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RATING THE COMPONENTS OF INDOOR ENVIRONMENTAL QUALITY IN STUDENTS CLASSROOMS IN WARM HUMID CLIMATE OF ULI, NIGERIA.

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Abstract

The indoor environment of classrooms needs to be comfortable for the occupants to perform their class work effectively. To achieve this objective, architects and engineers need to be proactive at the early design stage by considering the very component of Indoor Environmental Quality (IEQ) building occupants consider most as the hindrance to comfortable living. This paper presents the findings of a post-occupancy evaluation of students' subjective responses to the various environmental qualities; lighting, odour, noise/acoustics and heat/thermal comfort in warm humid university classrooms. The aim was to rank the IEQ on the scale of students' consideration for a comfortable indoor classroom work. This was done using questionnaire to get the subjective response from the respondents. The work was conducted in two university classrooms while the students were engaged in various class activities. Valid responses were gotten from sixty-five students. The result suggests that majority of occupants (62%) rated thermal comfort number one as the component of the IEQ that usually gives them the most concern, while 71% of the respondents rated ''preference to sit beside windows''. This result is consistent with earlier studies on IEQ attributes conducted in other climatic zones in Nigeria. The findings will be helpful to designers, engineers, facility maintenance managers when taking decisions in constructing sustainable classroom blocks.

***Keywords**: classrooms, indoor environmental quality, rating, students, thermal comfort.*

INTRODUCTION

Indoor Environmental Quality (IEQ) refers to the quality of a building's environment as it relates to the health and well-being of those who occupy it. This well-being, together with productivity, learning ability of the occupants are believed to be greatly improved when the IEQ is acceptable by them. These benefits of a good IEQ are confirmed by several studies such as Wargochi & Wyon (2006); Ayeni & Adelabu (2012); De Giuli et al (2012), to name a few. At the other end of the spectrum, studying in an unacceptable indoor environment has its negative consequences. A growing body of research recognises that poor IEQ in schools, for example, may result in illness, leading to student absenteeism as well as adverse health symptoms and decreases academic performance (Mendell & Heath, 2005; Simons et al, 2010; Haverinen-Shaughnessy et al, 2012). Also, research on IEQ conducted by numerous researchers has proved its significant influence on occupants' health and productivity regarding air quality, lighting, acoustics, and thermal comfort (Fisk, 2002; Wyon & Wargocki, 2013).

However, providing an acceptable indoor environment is possible if IEQ parameters are given adequate consideration at the early design stage of buildings. Bogenstätter (2000) had noted that 20% of any decision made in the early phase of design has 80% consequences on the overall design cost. Apart from cost implication, the 'Pareto 80-20 rule' also applies to other general design success or failure whereby 80% linked to failure in design may come from 20% cause. This cause may be attributed to an issue such as not seeking the opinion of 'would be users' when designing a building. As such, early design decisions are of great significance to design outcomes. Allu et al, (2013) also suggested that assessing the IEQ should be the first step to designing a low energy building and ensuring the comfort of the occupants.

The importance of IEQ of an indoor space has been highlighted in various literature works, but there is very limited research work involving building occupants that asks them to identify the component of it that gives them most concern, especially in school settings. Peretti & Schiavon (2011) argued that building occupants are very rich sources of information about indoor environmental quality and its effect on comfort and productivity. The post-occupancy survey has identified that occupants are more ''forgiving'' of and work effectively in buildings they like (Nicol et al, 2012). Watson (2003) defined Post-Occupancy Evaluation (POE) as a systematic evaluation of opinions about building in use, from the perspective of users. It aims at identifying what the occupant considers possible mistakes or omissions that hinder comfortable living, so that lessons will be learned for future design. However, this evaluation is achieved through mutual interaction between the buildings and the users with a goal of providing improvement.

IEQ of educational buildings has been vigorously studied in primary, secondary and university classrooms. However, the various research specifically concerned with the learning effect of the learning environment of students, tends to be carried out in Western Europe and particularly in the USA (Woolner et al, 2007). Furthermore, Peretti and Schiavon, (2011) mentioned North America, Europe, and Australia as focus of Centre for the Built Environment (CBE) surveys, noting the lack of data for Asia, Africa, and South America.

