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P6 Pattern of Biophilic Design: Impact on visual comfort and cognitive performance of architectural technology students

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Abstract: ***Scrutiny of the NBTE-approved curricula and course specifications for both National Diploma and Higher National Diploma students of Architectural Technology revealed that the revised document has new courses and upwardly reviewed course hours of some existing courses. Students are now expected to spend extended periods in the studio for sundry academic tasks. This puts considerable pressure on their visual comfort especially when lighting conditions are below-par, inappropriate, and ineffectual. With rising cases of asthenopia, ocular fatigue, and deteriorating academic performance of architectural technology students of NBTE-accredited schools of architecture, it has become necessary to float a study directed at understudying how the P6 Pattern of Biophilic Design impacts the academic performance and well-being of students. Precisely, this study investigated how lighting conditions of studios affect the visual comfort and cognitive performance of Architectural Technology students. The study involved 176 consensual participants, 44 participants per set, who were randomly selected across the Department of Architectural Technology, Federal Polytechnic Nekede, Owerri. A battery of tests, including delta blink rate calculations and surveys, were directed at measuring cognitive performance, eye strain fatigue, and ocular fatigue within four lighting conditions - static cool white light, static warm white light, dynamic light, and diffuse light. Analysis with dual-axes composite graphs and scatter plots informed patterns, relationships, and findings which indicated that dynamic lighting conditions impacted positively cognitive performance. Participants exposed to dynamic lighting exhibited an improved cognitive performance of 1.06%, 2.17%, and 7.1% respectively over similar cohorts exposed to diffuse lighting, static cool white lighting, and static warm lighting conditions. Even though diffuse lighting conditions indicated approximate findings, ocular fatigue remained significantly lowered while eye strain fatigue tended towards a best-case scenario in dynamic lighting conditions, signifying improved visual comfort. To this end, it became pertinent to advance a recommendation that advocates for appropriate lighting conditions that mimic natural environments while supporting the circadian rhythm of students in studios, workspaces, and areas where intense mental acuity is required.***

Keywords: Biophilic Design, Circadian Rhythm, Cognitive Performance, Lighting Conditions, Visual Comfort.

1. Introduction

Lighting is a critical component of educational environments, affecting students' physical and psychological well-being. Architectural technology students need optimal lighting conditions because their curricula require them to continuously execute extended scheme designations, technical presentations, intricate photography and modelling assignments, and detailing. Such protocols require proper lighting towards the enhancement of visual acuity, reduction of eyestrain, and improvement in overall cognitive performance leading to improved educational outcomes (Rostam, Hanieh, Negar, Abbas, & Nematullah, 2021).

The sixth pattern of biophilic design is dynamic and diffuse light. It drives the varying intensity of light and shadow, which changes over time thus creating some conditions found in nature (William, Catherine, & Joseph, 2014). Dynamic lighting (DL) entails lighting systems that change in intensity and colour temperature throughout the day, thus mimicking the natural daylight cycle (Walter Pack, 2024). Such lighting, as produced by smart LED bulbs, matches the human circadian rhythm, promoting alertness and cognitive function through a natural and stimulating environment. On the other hand, diffuse lighting (DiL) is created from its uniformity of distribution, which reduces shadows and glare (Royal Brinkman, 2024). This kind of lighting thus reduces visual discomfort and cognitive workload generated from eye strain, thus increasing the ability to focus on tasks that require sustained attention and precision (Rostam, Hanieh, Negar, Abbas, & Nematullah, 2021). Therefore, diffuse light creates a visually comfortable environment, with significant importance to detailed visual work, such as architectural design and drafting (Amir, Astrid, Hong, & Aris, 2021). There are also static warm white light and static cool white light. Static Warm White Light (SWWL), is the type of lighting that emits a constant, steady light with a warm-coloured temperature typically between 2700K and 3000K. It resembles the colour of classic incandescent bulbs, thus creating a cozy and welcoming atmosphere with lux values ranging from 50-200 lux in the bedrooms to 200-300 lux in the bathrooms. Static Cool White Light (SCWL) simply refers to the lighting with a consistent, steady light with a cool colour temperature. Typically, this bluish-white light ranges between 4000K to 5000K. This gives a much brighter and crisp effect than warm white light. Their lux values can generally be considered in ranges that vary from the lowest range of 300-500 lux in classrooms, workshops, and offices to the highest range of 500 – 1000 lux in workshops, retail stores and industrial environments. Generally, a studio with a maximum capacity of thirty to forty students requires 1,100 – 1,600 lumens of light per square meter for a standard application of light (Luxific, 2024).

