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Post Occupancy Evaluation of Contemporary Educational Buildings in Ghana. A Case Study of the KNUST/IDL Building at Kwabenya

by

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DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Kwame Nkrumah University of Science and Technology, Kumasi or any other educational institution, except where due acknowledgement is made in the thesis.

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ABSTRACT

The general notion in most public buildings is that occupants are comfortable with their indoor environmental conditions so long as they report to work and carry out their assigned duties. Such a notion has led to failure to consider it necessary to monitor and evaluate occupants' perception of comfort in their respective working environments. Essentially, the value of systematic learning from Post Occupancy Evaluation (POE) is primarily to identify additional benefits that can be obtained from the evaluation allowing for the fine tuning to enhance the performance of future buildings. The study adopted POE and its rationale as a building feedback mechanism. The aim of the study was to conduct a POE of contemporary educational buildings in Ghana. The study narrowed down to the particular case of the KNUST/IDL building at Kwabenya in Accra. The objectives were to evaluate the performance of the case study building and to identify areas of improvement of contemporary educational buildings in Ghana. The study adopted qualitative research approach to evaluate the subjective responses of occupants in the case study building. Instruments for data collection included interviews, observation and case study approach. 94 respondents out of a population of about 658 participated in the study. Data was presented in the form of descriptive and explanatory narrations using content analysis for analyzing the data. Results showed that extensive use of glazing permit high penetration of solar radiation and heat gain leading to poor indoor environmental conditions. Results also showed that extensive use of glazing has led to the heavy integration of HVAC systems to achieve human comfort in contemporary educational buildings in Ghana. The study concluded that dissatisfaction with the built environment has negative effects on the health, comfort and productivity of occupants. The study recommended that passive design strategies which are sustainable, economical and environmentally friendly can be used to achieve human comfort.

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DEDICATION

To God Almighty, you never gave a promise that the journey will be easy but your grace and mercy has brought me this far.

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My deepest and foremost gratitude goes to the God Almighty, for the strength, resources and the idea that victory is for those who never give up. Father, you have always been with me through thick and thin.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Buildings should be designed to meet the needs and desires of occupants. The purpose of a building is defeated if the overall building performance cannot be measured against the following parameters: the function of the building, the environmental conditions of the place, aesthetic factors, the culture of the people and fit for purpose. According to Kportufe (2015) a poorly designed built environment can negatively affect occupants' productivity. Buildings have to provide both physical and psychological satisfaction to occupants. A well designed built environment has the potential to be therapeutic rather than ailing. To this end, buildings should not only be exemplars of form and aesthetics but should also aid in the development of the building occupants (Simon, 2015). To users and the community, buildings should meet their needs and aspirations by supporting their daily activities.

Public buildings are designed and built to meet specific needs of certain groups of people that are already determined before construction. The ability of a building to successfully accomplish the purpose for which it was designed measures its success (Mayaki, 2005). Building performance evaluation facilitates the realization of this objective and the factor of user perspective on buildings is crucial in the whole evaluation process (Olatunji, 2013).

According to Wilkinson et al (2011), the most important factor, as a benchmark of a building's success in meeting the design objectives is the level of user satisfaction. Studies have shown that user satisfaction is a highly valuable tool in assessing the performance of buildings and understanding human attitudes, needs and expectations towards buildings in use.

Post Occupancy Evaluation (POE) is one of the best practical ways to find and analyze the performance of buildings. According to Hewitt and Higgins (2005), POE is described in general terms as the broad range of activities aimed at understanding how buildings perform after construction is completed. Deng et al (2016) and Mustafa (2017) further explained POE as the process of evaluating buildings systematically from the perspective of the users after they have occupied the building. POE is valuable in the building industry, especially, healthcare, education, commercial and housing in which poor building performance will affect running cost, occupants' health and productivity (Lawrence, 2013). POE contributes to improving the quality of buildings and building projects delivery process by identifying the strengths and weaknesses of buildings from users' perspective (Kim et al, 2005; Khalil and Nawani, 2008). Such information, according to Lawrence and Keime (2016), can be used markedly to improve the process and design of buildings by highlighting areas for future designs improvement.

1.2 PROBLEM STATEMENT

Research has demonstrated that the quality of indoor environmental conditions has considerable impact on the health and productivity of occupants in public buildings (Sedzro et al, 2017; Agnieszka and Mats, 2013). Statistical evidence also shows that occupants of public buildings who are dissatisfied with indoor environmental conditions are less productive in their workplace (Adrian, 1995). The topic of indoor environmental quality (IEQ) therefore seems as a growing concern as a major factor influencing occupants' health, well-being and productivity. Human comfort as defined in the ISO 7730 standards is that condition of mind which expresses satisfaction with the surrounding environment (Hussein and Rahman, 2009).

A study by Simons (2015) involving the simulation-based exploration of the thermal performance of selected multi-storey office buildings in Accra, Ghana, suggests that comfort satisfaction within an environment is of major concern to occupants since it has direct influence on their productivity and as such should not be compromised. Available literature further reveals that comfort and satisfaction are not often attainable due to the complex nature of public buildings in Ghana (Sedzro et al, 2017).

The extensive use of glazing has led to the heavy integration of HVAC systems in the KNUST/IDL building at Kwabenya. As a result, there is considerable levels of dissatisfaction with certain aspects of the indoor environmental conditions in the building. Dissatisfaction in the building has negative effects on the health, comfort and productivity of occupants.

Much research has been conducted on occupants' comfort, satisfaction and productivity but there is a deficiency to find out the relationship between indoor environmental parameters and occupants' productivity in buildings. Furthermore, most of the researches on POE focus on aspects of energy efficiency and physical measurement of environmental conditions. Thus, there is the need to establish the relationship between human comfort and productivity in buildings from the perspective of occupants.

1.3 RESEARCH QUESTIONS

The study seeks to answer the following question:

1. What is the performance of the KNUST/IDL building at Kwabenya?
2. What are the areas of improvement of contemporary educational buildings in Ghana?

1.4 AIM AND OBJECTIVES

To conduct a Post Occupancy Evaluation (POE) of contemporary educational buildings in Ghana for fine tuning towards achieving human comfort and productivity in future projects.

The specific objectives are:

1. To evaluate the performance of KNUST/IDL building at Kwabenya; and
2. To identify areas of improvement of contemporary educational buildings in Ghana.

1.5 RESEARCH JUSTIFICATION

Buildings are designed and constructed to meet certain requirements. However most of the recently constructed educational buildings in Ghana do not perform as anticipated implicitly affecting running cost, occupants' performance, health, safety and in most cases human comfort (Sedzro et al, 2017). One of the efforts at addressing these challenges have essentially been through Post Occupancy Evaluation (POE) which provide useful information on the performance of buildings as well as feedback on the satisfaction or comfort of occupants. A significant contribution of this research to the body of knowledge is the provision of empirical evidence with respect to the influence of human comfort on productivity in buildings. To this end, the evaluation of post commissioning of contemporary educational buildings remain an extremely cost effective measure to improve occupants' productivity when carried out and implemented.

1.6 RESEARCH METHODOLOGY

The study was conducted based on case study description and POE surveys of users of the KNUST/IDL building at Kwabenya. The study analyzed the subjective views of users to

ascertain their opinions on the influence of human comfort on their productivity levels in the building. The survey questions covered environmental parameters like thermal comfort, acoustic comfort and visual comfort. The study adopted content analysis and qualitative research approach using a combination of descriptive and explanatory strategies. Data collection instruments included interviews, field observations and case study. The population for the study was occupants of the KNUST/IDL building at Kwabenya in Accra. The study adopted probability sampling using stratified random sampling to select participants until the point of saturation was reached. Ethical principles were strictly adhered to throughout the study in the process of collecting data from the participants.

1.7 RESEARCH SCOPE/DELIMITATION

The study was limited to the evaluation of occupants' comfort on indoor and outdoor environmental parameters such as thermal comfort, lighting and room acoustics in contemporary educational buildings in Ghana. Most studies on POE of buildings focus on energy consumption, running cost and physical measurements of environmental parameters such as temperature and relative humidity. According to Fransson and Vastfjall (2007), occupants' subjective ratings prove to predict overall satisfaction of comfort better than the above mentioned objective indicators. As a result the aforementioned POE indicators were beyond the scope of this study because the intention was to highlight occupants' feedback information as inputs for improving contemporary educational buildings in Ghana. The study focused on the KNUST/IDL building at Kwabenya as a case study for data collection and analyses. This particular building was chosen for case study because of the heavy integration of HVAC systems to achieve human comfort in the building. The study was limited in scope

to the performance of the case study building in relation to human comfort, health and productivity of the occupants.

1.8 RESEARCH ORGANIZATION

The research work was structured into five chapters as follows:

Chapter one highlights the background of the study, statement of the problem, the aim and objectives of the research, the research questions, the significance and scope of the study. Chapter two focused on review of relevant literature in the field of post occupancy evaluation of public buildings and occupants' perception. Chapter three described the research design, the population and sample of the study as well as data collection methods. Chapter four discussed and analyzed the data collected. Chapter five discussed the summary of the findings, conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter explores related Post Occupancy Evaluation (POE) studies. It discusses the various building performance indicators that claim to link human comfort in public buildings to the productivity of occupants. Over hundred documents including journal papers, conference papers as well as various dissertations have been examined in order to provide the

necessary background, to demonstrate the significance of the study and to identify specific knowledge gabs associated with human comfort and productivity in public buildings.

2.2 POST OCCUPANCY EVALUATION

Buildings are paramount to the day-to-day running of human activities. Technically speaking, the basic function of a building is to act as a shelter for its occupants and allow them to carry out their respective activities in a conducive environment (Pheng et al, 1998). Buildings like any other products are designed and constructed to meet the expectations of stakeholders (clients, professionals, users and the community).