Frontczak, (2011) summarized previous studies on IEQ undertaken between 1977-2009 and came out with findings that thermal, acoustics, visual environment and air quality all influence evaluation of the overall indoor environment. De Giuli, et al, (2012) evaluated the IEQ and pupil perception in Italian primary schools and found no significant differences between the reaction of girls and boys belonging to the same school. Kim, et al (2013) investigated gender differences in occupants' perception on various aspects of the indoor environmental quality with samples from North and South America, Asia, Middle East, Europe, and Oceania. Among the four main dimensions of IEQ notably Indoor Air Quality (IAQ), thermal comfort, lighting, and acoustics; the literature gave prominence to IAQ and thermal comfort. However, findings from these regions may not be generalized as being the same in other parts of the world, especially in the tropical regions, where very limited research on IEQ has been conducted.

Phase two of the Department of Architecture, Chukwuemeka Odumegwu Ojukwu University (COOU), Uli (Figure 1) is yet to be built. Students have been using phase one classroom/studio (Figure 2) for years. Literature reviews have reported various cases of unacceptable conditions in indoor spaces especially in institutions of higher learning in

Nigeria. For example, Olanipekun (2014), evaluated the thermal perception of occupants of naturally ventilated hostel blocks and observed that occupants frequently complained of inadequate comfort in their indoor environment of their buildings because of high temperature especially in the afternoon periods. Hayatu, et al (2015) assessed thermal conditions in school theatres in Nigeria and reported thermal discomfort as a major problem to the occupants of the theatres. Uzuegbunam, (2011) investigated the thermal conditions in hostel buildings in Enugu, Nigeria, and reported that the western style of architecture which conserves heat and limits infiltration of outside air to the interior (creating indoor thermal discomfort) is replicated in Nigeria. However, these research works focused only on thermal comfort which is one of the components of IEQ. There is a need to evaluate the various components of IEQ of the architectural studio of Uli Campus of COOU and get a feedback of how the users (students) rate the various components of IEQ. This feedback will provide guidance during the review of phase two of the architecture studio.

This paper, therefore, presents the findings of a field study of Post-Occupancy Evaluation (POE) of students' subjective responses to the various environmental qualities namely: lighting, odour, noise, and heat/thermal comfort in warm-humid university classrooms in Uli, Nigeria. The aim was to rank the IEQ on the scale of students' consideration for a comfortable indoor classroom work.

Figure 1: Phase 2 view from courtyard

Figure 2: Phase 1 view from courtyard

CONCEPTUAL FRAMEWORK

Indoor Environmental Quality (IEQ) refers to the quality of a building's environment as it relates to the health and wellbeing of those who occupy it. Researchers often narrow IEQ attributes to four basic components namely; Lighting, Noise, Thermal environment and Indoor air quality.

Buildings have to deal with acoustic issues coming from airborne sounds, noise from adjacent spaces, noise from office equipment, noise from nearby facilities or noise from students themselves in school. A more reliable finding is that chronic noise exposure impairs cognitive functioning and several studies have discovered noise-related reading problems (Haines, et al, 2001) and deficiencies in pre-reading skills (Maxwell & Evans, 2000). As a result, reviews of the consequences of aspects of the physical environment tend to conclude that acoustics and noise are important factors, especially, in a school environment (Earthman, 2004). Noise is used as an example to reiterate the need not to overlook the various components of IEQ when assessing building performance.

A good learning environment that is thermally comfortable cannot be overemphasised, especially in this era of global challenge posed by climate change. Thermal comfort is defined by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) as ‘‘that condition of mind that expresses satisfaction with the thermal environment’’ (ASHRAE 55, 2013) and sets an 80% satisfaction quota as target for human comfort. Thermal comfort factors include temperature, humidity and air flow. Air temperature is an important design parameter for thermal comfort. Relative humidity (RH) is a measure of the moisture in the air, compared to the potential saturation level. High humidity reduces evaporation of water and sweat. According to Elaiab (2014), high humidity accompanied by high ambient temperature causes a lot of discomfort, while Indraganti (2010) argued that low humidity can cause health related issues. In naturally ventilated buildings, especially in the tropics, air movement is also an important consideration in the thermal comfort of the subjects.

Exposure to an environment that has poor indoor air quality can result to major negative impacts on the health of the occupant. Early design considerations such as building location, orientation, well designed spaces that have good ventilation, help to solve the problems associated with poor indoor air quality. Al horr et al, (2016) added that based on research on sick building syndrome (SBS), it is important that buildings be designed in such ways as to reduce their exposure to indoor chemicals.

THE STUDY AREA

Nigeria is located just north of the equator, this makes it experience tropical climate characterised by hot and wet conditions. The country experiences two major seasons throughout the year, the dry season and the rainy season. For most part of the country (south east inclusive), the wet season runs from April to middle November, while the dry season runs from middle November to March.