Architectural technology students in NBTE-accredited polytechnics are subjected to complex cognitive tasks that demand high precision, creativity, and critical thinking (Mudashir & Abdulazeez, 2018). For the most part, the entire task of their jobs requires lengthy periods of concentration on minute drawings, computer-aided design (CAD) software, and psychometric design nuances. Their cognitive performance can be affected by an array of factors, including the type of lighting in their work environment and its quality. Research has been carried out to understand the general impact of lighting on cognitive performance. However, there is not enough in the exact area of the impact of dynamic and diffuse lighting on architectural technology students. In addition, case studies and interviews done on existing studio facilities across NBTE-accredited departments of Architectural Technology within the southeast geopolitical region of the country indicate that 80-87% of such facilities do not have any form of dynamic and diffuse lighting systems (Onwukwe & Ogbuokiri, 2020). This has far-reaching effects on students. Understanding these effects could make the lighting designs of educational facilities better, ultimately enhancing student performance and well-being. Therefore, this study aims to achieve the following objectives:

a. To determine the effects of dynamic lighting, diffuse lighting, static warm white lighting, and static cool white lighting on the cognitive performance of architectural technology students such as attention, memory and problem-solving abilities.

b. To investigate the impact of dynamic lighting, diffuse lighting, static warm white lighting, and static cool white lighting conditions on physical well-being indicators (PWIs) such as eye strain and fatigue.

c. To formulate evidence-based guidelines for implementing the sixth pattern of biophilic design in educational settings towards enhancing cognitive performance and well-being.

The objectives above, therefore, will be the entry points for an emulative study on how dynamic and diffused lighting will affect the cognitive performances of architectural technology students. Addressing these objectives would thus provide the basis for evidence-based recommendations toward informing the design of educational environments for improved student learning outcomes and well-being.

2. Methods

2.1 Study Design:

This was a mixed-method approach employed in assessing the cognitive performance of architectural technology students exposed to dynamic light, diffuse light, static cool white, and static warm white light in controlled learning environments. The approach integrated both quantitative and qualitative data collection methods designed to provide a comprehensive understanding of how different lighting conditions affect cognitive performance.

2.2 Participants:

The Department of Architectural Technology, Federal Polytechnic Nekede Owerri currently has a total of 319 students, including re-registration students, who are currently enrolled in the 2023/2024 academic session. Applying a 95% confidence level and 5% error margin, a total of 176 students was calculated to form the total sample size for this study (QuestionPro, 2024). 44 students participated in a set of experiments for each lighting condition. Each set of 44 students comprised 11 students from the 4 levels of NDI, NDII, HND I and HND II. Students aged 18-30, and currently enrolled in the Architectural Technology department were captured for the study while students with diagnosed visual impairments or neurological conditions that could affect cognitive performance were excluded from the study.

2.3 Experimental Setup:

The experiments were conducted in the four studios that provided workspace for architectural technology students in the department. Each of the tests ran from 9:15 am to 3 pm, capturing morning and afternoon sessions. The carrying capacity of each studio is 30. For each lighting condition, the studios were equipped with adjustable lighting systems capable of producing dynamic, diffuse, static, cool, and warm white light. 11 students from the four different levels of the department formed participants for every lighting condition.

Figure 1: One of the 4 studios adopted for the experiments - The HND I studio.
Source: Authors' fieldwork (2024)

Figure 2: Interior of the studios before retrofitting showing carrying capacity.
Source: Authors' fieldwork (2024)

A total of 4 experiments were conducted for the entire exercise.