Building evaluations have traditionally been through Post Occupancy Evaluation (POE) surveys that assess how satisfied occupants are with their surrounding environments (McDougall et al, 2002). The term POE is the study of performance evaluation on completed building projects from the perspective of users (Ilesanmi, 2010). In an attempt to widen the scope Duffy (2008) describes POE as that aspect of building appraisal that is principally concerned with the aim to find how completed buildings perform; determining possible misfits, mistakes or omissions and accumulating information for future programming and design efforts. Typically, the criteria for judgment are the fulfillment of the functional and the occupants' needs (Turpin-Brooks and Viccars, 2006). POE serves as a way of providing subjective and objective feedback that can inform planning and practice throughout the building's life cycle from the initial design to occupation (Gou and Lau, 2013). POE assesses how well buildings match occupants' needs and it also identifies ways of improving building design, performance and fitness for purpose. It also involves the systematic evaluation of

opinions about buildings in use, from the perspective of the people who use them (TurpinBrooks and Viccars, 2006).

POE is not a new concept, with its development in the UK, being encouraged in the early 1960s through architectural practice research of the Royal Institute of British Architects (Turpin-Brooks and Viccars, 2006). Egan (1998) posits that the re-emergence of POE was due to a proposal that the construction industry should focus on the customer. Internationally, POE has been endorsed on a longer term basis as a useful addition to architectural practice (Cooper, 2001). Turpin-Brooks and Viccars (2006) confirm that POE can provide an objective measure of users' satisfaction for improvement in the construction industry. Smith et al (2011) advocates that user perception in the built environment has shown that perceptions are an integral component of workplace satisfaction. According to Kim et al (2005) and Meir et al (2009), users' perspective while evaluating the performance of buildings can be captured by adopting the following building performance indicators: spatial or functional comfort, building integrity in terms of structural and material performance, indoor and outdoor air quality, visual comfort, thermal comfort and acoustic comfort.

2.3 TOTAL BUILDING PERFORMANCE

Total building performance is a set of integrated strategies, which focuses on bringing about utmost efficiency and performance in the design and construction of buildings (Pheng et al, 1998). It is the process of integrating inherently the following concepts into a building: air quality, visual performance, spatial performance, acoustical performance, thermal performance and building integrity (Low et al, 2008). These six concepts will be the focus of the study in examining the impact of human comfort on productivity. Yang and Peng (2001) propose measuring the performance of a building by considering its organizational flexibility,

technological adaptability, individual comfort and environmental performance. Wagner et al (2014) and Fathian and Akhavan (2006) further advocate that in assessing the performance of a building, occupant comfort becomes a decisive factor. This is to suggest that total building performance aims to develop processes to deliver high performance buildings to cater for the needs and requirements of occupants.

Leaman and Bordass (2000) present evidence that air-conditioned buildings that are usually 15m deep across have more negative effect on perceived productivity than naturally ventilated buildings that are less than 15m across. Most of the recently constructed public buildings rely on technology aided strategies to achieve human comfort with increasingly sophisticated heating, ventilation and air conditioning, which according to Pheng et al (1998) in such enclosed spaces, unpleasant odours can be inevitable.

2.4 COMFORT AND PRODUCTIVITY

According to Feige et al (2013) factors that constitute comfort is subjective and varies from person to person, however, it is possible to define factors which can be perceived as unpleasant for most people. In general terms, Feige et al (2013) define comfort as the absence of unpleasant sensations, which has positive effects on the well-being of occupants. To determine what people find comfortable in their environment, Feige et al (2013) in their study, identified three environment-related parameters namely physical comfort, functional comfort and psychological comfort. The study explained further that "physical comfort refers to biological responses and body dimensions such as protection and security, light and illumination, air quality, climate, noise and ergonomics. Functional comfort also relates to the suitability of the environments for specific tasks, including disturbances and distractions, interruptions,

distances between work colleagues, supervisors, resources and functional areas. Psychological comfort refers to individual and interpersonal space-related needs such as social and spatial variables like privacy, crowding, territoriality, status and control over the environment". The study juxtaposed that physical comfort is the necessary condition for the other two categories of comfort. Leaman (1995, 1990) presented the idea that a possible relationship exists between the quality of environmental conditions and the productivity of occupants. A survey conducted by Hughes (2007) suggests that environmental qualities that encompass spatial arrangement, thermal comfort, visual comfort as well as acoustic comfort will affect the attitude of occupants. In addition, many studies have shown that the factors of design qualities and environmental qualities such as layout and ergonomics, air quality, thermal condition, lighting and noise have influence on occupants' productivity (Sullivan et al, 2013).

According to Madeo and Schnabel (2014), there is a growing body of evidence linking the physical environment to occupants' productivity. Productivity is considered as the key to success in every organization, however, Jaaskelainen and Laihonen (2013) advocates that it is a very difficult task to measure occupants' productivity as there are no exact measuring indicators. Occupants' productivity is dependent on comfort and satisfaction in the built environment (Clements-Croome and Kaluarachchi, 2000); in support of this, Gensler (2005) adds that a better working environment could significantly increase productivity. While there is no proof that maximum comfort leads to maximum productivity, ample evidence shows that an improved healthier environment would decrease worker complaints and absenteeism, thus indirectly enhancing productivity (Abdou et al, 2017). A number of studies have proven that evaluating productivity of occupants could be carried out through individual measures by

checking on issues like sick building syndrome, rate of absenteeism and job satisfaction (Sullivan et al, 2013). Clements-Croome (2015) further highlighted that a lack of productivity in the workplace can be equated to many issues such as leaving early, arriving late, taking frequent and longer breaks along with a general frustration with the built environment.

Sick building syndrome is a very subtle cause of dissatisfaction among most building occupants (Azlan et al, 2015) and it is one of the key negative health aspects and discomfort in buildings (Smith and Pitt, 2011). The environmental conditions of sick building syndrome emerged as a recognizable environmental problem in the 1980s when the move for airconditioned buildings began (Tong and Leaman, 1993). Smith and Pitt (2011) identified poor ventilation, enabling the build up of air pollutants as one of the major causes of sick building syndrome. Symptoms of illness relating to sick building syndrome include mental fatigue, headaches, dizziness, itching, nausea, wheezing, hoarseness, cough and airway infections; eye, nose and throat irritation; skin rash, dry skin and mucous membranes (Rooley, 1997). These symptoms, according to Smith and Pitt (2011), generally disappear shortly after leaving the building. Fisk (2000) conducted a study which found that sick building syndrome is a major factor for absenteeism among workers who are dissatisfied with their workplace environment. Roelofsen (2002) conducted a study of 61 office buildings, with approximately 7,000 respondents, regarding their perception of and satisfaction with the quality of environmental comfort in their office. The results show that about 50% of workers reported that sick building syndrome is very notorious and disengage them from their work. It further shows that the rate of absenteeism for workers who experience signs of environmental discomfort in their workplaces is 5% of 2,000 working days. It is therefore reasonable to conclude that workplace environmental discomfort leading to sick building syndrome is a

major cause of absenteeism among occupants in public buildings. The linkage between sick building syndrome and the frequency of absenteeism indirectly affects occupants work and productivity. This is to suggest that a healthy building with optimum environmental conditions usually results in healthier and more productive occupants. Therefore, this study intends to further establish the relationship between environmental comfort and occupants' productivity.

2.5 DESIGN QUALITY

Architects and other leading building professionals should consistently direct and guide project team members through the process of achieving total building performance, human comfort and productivity. Research has shown that improving the working environment reduces complaints and absenteeism and increases productivity. Designers should therefore aim to design public buildings to be as intuitive as possible. According to Dorgan and Dorgan (2005) the design quality is composed of factors such as space, interior design and layout, building envelope and structural systems. Haynes (2007) suggests that to ensure that optimum built environment is created, consideration should be given to the needs of the occupants.

Leaman and Bordass (2005) conclude that to ensure public buildings are best for human occupation and productivity:

- There should be opportunities for personal control.
- There should be rapid responds to environmental issues.
- There should be shallow plan forms, preferably with natural ventilation and less technical and management-intensive systems.
- There should be enough room for people to work in, and appropriate zoning and control of heating, cooling, lighting and ventilation.

According to Pheng et al (1998), in almost all environments, the layout of a building should be designed and oriented in such a way that direct sunlight will not penetrate the working areas. The building orientation must be taken into consideration because the path of the sun affects the performance of daylight in the working spaces (Pheng et al, 1998). Spatial performance elements address the functionality and efficiency level of the features of building facilities. These elements include accessibility, spatial capacity for activities and adequacy of necessary facilities (Hamzah et al, 2016). These elements, according to Pheng et al (1998) are directly connected to the activities within a building and are required to be in conformity to the specific needs of occupants. Building envelope including its appearance exerts a certain influence over the amount of daylight and heat that penetrates and stores in buildings respectively (Pheng et al, 1998), for instance in the case of a double-layer façade. Pheng et al (1998) posit that the material properties of the building envelope such as the transmission, diffusion and colours of the materials used can also affect human comfort.

2.6 ENVIRONMENTAL QUALITY

Environmental quality has direct influence on the health and productivity of occupants (Fisk, 2001). From an environmental perspective, the research addresses the issues of indoor and outdoor environmental qualities which affect the comfort, health and productivity of occupants (Choi et al, 2012). The environmental quality is composed of factors such as temperature, humidity, noise and lighting (Dorgan and Dorgan, 2005; Lan and Lian, 2009). According to Wang et al (2012a, 2012b) and Pei et al (2015), the following basic factors measure the quality of living in a built environment – thermal comfort, visual comfort, acoustic comfort and air quality. It is essential for buildings to have a good quality environment, as it affects the productivity and health of the building occupants

(Kamaruzzaman and Sabrani, 2011). Leaman (1995) in his attempt to establish the relationship between environmental quality and productivity of occupants concluded that occupants who are dissatisfied with temperature, air quality, lighting and noise conditions in their surroundings are more likely to be less productive.

