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The Effects of Artificial Classroom Lighting on Students Academic Performance

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ABSTRACT
Light directly influence each element of human life and is the greatestcentralecological input after human basic needs (food, shelter and clothing) in regulating body functions. Human life and activities especially the process of acquiring knowledge and skills depend on light. The essential mission of schools is to provide good learning environmentsof which light is a key factor. Therefore, lighting is an important factor in designing classrooms. Artificial classroom lighting impact on students' academic performance is underestimated. In spite of technological advancements that have greatly improved the quality of artificial lighting, most secondary schools classrooms in Nairobi County of Kenya have insufficient artificial lighting and this negatively influence the overall students' academic performance. The objective of this study was to assess artificial classroom lighting effects on secondary school students' academic performance. The quality and distribution of artificial classroom lighting was studied. The study sampled forty form three secondary school students in Westlands Sub-County of Nairobi County in Kenya. The study experiment materials and equipment were validated and reliability determined using Cronbach's alpha. Quantitative data was analyzed using descriptive statistics. Statistical Package for Social Scientists (SPSS) computer package was used to analyze the data. The data for the study was presented in tables and charts. The study found out that quality artificial classroom lighting had a positive influence on secondary school students' academic performance. The study recommend that artificial classroom installation should meet the required distribution and illumination quality standards.
Keywords: Secondary schools; artificial classroom lighting; academic performance

I. INTRODUCTION

Light directly influence each element of human life and is the greatest central ecological input after human basic needs (food, shelter and clothing) in regulating body functions. Human life and activities especially the process of acquiring knowledge and skills depend on light. The essential mission of schools is to provide good learning environments of which light is a key factor. Therefore, lighting is an important factor in designing classrooms. Artificial classroom lighting impact on students' academic performance is underestimated. In spite of technological advancements that have greatly improved the quality of artificial lighting, most secondary schools classrooms in Nairobi County of Kenya have insufficient artificial lighting and this negatively influence the overall students' academic performance. The objective of this study was to assess artificial classroom lighting effects on secondary school students' academic performance. The quality and distribution of artificial classroom lighting was studied. The study sampled forty form three secondary school students in Westlands Sub-County of Nairobi County in Kenya. The study experiment materials and equipment were validated and reliability determined using Cronbach's alpha. Quantitative data was analyzed using descriptive statistics. Statistical Package for Social Scientists (SPSS) computer package was used to analyze the data. The data for the study was presented in tables and charts. The study found out that quality artificial classroom lighting had a positive influence on secondary school students' academic performance. The study recommend that artificial classroom installation should meet the required distribution and illumination quality standards.

Light is an important factor in learning but availing it adequately in the classroom is a challenge in many schools. Natural daylight provides the best light for reading with a number of positive effects but at night and during fore-cast days, artificial lighting remains the only substitute (Garibaldi and Josias, 2015).

Even though there have been great advancement in lighting technology, artificial classroom lighting conditions in many secondary school classrooms are worse or below the required threshold. Despite the fact that studies have shown that artificial classroom lighting is related to students' academic achievement, many institutions have not put any effort to improve the quality of artificial classroom lighting (Pulay, 2010). Many of the secondary school classrooms have inefficient lighting that has been attested to cause discomfort, visual impairment, lighting related illness and learning difficulties (Glavand et al., 2016 and Bullina, 2016). This

indicate that there is a problem of inadequate artificial classroom lighting which is likely to negatively affect students' academic achievement. Blazer (2012) revealed that millions of students attend structurally deteriorating schools with inadequate classroom artificial lighting which put their health and safety at risk. Gilavand et al. (2016) suggested that there is a necessity for more, investigationon the effect of artificial light on learners in the learning setting. Sleegers et al. (2010) reported that there was a dispute on artificial classroom lighting influence on students' academic performance and recommend a study to be conducted to bring an understanding of the influence of artificial lighting on students' academic performance. Wall (2016) also recommends a study be conducted on artificial classroom lighting as part of planning and delivery to leverage the full potential of its impact on students' outcome.

It has been revealed that classroom lighting is a vital factor in learning. Most of the studies on artificial classroom lighting that have been conducted have assessed elementary school learners. Little studies have been done on artificial classroom lighting effects on secondary school students' academic performance especially in Africa and particularly in Kenya. This study endeavored to bridge that gap.This situation prompted the researcher to investigate the effects of artificial classroom lighting on students' academic performance in Nairobi County of Kenya secondary schools.