2.4 Lighting Conditions:

For each experimental session, the studios were retrofitted with lighting fittings appropriate for each of the 4 lighting conditions.

a. Dynamic Lighting: In mimicking the natural patterns of daylight in terms of appropriate lighting scenes and colour temperatures, smart LED bulbs and fixtures were adopted for lighting (Hakimi, 2023). These were controlled by apps installed on authors' smartphones.

b. Diffuse Lighting: Diffuse lighting through flat LED panels was adopted (GRNLED, 2024). These were controlled with dimmer switches.

c. Static Cool White Light: To achieve a 5000K-6500K colour temperature and a bright, bluish-white light, static cool white light was provided by the installation of the T5 fluorescent tubes (Jason, 2021).

d. Static Warm White Light: This was provided through the installation of A19, 100W incandescent bulbs (Schneider Electric, 2024).

2.5 Cognitive Performance Assessment Modules (CPAM):

In each lighting condition, participants' cognitive performance was tested in:

a. Attention and Concentration
b. Memory and
c. Problem-solving and Creativity.

a. Attention and Creativity

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Participants' reaction time was tested through the adoption of the timed ruler-grabbing test (Aranha, et al., 2017). General assessment questions were administered to test for accuracy while the use of an online computerized test was adopted to measure tonic alertness (Dana & Jelena, 2018). All tests were based on a 100% maximum score.

Mean % CPAM = $^{sum\ of\ all\ CPAM\ modules}/_{8}$

(1)

b. Memory

Short-term memory was measured through the use of computer-generated tests and observation of gaming platforms. Working memory capacity was measured by asking students to take note of the list of items/objects before each session and then requesting them to recount how many they could remember after the session (Oliver, Andrea, & Klaus, 2013).

c. Problem-solving and Creativity

To test for fluency percentage, a passage was given to each participant to read for 60 seconds. As the participant reads the passage, problem words (PW) are noted. These include words that were kipped, pronounced wrongly or hesitated. At the 60-second mark, the participant is stopped from reading. The total number of words at the end of the 60 seconds is the Word Per Minute WPM) (Hasbrouck, 2024).

WPM – PW = ACCURACY (2)

$^{ACCURACY}/_{WPM}$ *x 100 = Fluency %* (3)

Administration of a simple brief and engagement in a design scheme for 2 hours was conducted to measure the originality of participants' solutions. The design session is the major and first task that supersedes all other tests.

A short defence session where participants rendered feedback on the scheme they engaged in was conducted. This was meant to measure dexterity in the elaboration of ideas by participants. This lasted for a maximum of 10 minutes.

2.6 Eye Strain and Fatigue (ESF):

These are 6 personalized survey questions and blink rate tests conducted to elicit qualitative responses and measure the percentage of ocular fatigue (OcF) after each lighting condition session. Responses were assigned numerical values using a ternary coding system – 1 (No), 1.5 (Maybe) and 2 (Yes) respectively (Dave & Prem, 2012). A wearable eye-tracking headset measures the blink rate before and after each lighting condition session (Ngozi, Blanka, Nancy, Jiaying, & Isabelle, 2023).

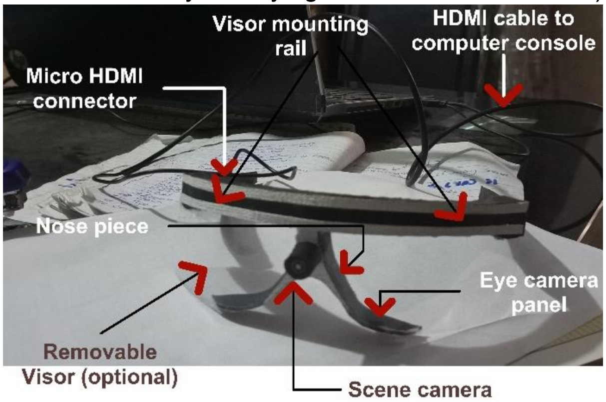

Figure 3: The wearable eye-tracking headset for measuring the blink rate of participants before and after every experimental session.
Source: Authors' fieldwork (2024)

Each of the 6 questions generates a response which is assigned a numerical value. The relationship between the average mean of all 6 questions from the entire students and the numerical codes of (1), (1.5) and (2) determines the status of ESF from a particular lighting condition. Percentage OcF is calculated thus:

Blink rate before test (br1) – blink rate after test (br2) = delta blink rate (Δbr) (4)