According to Smith and Pitt (2008), occupants prefer built environments with reasonable number of plants to those without. Plants can bring a range of qualities to the built environment including reducing ambient noise levels and improving air quality by absorbing toxins from vehicular and other mechanical emissions (Smith et al, 2011). Additionally, plants absorb carbon dioxide, balance indoor relative humidity and absorb airborne particles. A range of literature exists regarding the psychological and perceptual benefits of plants such as increasing privacy, acting in a restorative way, therapeutic influences and affecting mood (Relf, 2005; Shibata and Suzuki, 2002). Another study investigating whether stress-reducing effects occur when quality environmental conditions are present suggests that environments with plants are perceived to be more attractive (Dijkstra et al, 2008).

2.6.1 THERMAL COMFORT

Thermal comfort as defined by the International Standards Organization (ISO) and the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) is that condition of mind which expresses satisfaction with the thermal environment (Hamzah et al, 2016; ASHRAE, 2013 and ISO, 2005). According to Efeoma and Uduku (2014), the wider research community in the building industry including architects, engineers and quantity surveyors accept this definition of thermal comfort. Shove (2003) in his analysis described thermal comfort as a feeling of contentment or a state of physical and mental well-being. This

is to suggest that thermal comfort is a product of occupants' response to their thermal environment which is subject to their personal condition. From the above definition it can be deduced that thermal comfort is determined by environmental and personal factors. The environmental factors include radiation, air velocity and relative humidity whiles the personal factors include clothing, metabolic rate or level of activity, food and drink, acclimatization, body shape, subcutaneous fat, age, sex and state of health (Hamzah et al, 2016). Thermal comfort is not only determined by environmental factors because the same environmental conditions would provide different thermal comfort for occupants with different personal conditions. This research however focuses on only environmental factors to determine thermal comfort assuming the same personal factors apply to all occupants.

The thermal environment is one of the key factors that affect occupants' performance. A study of physical environmental comfort on employees' performance in office buildings in Malaysia was carried out by Azlan et al (2015). The study was based on case studies of three public universities in Malaysia. The study shows that maintaining comfortable environmental conditions in workplaces is vital as it creates a healthier building with optimum thermal conditions, which will enable employees to be healthier and have a lower absenteeism rate, and hence be more productive. Maintaining an acceptable level of thermal environment should therefore be addressed in a more sustainable manner. According to guidelines on Occupational Safety and Health in public buildings (OSH, 1996), occupants who sit nearer to direct sunlight and those who sit under air-conditioning vents in the same environment should have customized and regulatory control over their thermal environments. Studies show that the more control occupants have over their environment, the more likely they are to be satisfied and achieve greater productivity (ASID, 2005a).

2.6.2 ACOUSTIC COMFORT

Acoustic comfort is one of the most important concepts of total building performance. Low et al (2008) conducted a study and related acoustic discomfort to noise and vibration. The study established that unwanted noise and vibration can reduce performance levels and distract occupants of their tasks and this will greatly reduce productivity. Rasila and Rothe (2012) put forward that acoustic discomfort can affect occupants physiologically (headaches and tiredness), psychologically (lack of concentration and short-term memory failures) and cognitively (listening to others). Achieving acoustic comfort should therefore be one of the major priorities in contemporary public building projects. According to Low et al (2008) noise, defined as unwanted sound, is recognized as a nuisance in the built environment. Noise, which can be so detrimental, is considered a subjective phenomenon as it is dependent on the individual's perception of the sound (Frontczak et al, 2012). This means that acceptable levels of sound depend solely on the basis of the occupants' subjective reactions. How well noise can be managed in a space defines the acoustic performance of the built environment. Acoustic comfort is dependent on the orientation and layout of the building, as well as the qualities of the building materials used (Low et al, 2008). The quality of the building materials is critical to keeping out noise from outside. As communication is inevitable in the indoor environment, there will always be a certain level of noise present in the environment. This type of noise cannot be eliminated totally and can be disruptive and so detrimental to the occupants' ability to focus and concentrate on their tasks (Seddigh et al, 2014; Banbury and Berry, 2005). This can lead to feelings of frustration and increased levels of stress (Seddigh et al, 2014). According to Low et al (2008) space segregation and good building layout are some

of the design solutions that can reduce to minimum this type of noise to prevent disturbance to others. Noise and vibrations from building services such as HVAC systems is one of the main factors that can affect acoustic comfort. (Low et al, 2008). Thus, the positioning of building services is integral in preventing disturbance from noise produced by building services. Low et al (2008) therefore posits that building services should be located away from places where acoustic performances are of major priorities.

2.6.3 VISUAL COMFORT

Lighting is needed in workplaces in order to create a safe and enabling working environment for occupants. According to Pheng et al (1998), one important criteria of an environment is for it to fulfill its visual aspect because it forms the basis for carrying out the activities within it functionally. According to Azlan et al (2015), lighting standards vary with different working environments and in order to perform various tasks, different types of lighting are required. In public buildings, visual comfort is essential for pleasant and productive working environment. Visually, the environment should provide optimal lighting conditions for the occupants within to carry out their tasks adequately and ensure their safety (Pheng et al, 1998). Abdou (1997) suggests that significant improvement in lighting at workplaces can be a costeffective way of increasing productivity. According to Pheng et al (1998), provision for visual comfort should include natural daylight as well as artificial light as to when needed. Daylight is the most appreciated source of illumination in public buildings because its utilization has a positive effect on occupants' comfort (Sharp et al, 2014; Galasiu and Veitch, 2006). According to Sharp et al (2014), occupants tend to spend more time in day-lit spaces and this increases productivity. Abdou (1997) also put it that lighting is an important aspect of the built

environment, with daylight being of particular importance. Veitch (2005) emphasized that occupants prefer to have natural lighting in their environment to artificial lighting. Sources of daylight into interior spaces include direct solar radiation, diffused skylight and reflections from surrounding surfaces (De Luca et al, 2018) of which direct solar radiation is the most appreciated source of daylight in terms of quality, quantity and distribution potential (Reinhart, 2014; Johnsen and Watkins, 2010). Windows play important role in visual performance and comfort because the design of windows including its size, shape, spacing, orientation and shading devices determines the amount of daylight entering buildings (Pheng et al, 1998). De Luca et al (2018) also put it that daylight can be maximized by a correct design of glazing surfaces in terms of location, orientation, size and materials. According to Veitch (2005), occupants who have access to windows are more satisfied with their environment than those who do not have access to windows.

Glare can be categorized as one of the major factors that can lead to visual discomfort (Bureau of State Risk Management, 2003). When utilizing daylight, it is important to take into account the possible need for shading devices or deflectors to eliminate or decrease the potential effect of disturbing glare caused by daylight or direct solar radiation (Al-Obaidi et al, 2017; Byrd, 2012). Natural light can also be excessive during the day, as to disturb vision and generate unwanted solar heat gains (Byrd, 2012). The later makes it very important to correctly balance and design different elements, such as interiors, façade layouts, windows and shading devices to obtain the needed illumination and minimize energy consumption (De Luca et al, 2016; Haase and Grynning, 2017; Kim et al, 2016 and Darula et al, 2015).

2.6.4 AIR QUALITY

A subset of the environmental quality is air quality which is defined by factors such as air velocity and contaminants (Dorgan and Dorgan, 2005). The emphasis on air quality is as a result of cases of irritation of eyes and throats, and general respiratory problems transmitted by air pollutants inside enclosed spaces, particularly, air-conditioned spaces. The prime reason for researching and attempting to understand air quality within a space is that air circulation if not at optimum level can affect the health and productivity of occupants. Dorgan and Dorgan (2005) argue that, due to the amount of time that occupants spend in public buildings, it is important to ensure that the surrounding air is of an appropriate quality. They proposed that a linkage exists between the quality of the surrounding air and the health and productivity of occupants. Dorgan and Dorgan (2005) further concentrated on reviewing over 500 research reports that attempted to link air quality and productivity. They concluded the review and established that an average productivity loss of 10% was due to poor air quality and that productive benefit of 6% could be readily achieved by improving the air quality.

2.7 SUSTAINABLE DESIGN STRATEGIES

According to Xue et al. (2014) buildings are responsible for a large percentage of energy consumption and greenhouse emissions, as they consume about 40% of the total end-use energy and another 40% of CO_2 emissions more than any other sector all over the world (An et al, 2018). Subsequently, buildings are long lived products, typically designed to last more than 60 years (Shah, 2012; Meeus, 2012). In this context, the built environment is one of the biggest concerns for sustainable development as the building industry is one of the main reasons for natural resource depletion, greenhouse effect and climate change. Sustainability

aims to achieve healthy built environments, energy saving and environmentally friendly for occupants (Wei et al, 2015) Sustainability therefore is an inevitable requirement for future sustainable public building developments. The focus of this study is to examine sustainability in the built environment with the primary focus on the human perceptions of occupants and their expectations of a sustainable public building. In this regard, a sustainable building is to improve occupants' comfort and productivity and encourages a healthy ecosystem. Varied and complex definitions of sustainability exits, however, the most common mainstream definition is associated with the Brundtland Commission Report (United Nations, 1987) which defines sustainability as development that meets the needs of the present without compromising the ability of future generation to meet their own needs (World Commission on Environment and Development (WCED), 1987). Elkington (2004) further conceptualized and expanded the definition of sustainability with the development of three overlapping sustainable development principles known as the "triple bottom line" where principles of sustainability should be balanced and harmonized between the environment, the economy and social values. The Construction Industry Research and Information Association (2006) emphasized by stating that sustainable development involves three key factors; environmental responsibility, economic profitability and social awareness and achieving the right balance between them. According to Feige et al (2013) the intention for sustainability in buildings is the creation of an attractive built environment, fulfillment of ecological goals and the attainment of human comfort.

