The Designers' Task, Dynamics and Integration of Solar Energy in Buildings

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Abstract

Architectural design studio project experience result in a charade of events that take place within and outside the intellectual domains of the students' designers; both the design studio teachers and practitioners in the field are not unconnected with these realities of knowledge construction in Renewable Energy options. This happens especially when design problems occur to a building and major influences may impinge on the space organization as affected by heat, ventilation, air conditioning and lighting. Such operationalization may result to dysfunction when the knowledge construction of sustainability indices by architectural designers were not properly utilized and integrated in design projects.This study examined a review of Solar Energy systems with respect to designers' tasks, strategies of integration in Architectural design. A review of design studio works of some selected students as assessed by the jurors and interviews were used to gather the data for the study. The results obtained suggest that although the students were taught aspects of sustainability relevant to the integration of Solar Energy as alternative energy source in buildings, but they may not have utilized and internalized them properly. This is because the responses of the students on sustainability performance of their studio work were skewed and some students indicated little knowledge of some sustainable principles, which had already been incorporated into the curriculum. The study concludes with advocating for Experiential learning in architectural education with the sense of empathy as the user, client and architect-designer of spaces, which portray the principles that are taught in the curriculum of schools.

Keywords: **Dynamics, Knowledge construction, Passive Devices, Renewable Energy Sustainability Parameters**

1.0 Introduction

Solar Energy is, simply, energy given by the sun. It is the architectonics of solar radiation which makes the production of solar electricity possible; in reality, generated directly from photovoltaic (PV) cells within and outside buildings. Photovoltaic in the elementary sense points to "light" and "electric" (GRSF, 2014). The interdependence of energy availability, its supply, demand and utilization has been one of the major factors that control national development. The requisite parameters of knowledge construction, policy and practice has made the societal demands be placed on the building industry to express professional acumen; in addition to the traditional building demands of health, safety and welfare (Fraser and Wong, 1996). This request is especially in the maximization of the accrued benefits of solar energy and all its embodiments. The epistemology of ‘solar system’ contains arrays of information about sun and pedant-homage of planets in its periphery. Based on the immense benefits that follow the knowledge and practice of integration and installation of solar devices, a neo-framework of knowledge construction is needed with its ardent enforcement in the design studio learning and practice- integrated pedagogy.

This study evaluates some selected design studio works of in Architecture School of Covenant University as assessed by the jurors. The main objective of this study involves the simulation of architecture and architects’ roles in the empathy coordinates of architect as designers, architects as clients, and architects as users. This is an attempt to ensure a procedural integration of solar energy systems sustainability as incorporated from the inception of the design process to the completion of buildings.

2.0 Roles of Architects and Architecture in Solar Energy Integration

The role of architecture and architects in knowledge construction need to be juxtaposed with the realities of demands from clients (or society), practice ethics, and legal authority as relevant to buildings (codes) in order to forestall future occurrences. The Architect-designers’ tasks in design problem solving is multi-dimensional and highly iterative (Uji, 2002; Lawson, 1990). Design problems occur to a building and major influences may impinge on the space organization as affected by heat, ventilation, air conditioning and lighting. This results to dysfunction when the knowledge and practice of construction in sustainability terms was not properly utilized and articulated either in the architectural design studios or on construction sites. From this end, it is possible to imagine what happens to the lighting, ventilation, and other thermal characteristics of indoor, and outdoor environment of a building structure.

For instance, a good designer needs to know that PV cells are made from materials which exhibit the "photovoltaic effect" i.e. when sunshine hits the cell, the photons of light gingered the electrons in the cell and flow as electricity. In this regard, it informs an architect-designer at design conceptualization stage to find out about (i) sun's rays angle as inclined to the buildings, (ii) part of buildings to locate the solar equipment(or panels) (iii) what angles should the equipment be inclined to (iv) design allowance for installation (v) capacity of installation in relation to building size(s), etc.

In use, a designer should also have the idea that the solar energy produces no emissions. A recent research (GRSF, 2014) asserted that 'One megawatt hour of solar electricity offsets about 0.75 to 1 tonne of CO_2'. Another point noteworthy for designers is that 'in the city and in remote locations, to produce electricity for households, schools and communities, and to supply power for equipment such as telecommunication and water pumps, the grid-connected systems needs to be ensured during design process for effective implementation on the site.