Therefore,

$^{\Delta br}/_{br1}$ *X 100 = % OcF* (5)

2.7 Procedure:

44 different students took part in 4 different experimental sessions. Each session was conducted in 4 different studios retrofitted with lighting fittings mimicking the lighting conditions being investigated. Each experimental session involved 3 periods.

a. Initial Period:

i. Participants were exposed to the first half of working memory exercises before they were given simple briefs. The first half involved a video presentation of a specific number of objects and items in no predesigned order.

ii. Participants were assigned to studios in batches of 11 students per studio: ND I studio – 11 ND I students, ND II studio

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– 11 ND II students, HND I studio – 11 HND I students and HND II studio – 11 HND II students respectively.

iii. The entire initial period lasted for 10 minutes.

b. Testing Period:

i. Participants were administered the blink rate test. The wearable eye-tracking headset was used to take readings of blink rates before issuing the simple brief. This lasted a maximum of 50 minutes.

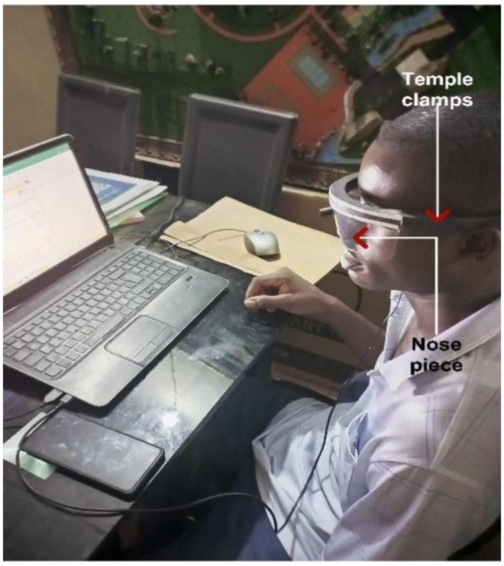

Figure 4: A blink rate testing session is being conducted on one of the participants.
Source: Authors' fieldwork (2024)

ii. Participants were issued simple briefs according to their levels. The October 2020 NBTE curricula provided sufficient information on the scope of the brief for Architectural Design I (ARC 121), Architectural Design II (ARC 211), Advanced Architectural Design I (ARC 311) and Advanced Architectural Design III (ARC 411). This tests the originality of the solution for the scheme. Each design session lasted for a maximum of 120 minutes.

iii. After the design session, participants were administered the ruler-grabbing test to measure their reaction time. This lasted for a maximum of 20 minutes.

iv. Participants were administered 10 questions to measure their percentage accuracy. All such posers were derived from general knowledge of Architectural Technology peculiar to their levels. This session lasted for a maximum of 10 minutes.

v. Participants were administered online computerised exercises to measure their sustained attention and short-term memory capacities. The tests were deployed from laptops. This lasted for 20 minutes.

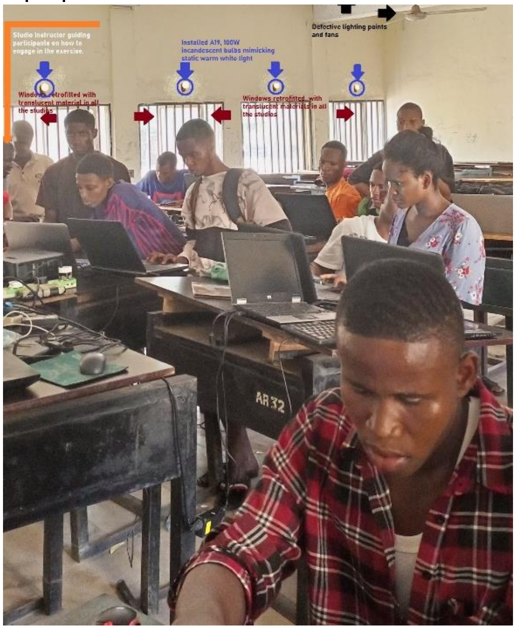

Figure 5: Participants in ND I studio engaging in sustained attention and short-term memory sessions during the Static Warm White Light experiment.
Source: Authors' fieldwork (2024)

vi. The working memory capacity tests were concluded by engaging the participants in the second half of the assessment. The participants were told to recall the objects/items they observed at the commencement of the session. This exercise lasted a maximum of 10 minutes.