The sustainability of a building is related to its capability to ensure safety, comfort, effectiveness and efficiency to the occupants (So et al, 1999). Smith and Pitt (2011) conducted a study and suggested that the practices of sustainable building can reduce the effects of sick

building syndrome and poor air quality which are contributing factors to ill health and reduced occupants' productivity. Ravindu et al (2015) also emphasized that the environmental quality of a sustainable building is expected to be better, more comfortable and more productive compared to a conventional building. In this context, sustainable practices can improve the quality of buildings for their occupants. Building owners and designers should therefore begin to consider the art of sustainable buildings in terms of energy efficiency, occupant comfort, development and operating costs. In addition to adequate physical space, occupants also require buildings to perform well in terms of operational efficiency and comfort. According to Love and Bullen (2009) the adaptation to climate change is emerging as one of the main requirements for buildings in satisfying environmental performance, thereby promoting sustainable design solutions. Perumal et al (2010) posits that sustainable buildings create an environment that maximizes the efficiency of building services, ensuring effective resource management with minimum life-cycle costs. In this context, sustainable buildings should place greater emphasis on the adaptability and management of space, providing a more useroriented approach.

2.8 CHAPTER SUMMARY

It can be observed from the review of literature above that attaining optimal human comfort in public buildings can greatly enhance productivity in Ghana. Literature has established that users in buildings with good environmental conditions feel comfortable and can work effectively. The studies have suggested that there is a link between human comfort and productivity. However, the study reveals that there is so much comfort dissatisfaction in public buildings because of their over reliance on technology aided strategies to achieve human

comfort rather than sustainable and environmentally friendly passive design strategies. It could be concluded that uncomfortable environmental conditions in public buildings leads to absenteeism as well as health-related issues such as feeling stuffy, being easily tired and having difficulty concentrating. The challenge facing public buildings in Ghana is therefore how to achieve optimal human comfort by considering passive design strategies which are environmentally friendly and sustainable.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

Research is an organized and a systematic way of finding answers to questions based on some philosophical assumptions (Gord, 2012). The aim of research is the discovery and interpretation of facts, revision of accepted theories in the light of new facts or practical application of such new or revised theories (Webster, 1985). To ensure a strong research, researchers choose a philosophical paradigm that is congruent with their beliefs about the nature of reality (Mills et al, 2006). Poetschke (2003) defines a paradigm as the researcher's "net", world view or a system of ideas, values and assumptions common to a community of researchers to generate knowledge. The research philosophy for the study will be positivism and relativism. According to Saunders et al (2003), positivism recognizes working with an

observable social reality that attempts to explain how the world works in a value-free way. The theory holding these criteria of judgment are relative, varying with individuals and their environment. As quoted by Plato (429 – 347 B.C.E) in the Ancient History Encyclopedia, "the way things appear to me, in that way they exist for me; and the way things appear to you, in that way they exist for you. This chapter will discuss the philosophical paradigm and covers a presentation on the overall design strategy underpinning this research. The chapter will also discuss the stages and processes involved in the study, the research methods, sampling and the instruments for data collection, processing and analysis.

3.2 RESEARCH APPROACH

Masons (2002) describes the research approach as "deciding what theory will be best to answer the research questions". The study adopted the qualitative research approach. Qualitative research is characterized by its aims, which relate to understanding some aspects of social life and its methods which (in general) generate words, rather than numbers, as data for analysis (Quinn and Cochran, 2002). Burns and Grove (2003) emphasized that qualitative approach to research focuses on the life experiences and situations of people to give meanings to them. For the purpose of this study, the research assumptions focused on understanding the perspectives and experiences of occupants of the KNUST/IDL building at Kwabenya in Accra. According to Creswell and Clark (2007) meaning is assumed to be highly subjective and best understood through social interaction and personal experiences. In view of the objective to analyze occupants' subjective feelings about their comfort and its impact on their productivity, the research was based largely on documents review, observational methods, as well as in-

depth interviews; and adopt inductive reasoning to derive a theory. According to Burney (2008), inductive approach to research begins with data collection through observation, looks for patterns by way of analyzing the data and then concludes by developing a theory to explain those patterns.

3.3 RESEARCH DESIGN

According to Boyd (2015), research design is an action plan or a set of steps and procedures for getting answers or results to a research problem while strategy refers to the overall action plan or structure of the research study. The research design for the study was a combination of descriptive and exploratory approach. The strategy for the study was based on direct and in depth interview with target groups, field observation and a case study as a means to gain insight into how human comfort can influence occupants' productivity in public buildings. According to Burns and Grove (2003) descriptive research is designed to provide a picture of a situation as it naturally happens. For the purpose of this study, descriptive research will be used to obtain a picture of the performance of the KNUST/IDL building and the comfort of occupants in the building. Exploratory research is also designed to investigate the full nature of a phenomenon and other factors related to it (Polit et al, 2001). In this study, the opinions of occupants regarding their comfort and its impact on their productivity will be explored using individual and focus group interviews. To observe is to collect information about events while to explore is to make a careful investigation of information available by drawing inferences. The study will adopt cross-sectional survey. According to Hemed (2015), crosssectional surveys are relatively cheap observational studies and can be conducted in a short time. Hamed (2015) also emphasized that cross-sectional survey take a snapshot of the

study population and can help to determine how many people are affected by a condition at one point in time.

3.4 POPULATION

Population is the entire group of people or items who are of interest to the study and from whom the researcher makes assumptions about (Gord, 2012). The population for the study is about 658 including students and the teaching staff who use the KNUST/IDL building at Kwabenya. The population contained too many individuals to study conveniently. So to ensure that the sample that was drawn for the study was credible and represented the entire population the survey was restricted to one or more samples that were drawn from it. Quinn and Cochran (2002) describe this strategy as maximum variation sample because it involved selecting key demographic variables that were likely to have an impact on the population parameters.

3.5 SAMPLING AND SAMPLE SIZE

Sampling is the process whereby a researcher selects a representative part of a population (subset) for the purpose of determining parameters or characteristics for the whole population (Fridah, 2002). On a representative basis, stratified random sampling was used to make sure each element in the population had an equal probability of being included in the study. Due to the heterogeneous nature of the study population, it was first stratified into the following groups or strata: students and teaching staff. The students were further stratified into occupants in large-sized lecture halls, medium-sized lecture halls and small-sized lecture halls. Simple random sampling was then used to select the sampling units. This guaranteed that the sample that was chosen was representative enough to make the conclusions drawn from analysis of

the sample to be valid. The richness of information that was drawn from the respondents were enough to form the basis for generalization of the study population.

A sample is simply the participants who are studied to gain information to represent the target population (Boyd, 2015; Dessel, 2013). In general, large samples are better, but they require more time and effort to manage (Boyd, 2015) while a smaller sample may not be credible enough (Dessel, 2013). Due to time constraints and limited resources, it was relevant to find a representative sample of the study population. One way to identify the number of participants in a qualitative research is to keep on interviewing until, in analysis, nothing new comes from the data; a point Quinn and Cochran (2002) refer to as saturation. Guest et al (2006) propose that saturation often occurs around 12 participants in homogenous group. To ensure that the study had the saturation the interview went beyond the point of saturation proposed by Guest el al (2006) to make sure no new major concepts emerged from the study. From table 1, 12 teaching staff were selected for the interview, 15 students each were selected from two large-sized lectures halls, 14 students each were selected from two medium-sized lecture halls and 12 students each were selected from two small-sized lecture halls for the interview making a total sample size of 94.

Table 1: Sampling and sample size for the field studies.

Sample	Sample Size
Teaching Staff	12
Students in large-sized lecture halls	30
Students in medium-sized lecture halls	28

Students in small-sized lecture halls	24
Total	94

3.6 DATA COLLECTION PROCEDURE

The researcher sought the consent of the participants before interviewing them as a requirement of ethical principles. Participants were assured that the purpose of this research was purely for academic exercise and that they remained anonymous throughout the study for any information given out. Data were collected from both primary and secondary sources. The source of the primary data sought firsthand information from participants during field studies. The primary data were collected from participants within the sample frame using different data collection methods including in-depth interviews, direct observation and case study approach by participating in the setting. The questions that were asked during the interviews were based on the research objectives. The perspectives and experiences of participants were sought by conducting the interviews using open-ended questions. Cross-sectional survey was used to find the status of the various target groups at a given point in time. The interviews with the participants were recorded using a digital recorder in order to preserve the verbal part of the field studies for playback during data analysis.

3.7 DATA PROCESSING AND ANALYSES

The qualitative approach to the study presented the data in the form of explanatory and descriptive narrations. An important aspect of data analysis in the qualitative study was the search for meaning through direct interpretation of what were observed and from the responses

of the participants. The aim for analyzing the qualitative data was to discover patterns, concepts, themes and meanings. The study adopted content analysis for processing the data. According to Hsieh and Shannon (2005), content analysis is a widely used qualitative research technique. Qualitative content analysis is defined as a research method for the subjective interpretation of the content of text data through the meanings underlying physical messages (Zhang and Wildemuth, 2009). This approach enabled the researcher to understand the social reality in a subjective but scientific manner. The process of qualitative content analysis was used in the early stages of data collection. This early involvement in the analysis phase helped to move back and forth between concept development and data collection, and helped to direct subsequent data collection towards sources that were more useful for addressing the research questions. Generally, the data were transformed into written text before analyzing them.

3.8 ETHICAL CONSIDERATION

Creswell (2003) reminds researchers that in the process of acquiring data for their research, they are in actual fact invading the privacy of participants. The researcher was first introduced himself to the respondents and informed them about the details of the study as a fundamental aspect of informed consent. This means that participants were not coerced or unfairly pressurized and that they were well-informed about what the participation entails. The researcher then assured the participants about ethical principles such as anonymity and confidentiality. This gave the participants some idea of what to expect from the interview and established the likelihood of honesty when responding to the research questions.

