.O. Box 74629 – 00200
NAIROBI

Ref: **RCE/NRB/GEN/VOL.1**

DATE: **25th October, 2018**

Caleb Magutu Oribo
University of Eldoret
P O Box 1125-30100
ELDORET

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 effects of artificial classroom lighting on reading, instruction, health and ultimate influence on students' academic performance in Kenya: A case of Nairobi County Public Boarding Secondary Schools".**

This office has no objection and authority is hereby granted for a period ending **12th October, 2019** as indicated in the request letter.

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

REGIONAL COORDINATOR OF EDUCATION NAIROBI 23 Oct 2018 MINISTRY OF EDUCATION P. O. Box 74629, NAIROBI

JAMES KIMOTHO
FOR: REGIONAL COORDINATOR OF EDUCATION
NAIROBI

C.C.

Director General/CEO
National Commission for Science, Technology and Innovation
NAIROBI

APPENDIX XXIX: RESEARCH PERMIT

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014.

CONDITIONS

1. The License is valid for the proposed research, location and specified period.
2. The License and any rights thereunder are non-transferable.
3. The Licensee shall inform the County Governor before commencement of the research.
4. Excavation, filming and collection of specimens are subject to further necessary clearance from relevant Government Agencies.
5. The License does not give authority to transfer research materials.
6. NACOSTI may monitor and evaluate the licensed research project.
7. The Licensee shall submit one hard copy and upload a soft copy of their final report within one year of completion of the research.
8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice.

National Commission for Science, Technology and Innovation
P.O. Box 30623 - 00100, Nairobi, Kenya
TEL: 020 400 7000, 0713 788787, 0735 404245
Email: dg@nacosti.go.ke, registry@nacosti.go.ke
Website: www.nacosti.go.ke

REPUBLIC OF KENYA

National Commission for Science, Technology and Innovation

RESEARCH LICENSE

Serial No.A 21265

CONDITIONS: see back page

THIS IS TO CERTIFY THAT:
MR. CALLEB MAGUTU ORIBO
of UNIVERSITY OF ELDORET, 0-30100 ELDORET,has been permitted to conduct research in *Nairobi County*

on the topic: *THE EFFECTS OF ARTIFICIAL CLASSROOM LIGHTING ON READING, INSTRUCTION, HEALTH AND ULTIMATE INFLUENCE ON STUDENTS' ACADEMIC PERFORMANCE IN KENYA: A CASE OF NAIROBI COUNTY PUBLIC BOARDING SECONDARY SCHOOLS*

for the period ending:
12th October,2019

.....
Applicant's Signature

Permit No : NACOSTI/P/18/65587/25752
Date Of Issue : 13th October,2018
Fee Recieved :Ksh 2000