vii. The participants were engaged in fluency exercises. The authors engaged the participants in a reading exercise. As the participant reads, the authors took note of all problem words (PW). These include words that were kipped, pronounced incorrectly or hesitated. At the 60-second mark, the participant was stopped. The total number of words at the end of the 60 seconds is the Words Per Minute (WPM). Accuracy and Fluency % is calculated from equations (2) and (3).

viii. Finally, the participants were engaged in a short defence session where they rendered feedback on their understanding of the scheme. This exercise measured their capacity to elaborate on the ideas they translated into the scheme. This lasted for a maximum of 50 minutes.

c. *Qualitative Data Collection Period:*

ix. Participants completed a survey regarding their subjective experience with the lighting condition related to the physiological condition of their sight. The 6 questions provided for this purpose were completed within 5 minutes.

In all, each procedure took between 340 and 345 minutes.

2.8 Ethical Considerations:

The participants provided informed consent before participating in the study as participation was voluntary with no coercion nor undue influence. Participants were provided with snacks at intermittent periods to cushion the long periods of tests which could predispose them to stress and discomfort. The participants' privacy and confidentiality were also considered by anonymising all data. However, permission was sought from the department to publish pictures and images containing the students. Such permission was also extended to allow the full use of the studios especially on weekends in order not to disrupt the participants' lectures. These authors also engaged in debriefing sessions as a way of explaining the significance of the study and its expected impact on the students. This also offered the opportunity to entertain questions from the participants on their experiences. Harm was minimized as much as possible by providing sufficient distance between participants and lighting fixtures and points. Retrofitting was also supervised by these authors to make sure the participants were not exposed to injurious wiring. As observed in Figure 3, newly installed fixtures were properly mounted. Areas spotting such fixtures were re-plastered and repainted. All fittings passed through integrity tests before being used for the experiments.

3. Results

This study advanced data for 4 lighting conditions, viz: (a). Dynamic Lighting (DL), (b). Diffuse Lighting (DiL), (c) Static Cool White Lighting (SCWL), and (d) Static Warm White Lighting (SWWL) for purposes of investigating how they impact the adaptation and cognitive performance of architectural technology students of NBTE-accredited schools of architecture. Under each lighting cohort, there are:

a. Cognitive Performance Assessment Modules (CPAM),
b. Eye Strain Fatigue (ESF), and
c. Ocular Fatigue (OcF) variables.

3.1 Collated Data Sets:

1. CPAM, OcF and ESF:

Data on CPAM and OcF were majorly collated during the testing period as numerical data, while data on ESF were collated during exit sessions and surveys as categorical data.

CPAM provided quantitative data on:

a. Reaction time
b. Accuracy
c. Sustained attention
d. Short-term memory
e. Working memory
f. Fluency
g. Originality, and
h. Elaboration of ideas.

All data were weighted to a maximum of 100%.

OcF provided quantitative data on:

a. Blink rate before sessions
b. Blink rate after sessions.

ESF provided qualitative data on the physiological conditions of the eye and the general status of the visual acuity of participants. 6 survey questions elicited responses using the ternary coding system:

a. Yes – 1 (Poor)
b. Maybe – 1.5 (Fair), and
c. No – 2 (Good).

The following tables provide data collated from all 4 lighting conditions.

Table 1: CPAM, OcF and ESF values for Dynamic Lighting condition

DYNAMIC LIGHTING (DL)				
S/n	LEVEL	CPAM	OcF	ESF
1.	ND I	82.34	5.42	1.96
2.	ND II	84.068	6.06	1.98
3.	HND I	81.48	7.18	1.977
4.	HND II	85.17	5.232	1.984
% MEAN		**83.26**	**5.97**	**1.97**

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Table 2: CPAM, OcF and ESF values for Diffuse Lighting condition

DIFFUSE LIGHTING (DiL)				
S/n	**LEVEL**	**CPAM**	**OcF**	**ESF**
1.	ND I	80.07	5.84	1.93
2.	ND II	83.55	6.62	1.96
3.	HND I	80.98	7.27	1.94
4.	HND II	84.19	5.58	1.97
% MEAN		**82.20**	**6.33**	**1.95**