II. MATERIALS ANDMETHODS

This study was guided by Dual Coding Theory which states that human beings use two different channels to process visual and hear information (Yilmaz-Soylu and Akkoyunla, 2009).The study employed an experimental research design. According Seltman (2018) experimental research design is a cautious harmonizing of several features including "power", generalizability, various forms of validity, practical and cost. This study was concerned with determining the effect of artificial classroom lighting on students' academic performance in Nairobi County of Kenya. The specific objective was to determine the effect of artificial classroom illumination on students' academic performance. Experimental design provided the researcher with control over other external factors that allowed the researcher to make a stronger claim that determined causality than any other type of research design. Also, the experimental research design enabled the researcher to shut out all extraneous influences (Glasow, 2005).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 study was conducted at St. George Athi Secondary School in Njiru Sub-county of Nairobi County of Kenya. Forty (40) purposively sampled students participated in the study.The study experiment materials and equipment were validated and reliability determined using Cronbach'salpha of 0.822.The quantitative data was analyzed using descriptive statistics. The statistical package for social scientists (SPSS) computer package was used to analyze the data.

The following hypothesis was tested in the study;

H_0: There is no significant relationship between artificial classroom light illumination and students' academic performance.

The researcher re-designed one classroom's artificial lighting and assessed its influence on students' academic achievement. The re-design of the classroom lighting was to ensure that there was adequate artificial lighting in the learners learning environment for the experiment group. The researcher conducted an experiment to assess the effect of artificial classroom lighting on students' academic achievement.

In the study, the students were placed into two groups, the experiment group and control group. 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 tested before (pre-test)the treatment was given to the experimental group and both groups were again tested after the treatment had been given(post-test). The sequence therefore was as follows:

Table 1 Experiment sequence

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

After post-test, statistical analysis was carried out to see whether the treatment had any effect.

Materials and equipment:

1. Lux meter 2. Fluorescent lamb electric light fittings, 3. Wires
4. Digital multimeter, 5. Fluorescent lambs 6. Electrical wiring cables
7. Camera 8. Side cutter 9.Priers 12. Tape measure
13. Pro-tra-ctor

Useful formulas:

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

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).
Luminance of the source element $L = \frac{\Delta I}{\Delta A Cos\varphi} = \frac{\frac{\Delta I}{\Delta A'}}{} {}^{cl}/_{m^2}$
= area of source element projected onto a plane perpendicular to specific direction.

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

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

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

Procedures:
1. The research measured the initial artificial classroom illumination per student siting station.
2. The research recorded the end of Term I examination scores.
2. The researcher re-designed the artificial electric lighting for the classrooms to meeting the recommended standards.
3. The researcher installed electric light fittings in the classroom as per the re-design.
4. The researcher measured illumination of the re-designed classroom artificial lighting and record.
5. The researcher allowed the students to do their studies in the re-designed artificial classroom lighting during Term II and record end of Term II examination scores.
The researcher performed measurements with HIOKI Lux Hi TESTER 3421 lux meter, with accuracy of 5% 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 following were the results of the experiment.

III. RESULTS AND DISCUSSION

Table: 2 The control group light illumination (lux)

	TERM I			TERM II		
Student	**Calculated**	**Measured**	**Test Score**	**Calculated**	**Measured**	**Test Score**
A	148	150	61	148	150	52
B	118	120	68	118	120	57
C	138	140	57	138	140	45
D	147	145	59	147	145	49
E	159	161	47	159	161	58
F	118	122	51	118	122	53
G	98	100	59	98	100	54

H	208	210	55	208	210	59
I	243	247	58	243	247	63
J	118	121	52	118	121	60
K	221	223	56	221	223	40
L	302	300	60	302	300	51
M	179	181	62	179	181	62
N	158	156	57	158	156	60
O	222	220	64	222	220	52
P	151	152	42	151	152	57
Q	179	181	51	179	181	58
R	222	28	76	222	28	59
S	158	160	65	158	160	57
AVG.			**55.00**			**52.30**

(Source: Field Survey 2019)

Table 3 The experimental group illumination (lux)

		TERM I			**TERM II**	
Student	**Calculated**	**Measured**	**Test Score**	**Calculated**	**Measured**	**Test Score**
A	179	180	63	327	321	70
B	151	150	57	355	351	60
C	222	200	65	342	339	72
D	158	160	42	295	300	52
E	179	180	51	336	337	60
F	302	300	76	361	359	74
G	221	220	65	318	321	75
H	118	120	61	344	347	65
I	242	240	69	317	319	79
J	208	210	57	328	329	54
K	98	100	59	355	350	72
L	118	120	47	342	339	55
M	159	160	51	332	334	60
N	218	210	60	309	311	65
O	147	150	55	351	356	53
P	138	140	58	343	338	60
Q	176	180	52	318	316	55
R	118	120	57	315	310	52
S	148	150	60	328	330	68
AVG.			**55.25**			**60.05**

(Source: Field Survey 2019)

Table 2 shows that the control group experiment test scoremean dropped by 5%, while Table 3 shows that the experimental group test scoremean increased by 10%. This indicated that adequate artificial classroom lighting improved students test scores by ten percent (10%).