3.9 CHAPTER SUMMARY

This chapter outlined the research paradigm, the research approach and strategies that were employed for the study including procedures for data collection, data processing and analysis. The study adopted content analysis and qualitative research approach using a combination of descriptive and explanatory strategies. Data collection instruments included interviews, field observations and case study. The population for the study was occupants of the KNUST/IDL building at Kwabenya in Accra. The study adopted probability sampling using stratified random sampling to select participants until the point of saturation was reached. Ethical principles were strictly adhered to throughout the study in the process of collecting data from the participants.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the findings of the field study and the analysis of the results. The research was carried out by using a qualitative approach. The study examined the performance of the KNUST/IDL building at Kwabenya and sought to identify areas of improvement as feedback to designers. The target group was comprised of occupants with similar tasks in the case study building. An unstructured questionnaire was designed to conduct interviews among students and lecturers.

4.2 FEATURES OF THE STUDY AREA

The KNUST/IDL building is located at Kwabenya in the Ga East Municipality of the Greater

Accra Region of Ghana. The climate of the study area falls in the savannah ecological zone. Rainfall pattern is bi-modal with the average annual temperature ranging between 25.1^0C in August and 28.4^0C in February and March (Ghana Statistical Services, 2014). The climate of the area can therefore be classified as hot and humid with much of its climatic conditions predominately outside the human comfort zone. The land area consists of both gentle and steep sloped landscapes. The topography of the place can generally be described as mountainous with numerous low lying areas.

4.3 CASE STUDY BUILDING

The KNUST/IDL building is located at Kwabenya in Accra, Ghana as shown in Figures 1 and 2 was selected for the study. The building was purposely built by KNUST for distance learning. This particular educational building was chosen based on the fact that the building makes good use of both technology aided and passive design strategies to achieve human comfort. Moreover, the building is not different from the numerous contemporary educational buildings in Ghana, thus a representative of the current design trends in Ghanaian high-tech educational buildings and therefore lessons drawn could be applied to all contemporary educational buildings in Ghana.

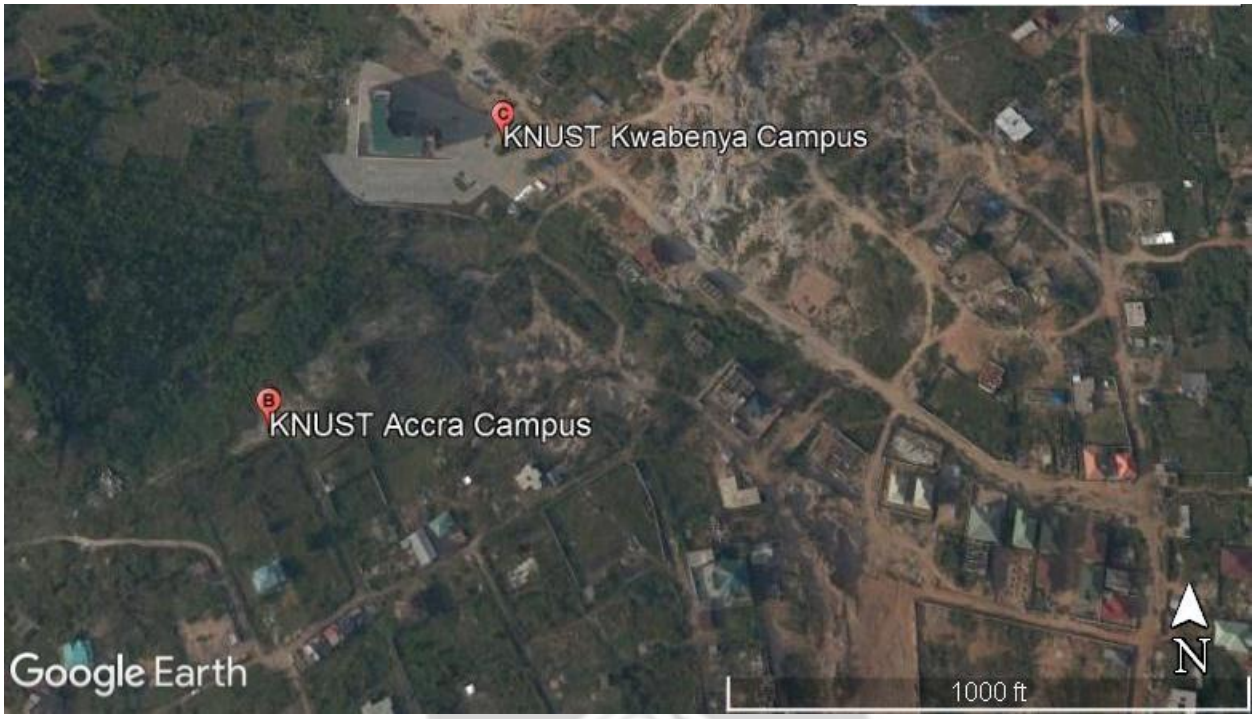

Fig 1: Location of the Case Study Building (Source: Goggle Maps, 2018)

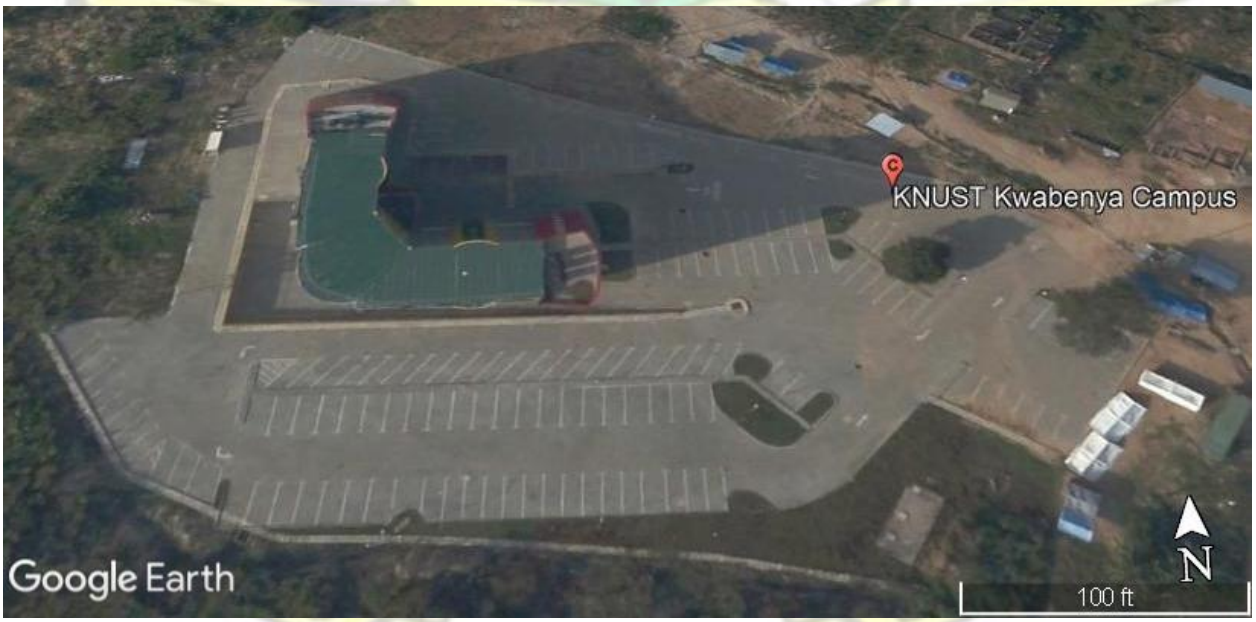

Fig 2: Ariel view of the Case Study Building (Source: Goggle Maps, 2018)

The facility is a 6-storey educational building with basement (Figures 3 and 4) to facilitate the operations of the university's Institute of Distance Learning (IDL). The building has 15 to 150 seater lecture halls, 120 seater computer laboratory, server rooms, staff rooms, administrative

offices and breakaway spaces. The construction of the building is a typical post and beam with reinforced concrete and cement blocks. Figures 3 and 4 show that the external fabric or cladding is made of alucobond material to protect the building, improve its insulation and appearance. Porcelain tiles and plaster boards are the materials for the floors and ceilings respectively. The building was designed in two blocks called east and west wings connected with a centralized staircase, circulation and breakaway spaces for students' interaction. The basement to the 4th floor of each wing has single rows of lecture halls while the 5th floor of both wings is a double banking system with administrative offices. At the ends of each block are washrooms, exit or emergency staircases and service ducts. The entrance is located at the middle of the building (Figure 3) from the basement via the central staircase and also accessible from the ends of each wing via the exit staircases. Some of the employed design qualities include the orientation of form, ventilation and shading. The building is oriented in such a way that some of the openings are exposed to the east and west directions. The building operates on central air-conditioning systems with operable windows to provide natural ventilation when needed. From Figures 3 and 4, the building has glazed sliding windows of which some are exposed to direct sunlight and others are shaded with the verandas in front of each floor. All the windows have blinds which are deployed to reduce glare from daylight.

Fig. 3: Front view of the KNUST/IDL Building at Kwabenya

Fig. 4: Back view of the KNUST/IDL Building at Kwabenya

4.4 SURVEY

Interviews were conducted during the field studies. A total of 94 respondents participated in the study including 12 teaching staff and 82 students in the KNUST/IDL building. 60 of the respondents were males and 34 of them were females. The age structure of the respondents is presented in Figure 5. The respondents were selected from six different lecture halls from the basement to the 5th floor for the interviews with their respective lecturers being booked for one on one in-depth interview after lectures. The criterion for selection was based on the size of the class including two large-sized lecture halls with over 100 students, two medium-sized lecture halls with about 75 students and two small-sized lecture halls with about 20 students. The transportation method used by the participants to arrive at the building was mainly by vehicle. From Figure 6, the activities of the participants were mostly reading, writing and listening to lectures at seated positions and they wore clothing which could generally be categorized as light summer clothes ideal for the tropics. Although the study did not take into consideration the transportation method to arrive at the building or the kind of activities of the participants in the building or the kind of clothes they wore, it is worth mentioning to place emphasis on the personal factors which could affect their responses.