.....
Director General
National Commission for Science, Technology & Innovation

APPENDIX XXX: MAP OF NAIROBI COUNTY

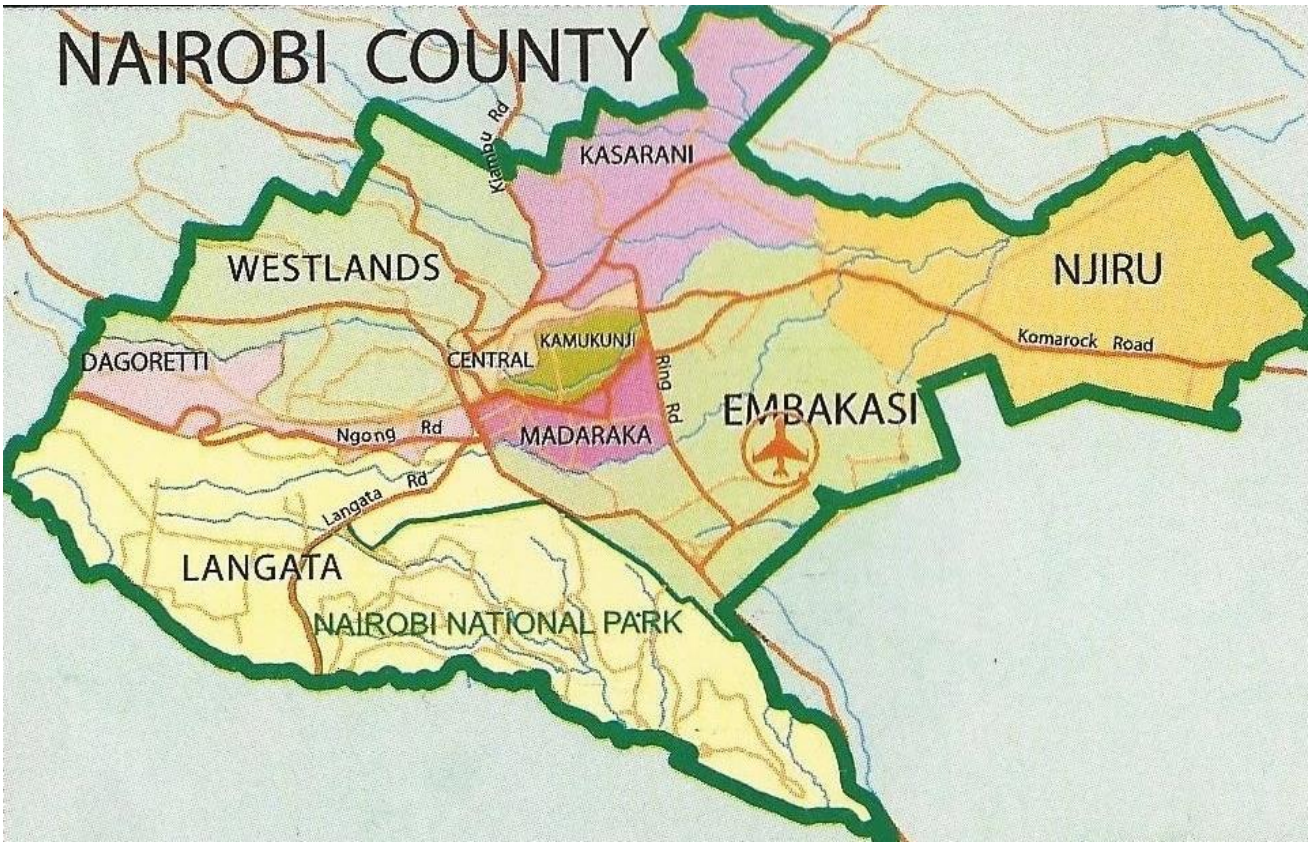


Figure 7.2: Map of Nairobi County. (Source : Google Maps)

APPENDIX XXXI: LIGHT AS ITS AFFECTS HUMAN PERFORMANCE AND HEALTH THROUGH THE VISUAL AND CIRCADIAN SYSTEMS

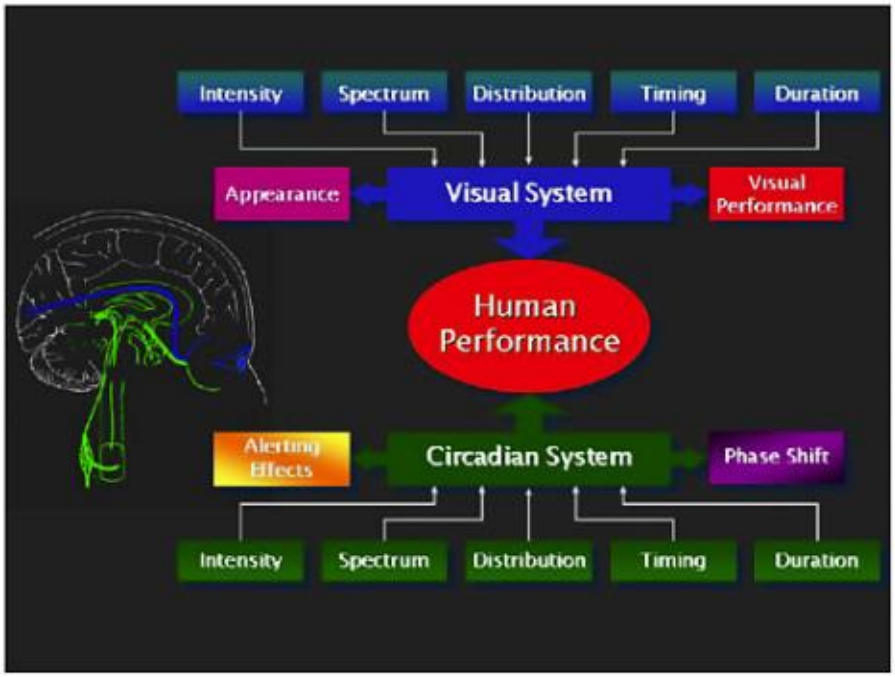


Figure 7.3 Light as it affects human performance and health through the visual and circadian systems (NASEM, 2018).

APPENDIX XXXII: RELIABILITY STATICS FOR THE STUDY

Students' questionnaire reliability statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Number of Items
0.822	0.702	51

APPENDIX XXXIII: RESEARCH WORK PLAN

Activities/ Critical stage			Month										
			Nov 2015	September 2016	September 2017	April 2018	May 2018	October 2019	March 2019	May 2019	July 2019		
Developing a research idea													
Developing a research proposal													
Developing research tools													
Proposal presentation													
Reviewing proposal													
Applying for consents from authorities													
Talking with a representative at research sites													
Piloting and validating tools													
Reviewing tools													
Training research assistants													
Selecting the sample													
Data collection													
Data verification, coding & entry													
Data Analysis													
Thesis report writing and proofreading													
Thesis presentation													
Review thesis and & submission													
Information to respondents & authorities													

APPENDIX XXXIV EXPERIMENTAL STUDY PROCEDURES

1. In term, the research measured the initial classroom illumination per student sitting station for both the controlled and experimental groups.