The study area, COOU, Uli is situated in Anambra State of South East of Nigeria, has geographical coordinates: 5° 47' 0" North, 6° 52' 0" East. There are basically three climate types within Nigeria: Hot & Dry, Warm & Humid and Composite between the two (Batagarawa, 2012). The study area under discussion falls within the Warm Humid, with an average temperature of approximately 28.5^{o}C. The dry season runs from the late part of November to March, while rainy season runs from April to mid-November. The annual relative humidity is 75% reaching 85% in the rainy season. COOU has three campuses; Igbariam, Awka and Uli campus. The department of architecture is in Uli campus. Highlighted in dark red colour in Figure 3 is the location of Uli in Anambra State, Nigeria while Figure 4 shows the location of the study school (Chukwuemeka Odumegwu Ojukwu University in Uli).

Figure 3: Map of Nigeria showing Anambra State
Source: wikipedia.org (2018)

Figure 4: Map of Uli
Source: Google (2018)

METHODOLOGY

Data collection

There is no post-occupancy evaluation tool generally accepted as the only standard adopted in measuring occupant ratings of the built environment (Veitch, et al 2007; Kim, et al, 2013). However, building sustainability rating tools assess the indoor environmental quality of buildings using two broad strategies: occupant questionnaires and instrument measurements of physical conditions inside buildings (de Dear et al, 2016).

Various types of scales have been adopted by researchers in the Post Occupancy Evaluation (POE) of the IEQ in buildings. Turunen et al (2014) evaluated the IEQ of sixth-grade students in Finland and used a 4-point rating scale of 1 (Excellent). 2 (Good), 3 (Satisfactory) and 4 (Poor) to ask children to describe their health status. A 4-point scale of 1(Never), 2 (Sometimes), 3 (Every week) and 4 (Almost daily) was adopted in the same survey to ask about the indoor air factors in the classrooms. De Giuli et al (2012) evaluated the IEQ of pupils of primary schools in Italy and used a four-point rating scale. The argument was that ‘‘it forces pupils to give an answer that is clearly positive or negative’’. Neutral option was removed, arguing that choosing neutral option results in loss of information. Some researchers adopted both objective and subjective methods while some others such as Stokols & Scharf (1990) used only subjective approach.

Questionnaires, observations and the physical measurement of the classroom spaces were adopted to collect data from the participants. Two classroom spaces randomly selected for this study, studio 300 level and M.Sc. 1 studio, measured 81m^2 and 143 m^2 respectively. The students that arrive early in the classrooms usually open the windows and those that leave late often close the windows. The two classrooms (phase 1) have been in use for years, so there was a need to evaluate them to guide in the review or design of phase 2.

The survey was conducted in January 2017 when the researcher visited the school. The administrative protocol to have access to the participants was brief because the researcher is a staff of the institution. The students, shown in Figure 3 receiving their lecture after the survey, had no prior information about the nature of the study. However, before the commencement of the survey they were informed that participation was voluntary and the information they provide would be kept confidential.

Figure 3: Students having lecture after the survey

Participants

A total of 75 subjects from a sample population of about 380 students of the department of architecture, Uli, randomly selected was distributed questionnaires. 65 participants completed the questionnaires representing 86%, while 10 opted out. 100% of these questionnaires were correctly completed. Out of these 65 participants, 77 % were male, while 23% were female. However, survey based on gender differences was not one of the objectives of this study. The majority of the students’ (78%) ages ranged from 18-24 years. Nigeria is typical of the tropical region where the sun is known to be directly overhead at noon. According to

Adunola, (2012); Eludoyin, (2014), 12:00 pm to 16:00 pm is the hot discomfort period of the day in the country, and it was deemed as the best time period to conduct the survey. An additional hour was spent to observe and note the behaviours of the respondents as they adapted to the indoor conditions.

Participants were asked to vote where they usually prefer to sit in the classroom (*"beside the window, at the rear of the classroom or centre of the classroom''*). A follow-up question asking them to rank the reason why they would prefer to sit in that position (''*to avoid noise, better lighting, better thermal comfort/temperature, to avoid odour''*) using a four-point scale ranging from 1(not important) to 4 (most important). The last question, using the same four-point scale, asked them to rank the components of the IEQ that they consider would make them become more comfortable while in the classroom (''*Less noise, better lighting, less temperature and less odour"*). The last two questions seemed related, but the reason was to see how the rating they gave to both questions correlated (validity).

RESULTS AND DISCUSSION

The findings of the PO evaluation of the students' subjective responses to the various IEQ are summarized below.