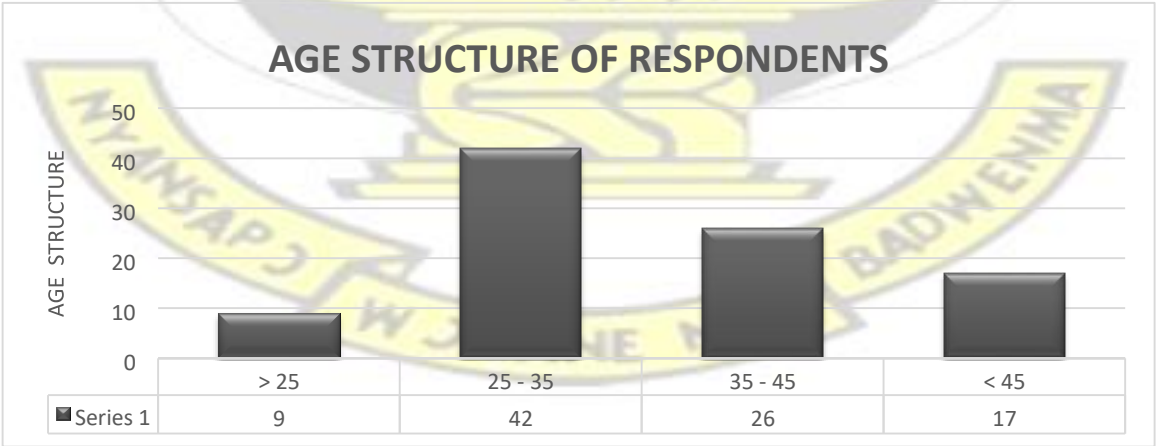

Fig. 5: Age structure of respondents

Fig. 6: Interior view showing students seated during lecture session

4.4.1 THERMAL COMFORT

The results of subjective responses to thermal preference in the building are presented in Figure 7. The results show that 53% of the respondents preferred air-conditions to natural ventilation in the building. According to ASHRAE Standard (2004), an acceptable thermal environment should have 80% of occupants vote. The study shows that majority of the respondents were not in thermal acceptable conditions in the building.

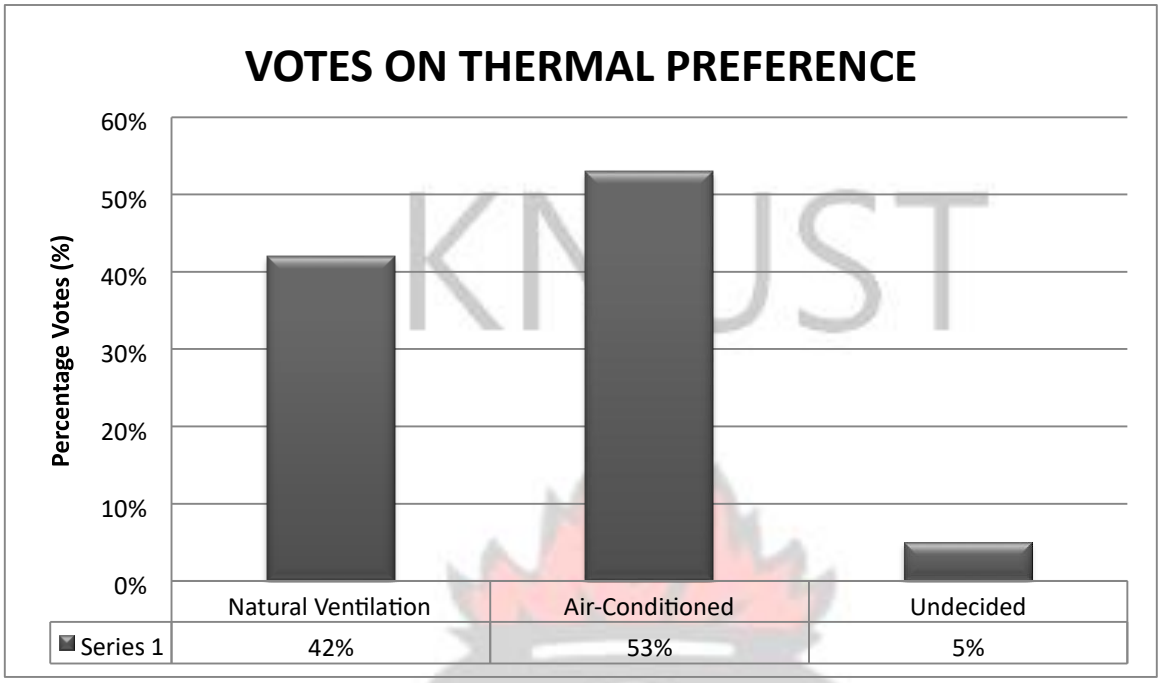

Fig. 7: Percentage votes on thermal preference in the building

The respondents who preferred the HVAC systems attributed their choice to the fenestration design, the class sizes and the unfavorable conditions of the external environment. The use of glazed sliding windows has led to the heavy integration of HVAC systems in the building. The sliding windows used for the building allow a maximum of 50% of air flow in and out of the interior spaces. Moreover, the windows at the back of the building are without shading devices allowing sunlight to penetrate directly into the interior spaces. The field study revealed that students who sat close to those windows either rolled down the blinds or moved away from the windows. During the field study, it was observed that majority of the lecture halls are large sized with the accommodation of large number of students at one place as shown in Figures 5 and 12. It was also observed that the external surroundings of the building are entirely paved with concrete blocks with very scanty vegetation (Figures 3 and 4). The extensive use of hard landscape absorbs radiations from the sun and transmits the heat into the

environment making the surroundings unbearable during the day. This undermines the quality of air that flows into the building.

The above mentioned conditions have led to the provision of thermal comfort in the building mostly based on technological strategies with high energy consumption rather than passive design strategies with minimal energy consumption. The study revealed that the thermal comfort conditions in the building were satisfactory particularly in the mornings when the atmospheric temperature is low and the HVAC systems were working efficiently while there were evidences of thermal discomfort in the afternoons when the atmospheric temperature is high and the HVAC system begin to function inefficiently. The respondents who voted for the HVAC system said they would have preferred natural ventilation had the building used louver blade windows together with electric fans. The respondents who voted for natural ventilation attributed their choice to the inefficiencies and unequal distribution of air from the HVAC systems. It was observed that occupants who sat directly under the air-conditioners felt too cold while those who sat further from the air-conditioners felt very warm. The students who felt too cold either relocated or worn pullovers to keep themselves warm while those who felt very warm used handheld devices to fan themselves. When the thermal conditions in the lecture halls become unbearable it was observed that the students become disengaged from lectures and begin to lose concentration. They begin to fan themselves with handheld devices (Figure 8) or willingly decide to take short breaks outside. The students had a strong urge to operate the windows even in the air-conditioned rooms. This means that students felt discomfort with the thermal environment in the lecture halls.

Fig. 8: Air-condition is on but window is opened due to inefficiencies of the HVAC systems

4.4.2 ACOUSTIC COMFORT

The results of subjective responses to acoustic preference in the building are presented in Figure 9. The results show a mixed response from the participants regarding their preference for PA systems or natural voice in the building.

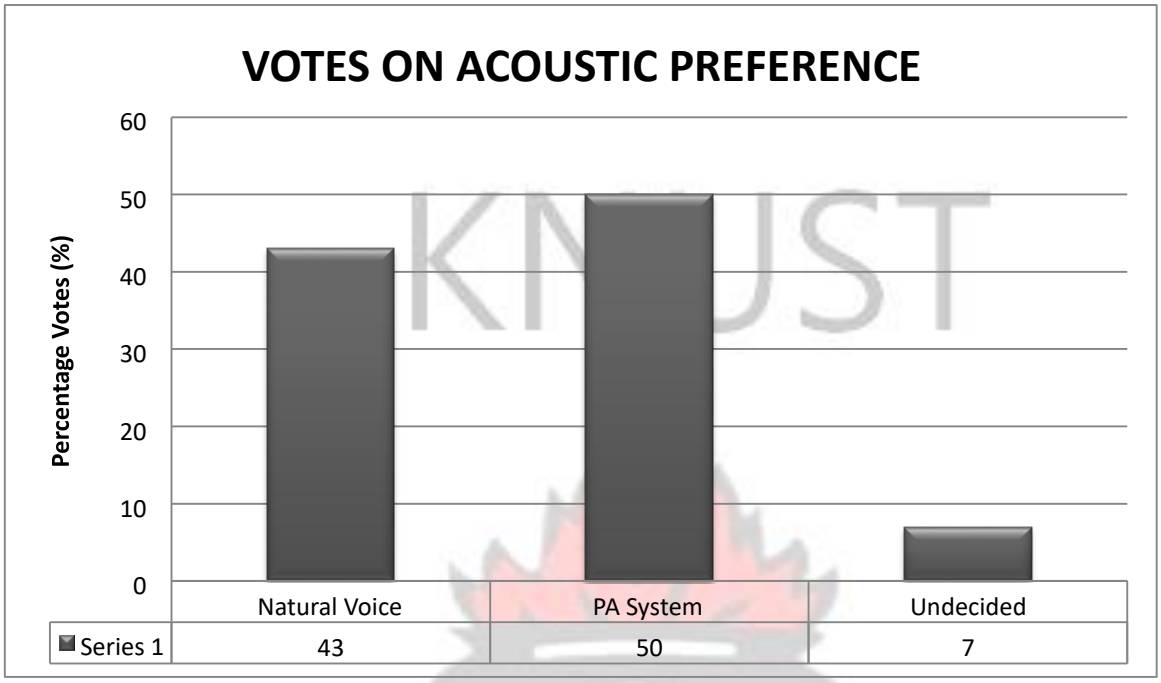

Fig. 9: Percentage votes on acoustic preference in the building

From the field study, all the students in the small sized lecture halls preferred natural voice while those in the medium and large sized lecture halls gave mixed responses. It was observed in the large sized lecture halls that students in the front row seats preferred natural voice while those in the back row seats preferred the PA systems. Students in the back row seats were not participating and they consistently complained of not hearing from the back. Lecturers in all the classes that were interviewed used natural voices for lecturing (Figure 10). According to them, the PA systems were readily available for use, however, the inefficiencies of the systems interrupt the free flow of lectures and so they have no other choice but to opt for natural voice. All the lecturers interviewed agreed that the PA systems were good for the large sized lecture halls provided the systems would function effectively. Lecturers in the large sized lecture halls complained that they got exhausted too easily because they have to speak louder in other to reach their audience. The field studies revealed that acoustic performance in the small and medium sized lecture halls were good but very poor in the large sized lecture halls. The poor