2. The research recorded the end of Term I examination scores for both the controlled and experimental groups.

2. In term II the researcher re-designed the artificial classroom (electric) lighting of the experimental group by increasing the lighting points from six (6) to twelve (12) so as to meet the recommended artificial classroom lighting illumination standards of about 240 lux - 500 lux.

3. In term II the researcher installed electric light fittings in the experimental group classroom as per the re-design.

4. In term II the researcher measured illumination of the re-designed (experimental group) and control group classrooms artificial lighting and recorded.

5. The researcher allowed the students to do their studies in the re-designed artificial classroom lighting for the experimental group and the control group during Term II and recorded end of Term II examination scores for both the controlled and experimental groups.

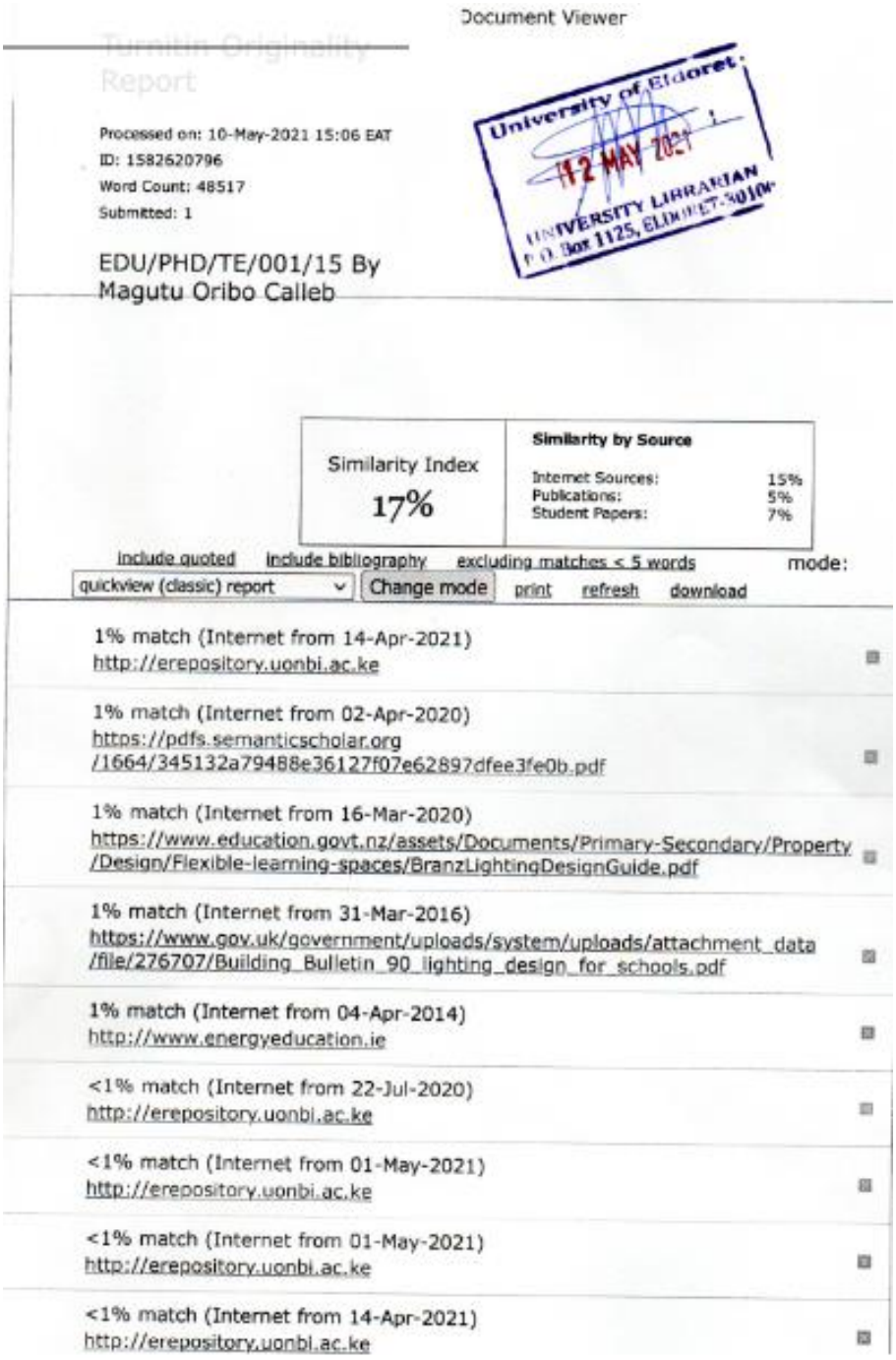
APPENDIX XXXV THE RESEARCHER MEASURING ARTIFICIAL CLASSROOM LIGHTING ILLUMINATION IN ONE OF THE SAMPLED SCHOOLS

(Source : Author, 2018)

APPENDIX XXXVI EXPERIMENT RESEARCH MATERIALS AND TOOLS

(Source : Author, 2019)

APPENDIX XXXVII SIMILARITY REPORT



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