(i) Subjects' response to the question "*where do you prefer to sit in the classroom*?''

The subjects' responses, as shown in Figure 6, indicate that 71% of the respondents prefer to sit beside the windows, while 23% would prefer the centre of the classroom as their sitting position. Only 6% of the respondents would prefer to sit at the rear of the classroom. 79% of this number which prefers to sit beside the window rated thermal comfort their number one reason. Hence, there is a strong relationship between thermal comfort and window openings which agrees with the previous studies that window opening is the number one adaptive opportunity by occupants of buildings to allow air movement. The fans, though in good condition, were not in use during the survey even when electricity was available. However, only 10% of the number that prefers to sit beside the window rated odour last on their scale of reasons for preferring to sit near the window. Hence, there is a very weak relationship between preferring to sit near the window and odour. The location of the campus in a non-industrial environment might be the reason for this weak relationship.

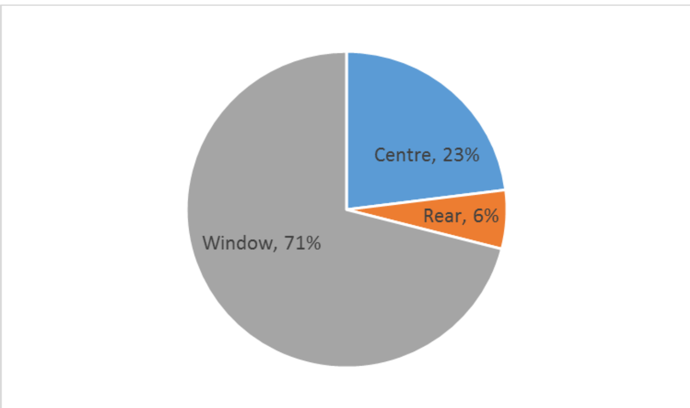

Figure 6: Pie Chart showing percentage of responses to sitting preferences in the class/studio {n (respondents) for centre=15, n for window=46, n for rear=4}

(ii) Subjects' response to the question "*rank the reason why you prefer to sit in that position''?*

Subjects' responses indicate that 65% of the respondents rated "better thermal comfort" as the most important reason why they prefer to sit in a particular position, better lighting, avoidance of noise and odour were rated 20%, 7.5% and 7.5% respectively. The responses are consistent with those in result (i). Furthermore, 89% of the respondents rated thermal comfort by voting ''*most important* (4) *and important* (3)*''* as their reason for preferring to sit near the window in the classrooms.

(iii) Subjects' responses to the question ''*rank the component of the IEQ you consider that will make you comfortable while in the classroom*"*'?*

Subjects' responses, as shown on Figure 7, indicate that the respondents ranked ''*Less temperature/ better thermal comfort''* 62%, ''*less noise/acoustic and better lighting''* each ranked 15% while ''*less odour''* was ranked only 8%. Questions (ii) and (iii) appear similar, but the intention was to check how consistent the participants were in answering questions and whether the answers to both questions could correlate. Generally, both questions show consistency having followed the same trend in the rating. Majority of the respondents rated thermal comfort very high, while odour was rated low in both questions (ii) and (iii).

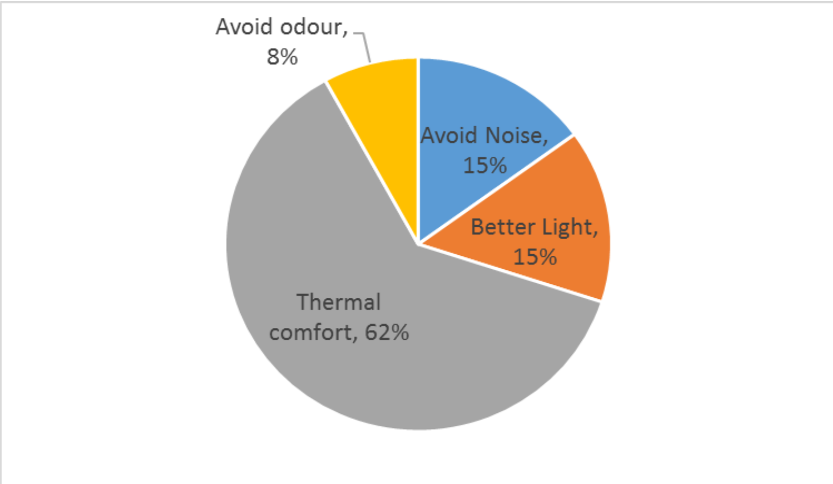

Figure 7: Pie Chart showing percentage ranking of IEQ components by the respondents {n(respondents) for noise=10, n for light=10, n for thermal=40, n for noise=5}

(iv)Subjects' acceptability answer to the question ''*is the classroom presently comfortable*"?