acoustic performance in the building disengaged the students making them lose concentration during lectures. The study did not record any form of noise or vibrations in the lecture halls from other occupants or from the mechanical installations. The quality of the building materials, the layout of the building, the segregation of spaces and the position of the mechanical installations at the extreme ends of the building wings are good design qualities that has helped to eliminate noise and vibrations from the building.

Fig. 10: A lecturer using natural voice to lecture in a hall with over 100 students

4.4.3 VISUAL COMFORT

The results of subjective responses to visual preference in the building are presented in Figure 11. The results show that the majority of the respondents preferred natural lighting to artificial lighting in the building.

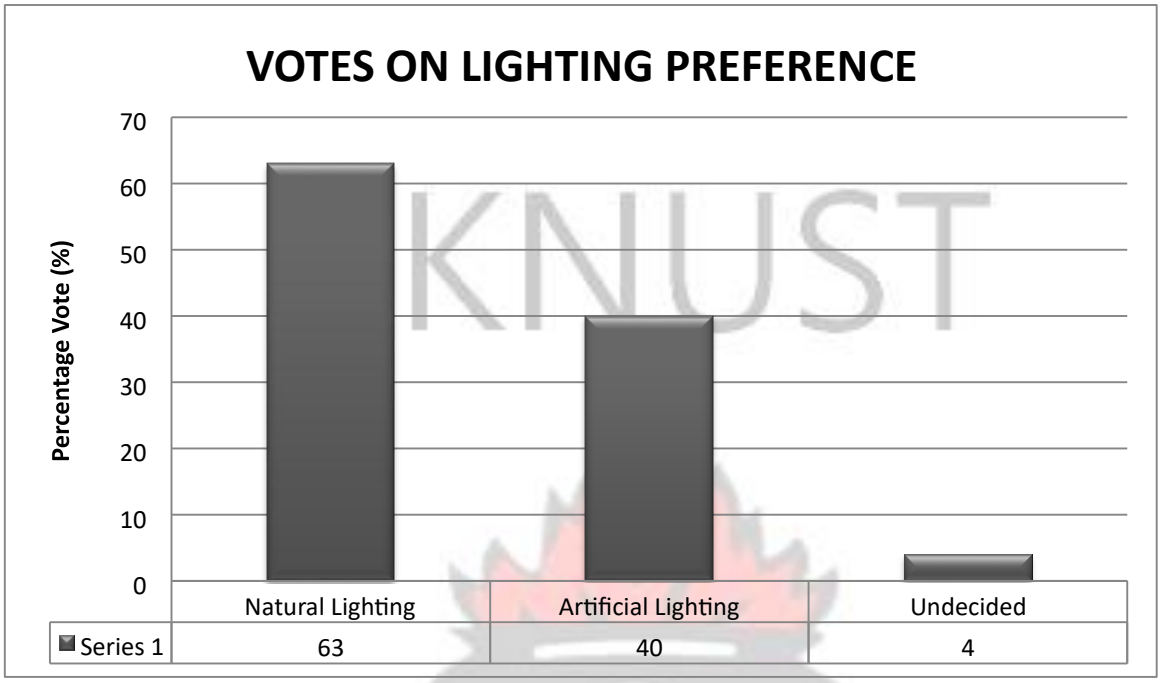

Fig. 11: Percentage votes on lighting preference in the building

In terms of visual comfort or lighting, daylight was the primary source of lighting in the building with artificial lighting being used complimentarily. All the students and lecturers interviewed appreciated the level of illumination in the building for educational purposes. The plane glasses used for the sliding windows allow maximum penetration of natural light into the interior spaces as shown in Figure 12.

Sources of artificial lighting included the provision of florescent bulbs to compliment the daylight. It was observed that glare from the sun was the major source of visual discomfort in the interior spaces. Windows in front of the building that were duly shaded by the verandahs allow diffused light from the sun into the building (Figures 8 and 10), whereas the windows at the back of the building that are without shading devices allow direct penetration of light in the form of visual glare from the sun into the interior spaces as shown in Figure 13. The interior spaces have blinds which are used to reduce glare from daylight as shown in Figure 14.

Fig. 12: Level of illumination in a lecture hall

Fig. 13: Visual glare from the direct penetration of solar radiation in the lecture hall

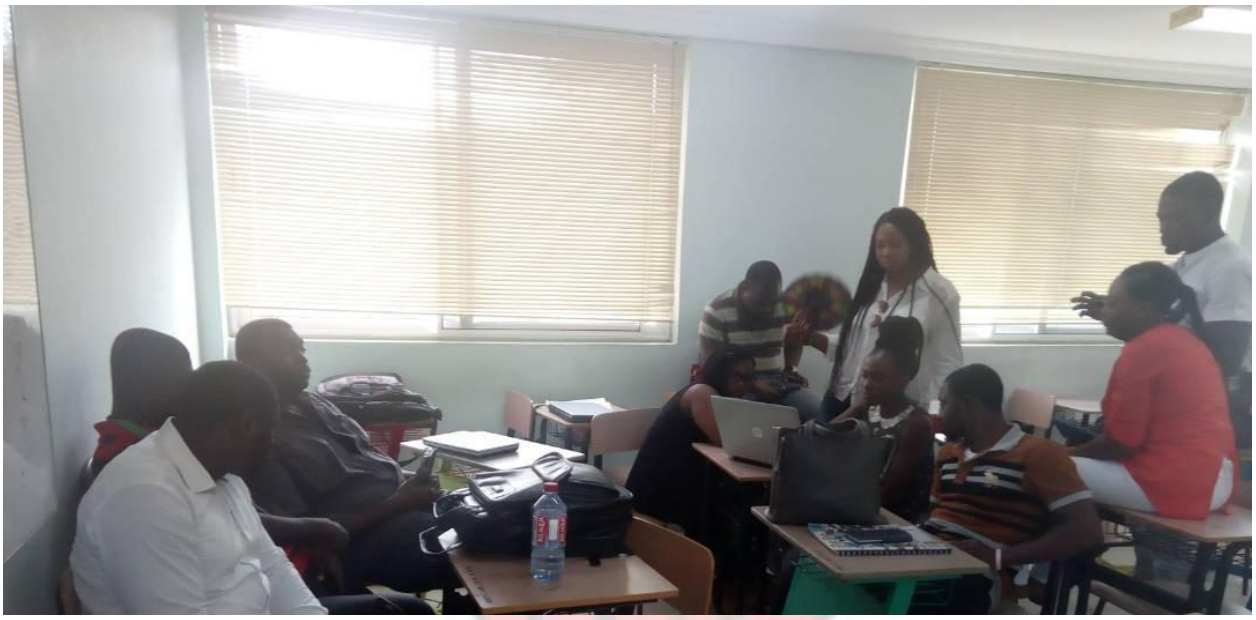

Fig. 14: Blinds used to reduce glare from the direct penetration of solar radiation

4.4.4 AIR QUALITY

The participants were satisfied with the quality of the air even in the air-conditioned rooms. They did not report any symptoms of respiratory problems or throat and eyes irritation. The nature of the topography facilitates the flow of cool breezes towards the building. However, the over extensive use of hard landscape for parking has created heat island in the immediate surroundings of the building.

4.4.5 DESIGN QUALITY

The general impression about the performance of the building is the creation of high quality interior and exterior atmosphere conducive for teaching and learning and so effective development of students can be achieved. From an observational point of view, the building and its surroundings is accorded with the highest premium for effective functioning and productivity. As an educational building, the facility provides spaces and services for the

acquisition of knowledge and socialization. The spatial attributes, the sequence, location, relationships and detail of spaces enhance the performance of the building. The interior layout of the building in terms of the arrangement of rooms on each floor, the width of the corridors for circulation, the location and number of stairs makes the building user friendly and safe for academic discourse. The layout of spaces, the convenient circulation and accessibility to various usable spaces within the building are of utmost importance to occupants' comfort and satisfaction.

4.4.6 SICK BUILDING SYNDROME

From the field study, symptoms of sick building syndrome expressed by the students as a result of the poor environmental conditions (thermal discomfort and visual glare) in the building included mental fatigue and dizziness. The poor conditions in the building did not only pose health hazards to students but they also influenced the performance of students. Although there were no records of student absenteeism during the field studies, the students expressed general frustrations with the built environment by arriving late for lectures, taking frequent and longer breaks during lectures and leaving early after lectures.