Table 3: CPAM, OcF and ESF values for Static Cool White Lighting condition

STATIC COOL WHITE LIGHTING (SCWL)				
S/n	**LEVEL**	**CPAM**	**OcF**	**ESF**
1.	ND I	79.77	6.25	1.87
2.	ND II	82.73	6.07	1.89
3.	HND I	78.97	8.00	1.89
4.	HND II	82.88	6.50	1.77
% MEAN		**81.09**	**6.70**	**1.85**

Table 4: CPAM, OcF and ESF values for Static Warm White Lighting condition

STATIC WARM WHITE LIGHTING (SWWL)				
S/n	**LEVEL**	**CPAM**	**OcF**	**ESF**
1.	ND I	75.88	6.48	1.79
2.	ND II	79.12	6.97	1.78
3.	HND I	73.88	8.60	1.70
4.	HND II	75.75	7.52	1.59
% MEAN		**76.16**	**7.39**	**1.72**

2. Analytics-driven Visualisation:

Composite graphs were adopted to wholistically integrate the numerical data with the categorical data in a cohesive and interpretable manner (Micro Focus ADM, 2024).

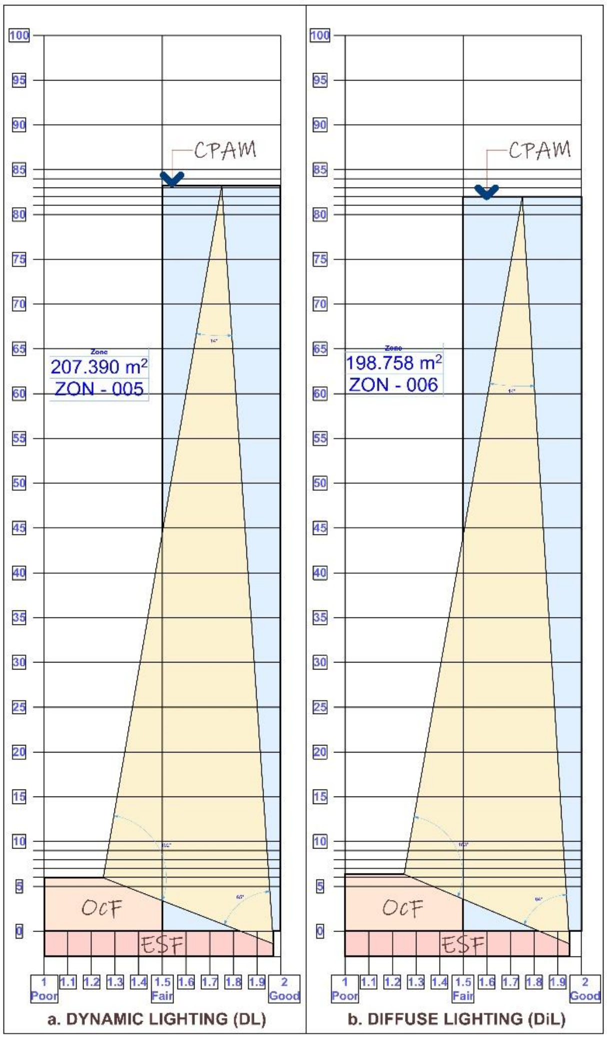

Figure 6: Dual-axes charts of DL and DiL.
Source: Authors' Archicad Workstations

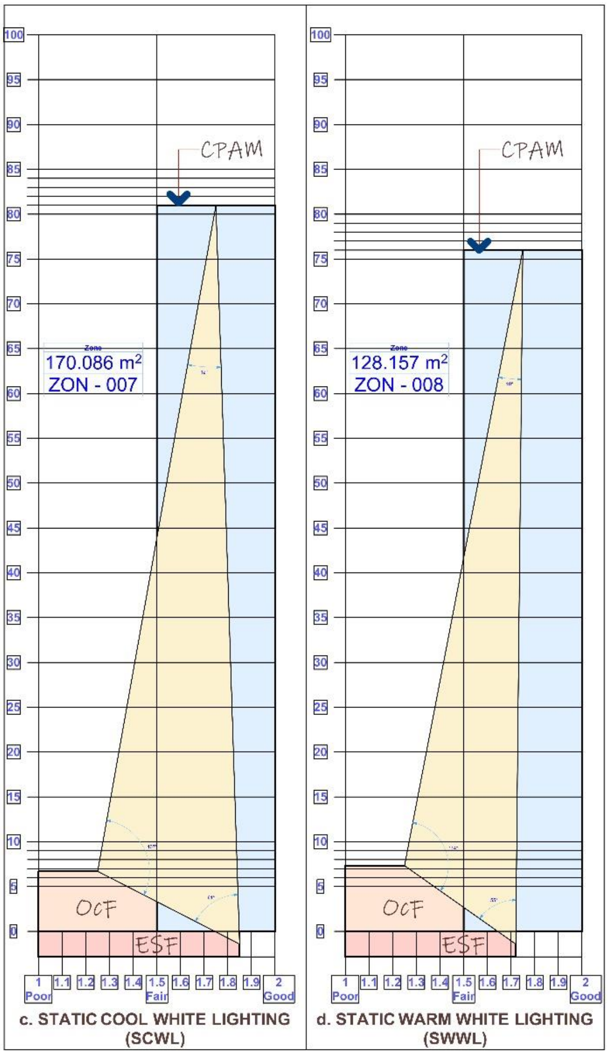

Figure 7: Dual-axes charts of SCWL and SWWL.
Source: Authors' ArchiCAD Workstations

As observed in Figures 6 and 7, multiple y-axes were used to illustrate the relationship among OcF/CPAM (proportional data), and ESF (ordinal data) in a single view.

3.Scatter presentation:
The concomitant scatter graph, as shown in Figure 8 below, elucidates the relationship between CPAM and OcF. It also identified patterns, correlations and potential outliers existing among the lighting conditions.

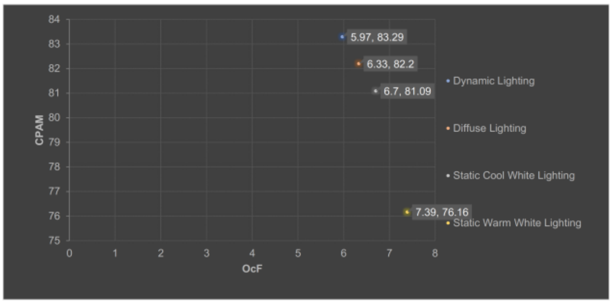

Figure 8: Scatter graph showing the relationship between CPAM and OcF.
Source: Authors' Excel Workstations.

3.2 Interpretation of Results:
The following can be deduced from the analysis of the results captured in 1, 2 and 3 respectively.

a. There existed a discernible pattern in the behaviour of the values of the CPAM, OcF and ESF. The highest value of the CPAM was observed in dynamic lighting (DL) experiments but progressively depreciated as the experiments tended towards the static warm white lighting (SWWL) conditions.
b. Ocular Fatigue (OcF), on the other hand, was highest at SWWL conditions.
c. The Eye Strain Fatigue (ESF) values were designed to respond to 'worse-case' scenarios as '1' and 'best-case' scenarios as '2'. The midway responses of '1.5' were adjudged to be 'fair'. Values advanced by this study identified that ESF tended towards '2' in dynamic lighting conditions.
d. ESF and OcF exhibited traits of a bivariate relationship (Richard, Peter, & Ruth, 1980).
e. CPAM, OcF and ESF exhibited traits of a trivariate relationship (Richard & Dean, 2007).
f. This study observed a *dose-response relationship*' effect (Wayne & Chad, 2012). This will be discussed in the preceding section.
g. Observations of the scatter graph pinpointed a potential outlier surrounding the static warm white lighting condition.

4. Discussions
This study can posit that dynamic lighting (DL) and diffuse lighting (DiL) remain the best forms of lighting that should be adopted for learning environments. Cognitive performance improved significantly in learning environments retrofitted with dynamic lighting conditions. Such an outcome meant that participants experienced lower eye strain fatigue which led to very low ocular fatigue.