Subjects' responses as shown on Figure 8 indicate that the classrooms' general comfort was acceptable to 54% of the respondents, while 46% rated it unacceptable. Since comfort zone is defined in terms of thermal environment that are ''acceptable to at least 80% of the occupants'', direct acceptability question can be adopted (Kwok, 1977), in determining a comfortable indoor environment. Considering this requirement, the percentage of students who were satisfied with the indoor environmental conditions was significantly lower when compared with the 80% acceptability criterion set by ASHRAE Standard, 55.

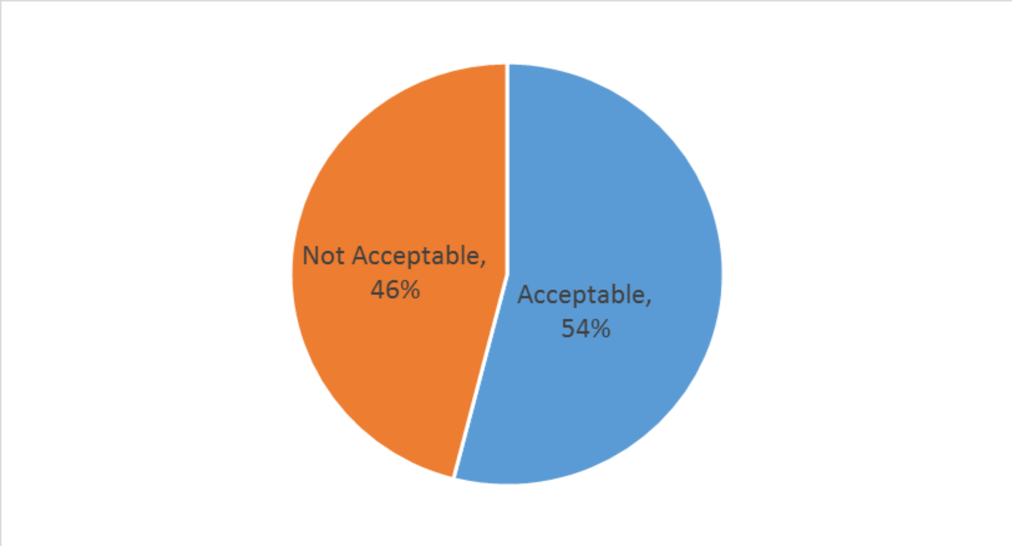

Figure 9: Pie Chart showing percentage of acceptability to IEQ {n(respondents) for acceptable=35, n for non-acceptable=30}

CONCLUSION

Field subjective survey of 75 subjects, with 65 participants completing the questionnaire, (using POE survey technique), in the university classroom of COOU, Uli campus was conducted. The following are the key conclusions of the study:

i) Majority of the respondents ranked thermal comfort as the component of IEQ that gives them most concern for comfortable indoor classroom work. This is consistent with other previous work in Nigeria. Since thermal comfort was rated highest among the components of IEQ, it is argued that it plays an important part in determining whether an indoor environment is acceptable or not

ii) The majority of the respondents prefers to sit beside the window. Thermal comfort was adjudged the number one component of the IEQ that gives them most concern to comfortable indoor classrooms. Thus, the preference to sit beside windows correlates well with window opening.

iii) The majority of the respondents accepted the general indoor condition of the classrooms. In addition to the above findings, the researcher observed different adaptive options employed by some students to maintain comfort, especially those staying in the middle and at the rear of the classrooms. While some were drinking water, fanning themselves with papers, some others adjusted their positions by moving closer to the window. What actually surprised the researcher was the inability of the students to put on the ceiling fans which were in good condition even when electricity was available. However, it was reasoned that it might be because most of the students who accepted the general thermal condition of the classrooms may not like the ceiling fans, to be put on. However, on further discussion with the students most seem oblivious of the existence of the fans in their classrooms.

The results of this study show the rating of the different components of IEQ in a university building and highlight the importance of a post-occupancy evaluation. The findings from this report may be useful in the review and design of the second phase of the department of architecture COOU. This information is also important for further research on thermal comfort. The findings may also generally be useful to designers, engineers, facility maintenance managers and other stakeholders in educational institutions when taking decisions on construction of classroom blocks in order to increase the comfort of the occupants.

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