4.5 LIMITATIONS OF THE STUDY

The study was limited in scope due to a number of reasons. The only times available to get the students as a group for the interviews were right before lectures or immediately after lectures. There was not enough ample time for in-depth interviews with the participants because it was either a lecturer was in for lectures so the interview had to pause or the students were in hurry to leave after lectures.

The time frame for the submission of the thesis work was also very short. As a result, various in-depth analyses could not be conducted because the study was limited to only occupants of the KNUST/IDL building at Kwabenya in Accra. A study of this nature would have required a larger sample size from the entire study population.

Very little studies have been done on POE of public buildings in Ghana. This made it difficult get to enough previous studies on public buildings in Ghana. However, these limitations did not in any way affect the reliability of the findings and the results can be taken to represent public buildings in Ghana.

4.6 CHAPTER SUMMARY

The subjective responses of occupants reflect the performance of the KNUST/IDL building at Kwabenya in Accra. Data was gathered using the Post Occupancy Evaluation process applied to a case study building. A combination of field observation and interviews were conducted over the period of the study. Results from the study demonstrated considerable levels of dissatisfaction with certain aspects of the indoor environmental qualities like thermal discomfort, visual glare and acoustic discomfort in the building. Such observations of dissatisfaction were consistent with the findings of literature in which the negative effects of poor indoor environmental qualities such as fatigue and sick building syndrome were reported. Results from the study also demonstrated considerable levels of satisfaction with certain aspects of the indoor environmental qualities like visual performance in the building. Such observations of satisfaction were also consistent with the findings of literature in which positive effects of good indoor environmental qualities such as comfort, good health and productivity were reported.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents the summary of findings, conclusion and recommendations that emerged from the study. It summarizes the performance of the KNUST/IDL building at Kwabenya in Accra by highlighting the challenges occupants in the building encounter with the environmental qualities during the field studies. It also presents the final conclusion of the study and gives practical recommendations for improvement of buildings of such nature in Ghana as feedback to designers.

5.2 CONCLUSION

The aim of the research was to conduct a Post Occupancy Evaluation of contemporary educational buildings in Ghana. The objectives that were set out to achieve the aim of the study were to evaluate the performance of the KNUST/IDL building at Kwabenya and to identify areas of improvement as feedback to designers. The research adopted a Post Occupancy Evaluation process using a qualitative research approach to evaluate the case study building. Occupants of the case study building were interviewed for their subjective responses on indoor environmental qualities such as thermal comfort, acoustic comfort, visual comfort and air quality. The results of the study showed that the occupants were dissatisfied with certain aspects of the environmental conditions. The extensive use of glazed sliding windows and the large sized lecture halls have led to the heavy integration of HVAC systems in the building. As a result the occupants are dissatisfied with the thermal conditions and the acoustic performance of the building. The study confirmed that dissatisfaction with the built

environment has negative effects on the health, comfort and productivity of occupants in the building. The results of the study also showed that the occupants were satisfied with certain aspects of the environmental conditions. Occupants were satisfied with the level of illumination in the building. The study also confirmed that satisfaction with the built environment has positive effects on the health and productivity of occupants.

As part of the sustainability measures to reduce heat islands as a result of the large hard landscape required for parking, the designer could have make good use of underground parking. The nature of the topography would have made it easy to accommodate parking spaces underground making room for more vegetation on the surroundings of the building. Moreover, the use of the glazed sliding windows are aesthetically pleasing but they only allow a maximum of 50% air flow which has led to the heavy integration of HVAC systems in the building. Louver blade windows would have provided a good alternative to the glazed sliding windows in the building because they allow more than 90% of air flow especially when complimented with electric fans. The acoustic performance in the building could also have been improved by reducing the lecture halls to smaller sizes. Preferably, all the windows should have been positioned in the north and south orientation and that no window should have been exposed to direct solar radiation. All the glazed windows should have been appropriately shaded to reduce heat gain and eliminate visual discomfort in the form of glare from the sun. A significant contribution of this research to the body of knowledge is that these approaches would improve the level of sustainability and the overall performance of public buildings in Ghana from environmental, social and economic points of view through reduced energy consumption and operation cost, improved human comfort, health and productivity of occupants in the building.

5.3 RECOMMENDATIONS

The following recommendations were made as feedback to designers help to improve public buildings in Ghana.

i. In this era of climate change and global warming passive design strategies are arguably more sustainable and economical than considering technology aided solutions. Passive design strategies provide the benefit of achieving human comfort with minimal energy consumption to help abate these environmental changes. The first step to achieving human comfort in a more sustainable way is by properly locating, orienting, insulating, employing natural ventilation and natural lighting strategies in public buildings. The combination of louver blade windows with electric fans will implicitly facilitate efficient energy use compared to the combination of glazed sliding windows with

HVAC systems.

ii. Buildings have evolved, moving away from the traditional function as shelter to responding to the environmental conditions and minimization of energy consumption. There is therefore the need to retrain and orient professionals on the trends of contemporary design solutions to achieve human comfort. Moreover, stakeholders including the government, policy makers, architects, engineers and other construction professionals should collaborate and organize workshops and seminars on the need for sustainable design solutions in public buildings.

iii. Finally, results of this research highlight the limitations of Post Occupancy Evaluation of contemporary public buildings in Ghana, emphasizing the need for more research

in this field.

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APPENDICES

APPENDIX 1: INTERVIEW GUIDE

Theme: **General Questions**

1. How long have you been accessing the KNUST/IDL building?
2. Tell me your mode of transportation to access the building?

Theme: **Performance of the KNUST/IDL Building**

1. Tell me your general impression of the KNUST/IDL building as a public facility?
2. Does the performance of the building meet your expectations as a user?
3. Do you experience any form of dissatisfaction with the built environment?

3.1. If yes, tell me your general dissatisfaction with the built environment?

3.2. Do you experience any form of sick building syndrome as a result of your dissatisfaction with the built environment?

4. Do you find the built environment comfortable as a user?

4.1. If yes, what make you feel comfortable with the built environment?

5. What is your assessment of the thermal performance in the building?
6. What is your assessment of the acoustic performance in the building?
7. What is your assessment of the visual performance in the building?
8. What is your assessment of the quality of air in the building?
9. What is your assessment of the building's landscape for outdoor living?

Theme: **Improvement of the KNUST/IDL Building**

1. What is your preference for PA Speaker System or Natural Voice for lectures?
2. What is your preference for Air-conditioners or Natural Ventilation for lectures?
3. What is your preference for daylight or artificial light for lectures?
4. What is your preference for soft landscape or hard landscape for outdoor living?

APPENDIX 2

Fig.1: Location of the Case Study Building (Source: Goggle Maps, 2018)

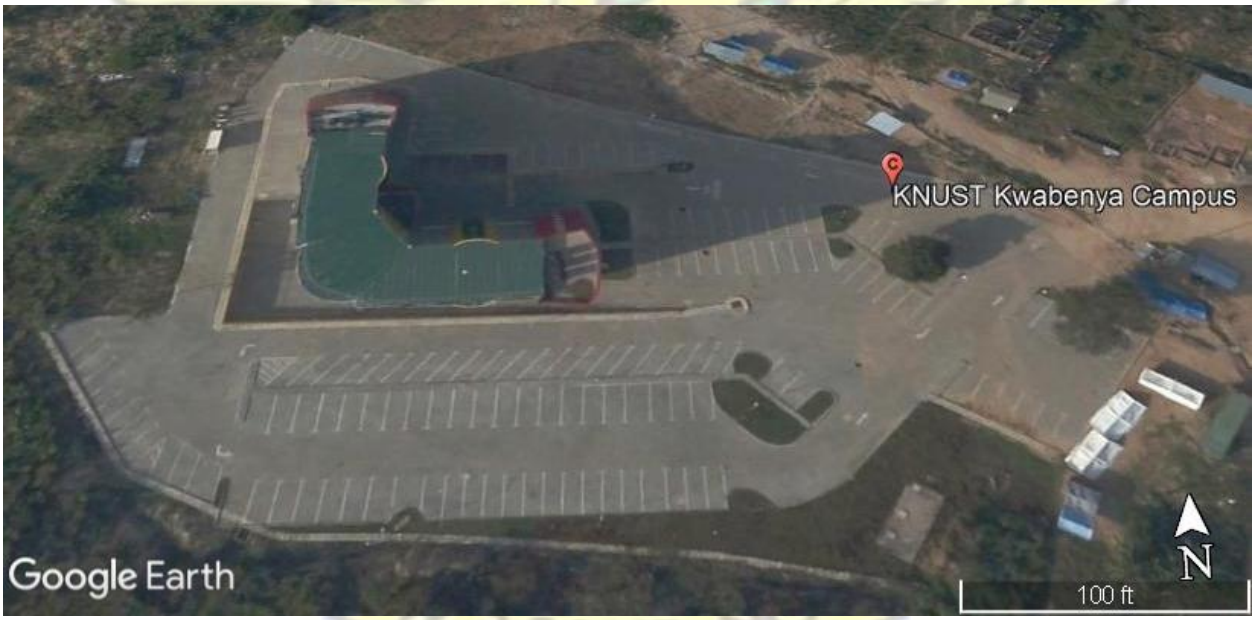

Fig. 2: Ariel view of the Case Study Building (Source: Goggle Maps, 2018)

Fig. 3: Front view of the KNUST/IDL Building at Kwabenya

Fig. 4: Back view of the KNUST/IDL Building at Kwabenya

Fig. 6: Interior view showing students seated during lecture session

Fig. 8: Air-condition is on but window is opened with Student fanning herself during lectures

Fig. 10: A lecturer using natural voice to lecture in a hall with over 100 students

Fig. 12: Level of illumination in a lecture hall

Fig. 13: Visual glare from the direct penetration of solar radiation in the lecture hall

Fig. 14: Blinds used to reduce glare from the direct penetration of solar radiation