Static warm white lighting (SWWL) conditions generated indicative situations which showed that participants experienced more visual discomfort when exposed to such lighting conditions. SWWL conditions spiked eye strain fatigue as participants' responses tended towards a positive affirmation of visual discomfort. This led to increased ocular fatigue and a significant drop in cognitive performance.

This study identified a bivariate relationship between eye strain fatigue (ESF) and ocular fatigue (OcF). As measures of visual discomfort, ESF is deducted from the individual responses of participants in such lighting conditions and their experience thereof (Amy & James, 2018) while OcF shows the change in blink rate before and after exposure to lighting conditions (Ali, 2017). This study identified that ESF and OcF are directly proportional. As ESF depreciated/tended towards '1', OcF increased. Eye strain fatigue worsens with increased ocular fatigue. This is supported by Excel data sheets of lighting conditions which linked depreciating ESF to an increased Δbr.

This study observed a trivariate relationship between cognitive performance, eye strain fatigue and ocular fatigue. CPAM is at its peak when OcF is at its lowest and consequent graduation of the ESF to '2'. CPAM is at its lowest when OcF was at its highest and consequent graduation of the ESF to '1'. This means that cognitive performance is greatly improved when participants experience lower/nil Δbr which leads to lower complaints of eye strain fatigue. Scrutiny of Figures 6 and 7 will identify that joining the midpoints of CPAM, OcF and ESF bars will form a scalene triangle whose area seems to interact with the outcome of the CPAM. This '*dose-response relationship'* effect comes into play between cognitive performance and the area of the triangle.

Table 5: Dose-response relationship effect between the CPAM and areas of triangles

S/n	CPAM	Area of Triangle (m^2)
1	>83%	207.390
2	≥82%	198.758
3	>81%	170.086
4	>76%	128.157

Source: Authors' excel sheets

As the areas of these scalene triangles increased, participants' cognitive performance increased and vice versa.

Data collated identified a potential outlier generated during experiments with static warm white lighting conditions. These authors revisited the SWWL data sheet for errors and/or possible oversights and observed that such errors could emanate from fittings adopted during the study. 100W bulbs were used as the source of lighting which produced considerable heat compared to other lighting fittings like 60W bulbs (Blanco County, 2024). Such intense heat could pose as a marked outlier.

5. Conclusions and Recommendations

Different lighting conditions affect the visual comfort and cognitive performance of students in the Architectural Technology programme. Understanding these effects helps in designing learning cocoons that optimize lighting conditions that will be directed toward supporting concentration, improving creativity, and general well-being. Integrating appropriate lighting strategies in consideration of both functional and aesthetic aspects is crucial for enhancing educational experiences and promoting student academic success in architectural studies. Continued research and evaluation of lighting technologies and their impact on human factors will inform best practices in educational and architectural lighting designs.

To this end, the following recommendations suffice:

a. Dynamic lighting conditions are best suited for learning environments, especially studios of architectural technology students considering the enormous academic tasks demanded by the NBTE-accredited programme. The provision of programmable controls will allow users to adjust lighting intensity, colour temperature and distribution to suit their circadian clock.

b. Fittings and fixtures concomitant with Static Warm White Light as adopted as lighting conditions in learning environments should be discontinued. This would go a long way in ensuring the visual comfort of students while improving their cognitive performance and mental acuity during learning activities.

c. The subsisting inflationary trend could deter institutions from adopting the dynamic lighting condition for their studios. In this regard, diffuse lighting could offer a suitable substitute for dynamic lighting. However, such lighting must align with natural daylighting strategies to maximise visual comfort and encourage contact with outdoor scenery.

d. Periodic testing and surveys should be carried out to get feedback from students on the lighting conditions of their studios. This will help the department, management of the institution and concerned authorities monitor the trend of academic and wellbeing performance of their students.

iv. Engagement with lighting experts in educational facility planning must be encouraged to integrate optimal lighting solutions that ensure a balance between aesthetics and functional performance.

v. The NBTE accreditation team and assessors should focus more on the lighting conditions of drawing and modelling studios of Architectural Technology departments and ensure that they meet appropriate lighting standards as these students spend the majority of their academic calendar in such spaces.

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