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

Artificial classroom lighting affects hormonal balance in the body. Hormonal balance is one of the key factors in learning.Gilavand et al. (2016) investigated the impact of environmental factors on learning and academic achievement of elementary students to determine whether school's open space, noise and lighting had a significant influence on elementary students' academic achievement. This study indicated that the quality of artificial lighting inhibit stress hormones. Studies suggest that the intensity and colour temperature of artificial

lighting affect various physiological processes in the human body, such as blood pressure, heart rate variability, EEG, core temperature and melatonin (Sleegers et al., 2012).

A good choice of colour and contrast of artificial classroom lighting promotes the learning capability of visual and hearing-impaired students. Lighting and acoustic criteria are very important to the visually impaired and hearing impaired learners. Loe et al. (1999) indicated that colour and contrast are particularly important to the hearing impaired and visually impaired. They revealed that down lights in in a classroom yield severe shades which impede lip reading. They recommended the use of artificial lighting with contrasting colourat a height that is helpful to the visual impaired learners.

The variations of artificial classroom lighting is key for maintaining desirable lighting situations for different classroom tasks. Teachers prefer to have control over lighting levels (Mirrahimi et al, 2012). Increased light levels improves students' academic performance (Heschong et al., 2002).Lighting the learning space is a chief aspect in the teaching and learning process and is vital in determining students' learning outcome. Light is a dominant source of energy that synchronizes a human being's endogenous circadian pacemaker with the environs and is a mediator in promoting intellectual achievement (Keis et al., 2014). Mott et al. (2012) indicated that light is a strong enabler for visual performance, regulates a large variety of bodily processes such as sleep and alertness, is essential for cognition and mood, enables production of important hormones such as melatonin and cortisol, and is essential for a healthy rest-activity pattern. They further noted that light is a key ecological input after human basic needs in regulating body functions. Generally speaking human life and human activities especially the process of acquiring knowledge and skills is centered on learning environment lighting.

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. This study tested the following hypothesis;

H_{01}: There is no significant relationship between artificial classroom lighting and boarding secondary school students' academic performance in Nairobi County.

Table 4 Pearson's correlation coefficient results on the relationship between artificial classroom illumination and students' test scores

Variable	N	Mean	Std.	Minimum	Maximum	Possible	r
Illumination	80	3.06	1.35	28	363	240 - 500	0.275*
Test Scores	80	2.91	0.83	31	87	0 - 100	

Table 5 Pearson's correlation coefficient results on the relationship between artificial classroom illumination and students' test scores matrix

	1	**2**	**3**
Group	1		
Illumination	0.661**	1	
Test Scores	0.183	0.275*	1

** cc is significant at 0.01 level (2-tailed)

* cc is significant at 0.05 level (2-tailed)

Table 4 shows that the Pearson's Product Moment correlation statistical analysis resulted in a positive significant correlation r = 0.275 ($p < 0.05$). It was concluded that there was a significant positive and linear relationship between artificial classroom lighting illumination and students test scores.

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 quality of artificial classroom lighting illumination 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 20 – 1 = 19 and $\alpha = 0.90$ the critical value was 11.651.

Table 6 The Chi-Square source table of the results of level of relationship between artificial classroom lighting and students' academic performance

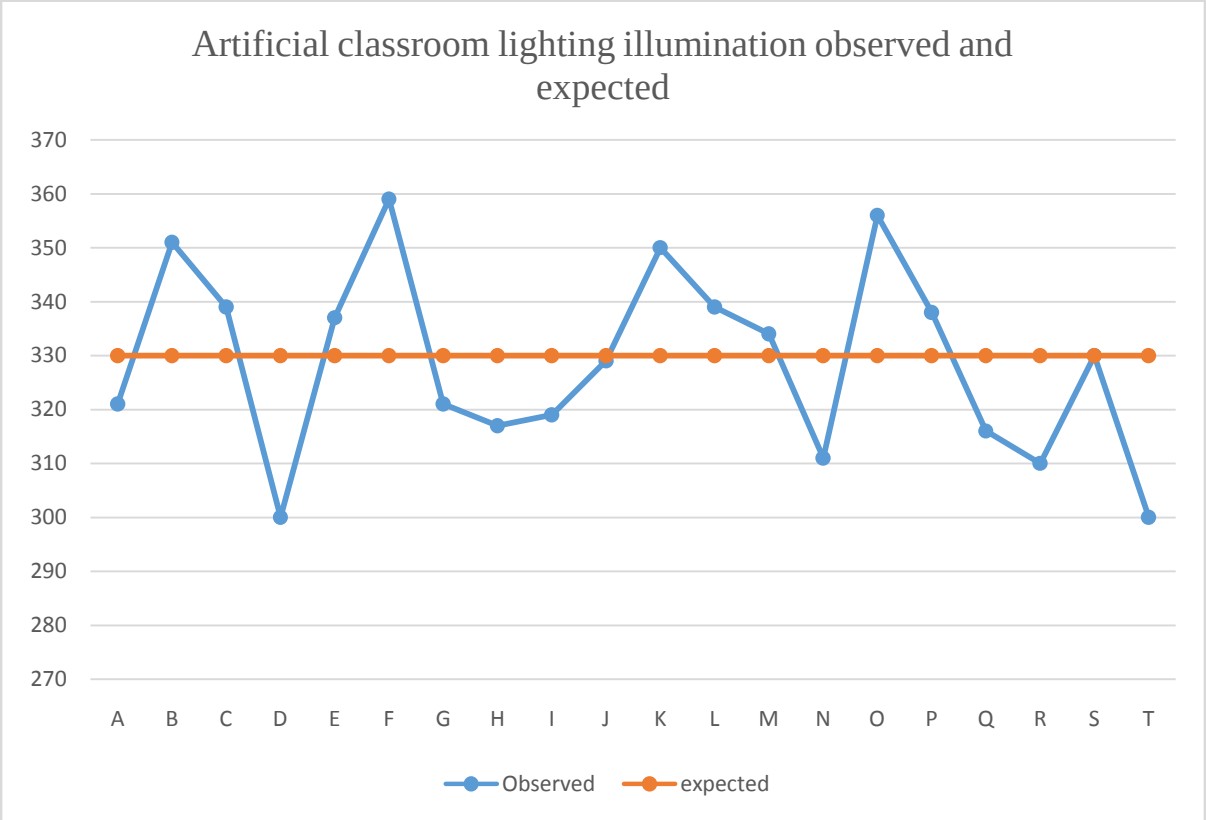
Station	**df**	**Observed**	**Expected**	**O-E**	**(() – E)^2**	**$\frac{(O - E^2}{E}$**
A	1	321	300	21	441	1.47
B	2	351	300	51	2601	8.69
C	3	339	300	39	1521	5.07
D	4	300	300	0	0	0
E	5	337	300	37	1369	4.563

F	6	359	300	59	3481	11.60
G	7	321	300	21	441	1.47
H	8	317	300	17	289	0.96
I	9	319	300	19	361	1.20
J	10	329	300	29	841	2.80
K	11	350	300	50	2500	8.33
L	12	339	300	39	1521	5.07
M	13	334	300	34	1521	3.85
N	14	311	300	11	121	0.40
O	15	356	300	56	3136	10.45
P	16	338	300	38	1444	4.81
Q	17	316	300	16	256	14.51
R	19	310	300	10	100	0.33
S	20	330	300	30	900	3.00
T	19	320	300	20	400	1.33
Total						**89.883**

(Source: Field Survey 2019)

Decision: The decision rejected that claim since 89.883 > 11.651. From the test results there was enough evidence to reject that claim that there is no significant relationship between artificial classroom illumination and students' academic performance.

Figure 1 shows that there is a great deviation between observed graph and the expected graph. The gap between the two graphs show how the results of the Chi-squares test for goodness-of-fit-test is not a good fit.



NOT GOOD FIT

Figure 1: Results of the Goodness-of-fit for artificial classroom illumination

A well designed and quality artificial classroom lighting improved students' academic performance in Nairobi County of Kenya public boarding secondary school.Artificial classroom illumination ranging between 300 lux and 500 lux positively affect students' academic performance.Sleegers et al. (2012) conducted triple studies in Dutch to assess the effects of vertical illumination ranging between 350 luxand 1000 lux with a correlated colour temperature that ranged between 3000 K and 120000 K on primary school pupils

attentiveness. The results of this study showed that quality artificial classroom lighting can have positive effects on learners' working speed, accuracy, and task performance.

IV. CONCLUSION AND RECOMMENDATIONS

Conclusion: The purpose of the study was to assess the effect artificial lighting on secondary school students' academic performance. It was clear that artificial lighting in many of the classrooms in Nairobi County of Kenyaboardingsecondary schools was not sufficient for learning. In general, a well-designed and quality artificial classroom lighting will improve secondary school students' academic performance. A good artificial classroom illumination ranges between 300 lux and 500 lux.

Recommendation: The Kenyan government should ensure that artificial classroom lighting installations in secondary schools is at least 300 lux and at most 500 lux. This will create a conducive learning environment that will increase students' concentration and enable them to attain high academic performance.

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