In recent research and development; scholars from international communities have placed emphasis on prudent management of energy and economic resources. Li and Lam (2008) however argue that proper façade design can contribute immensely to the environment, energy reduction, and economic aspects of building development and maintenance. Therefore, as Africa (Nigeria's affiliation) is one of the sunniest continents in the world enjoying average daily sunshine of 6.25 hours and an annual average daily solar radiation of about 5.25 KW/m^2 per day.

There is large potential for solar PV to make a significant contribution to electricity generation, it is therefore an emergent demand on architect-designers, allied professionals and objects of architecture to venture for exploit in this area in order to maximize the naturally abundant but sparingly tapped potentials available to the habitué of ecosystem (Okafor and Joe-Uzuegbu, 2010; Simba Solar, 2010 and Dare-Abel, 2010).

3.0 Methodology

The study utilizes the review of secondary data derived from students' results, jurors' reports and selected design studio submissions (drawings). The process resulted in the filtration of the salient data from the available data. Tabulations, content analysis and design critique were techniques applied in the study. The 300 level students of the department of architecture numbering 82 (35.65%) out of a total of 230 students were chosen as the study sample. This class is the largest within the programme and also the point at which energy efficiency in design is properly consolidated in the design studio classes.

4.0 Jurors' Assessment Records and Sustainability Parameters

Design solutions to the projects assigned to the class were carefully checked and critiqued according to the demands of the brief and the scoring objectives. The reports of the jurors on all students were analyzed and these revealed patterns, distributions, similarities and differences among the design solutions. Observations were further checked against the prevailing knowledge construction that exists among the students. An understanding of the situation has propelled the proposal of a method of experiential learning that could improve students' overall application of the acquired knowledge.

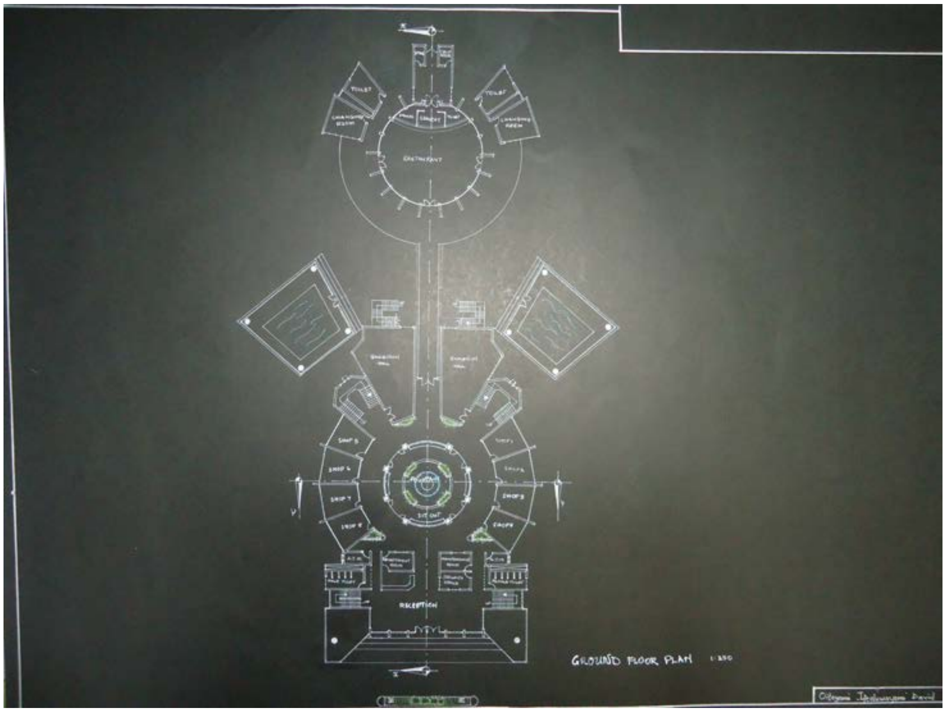

Figure 1: Ground floor plan of one of the students design solution

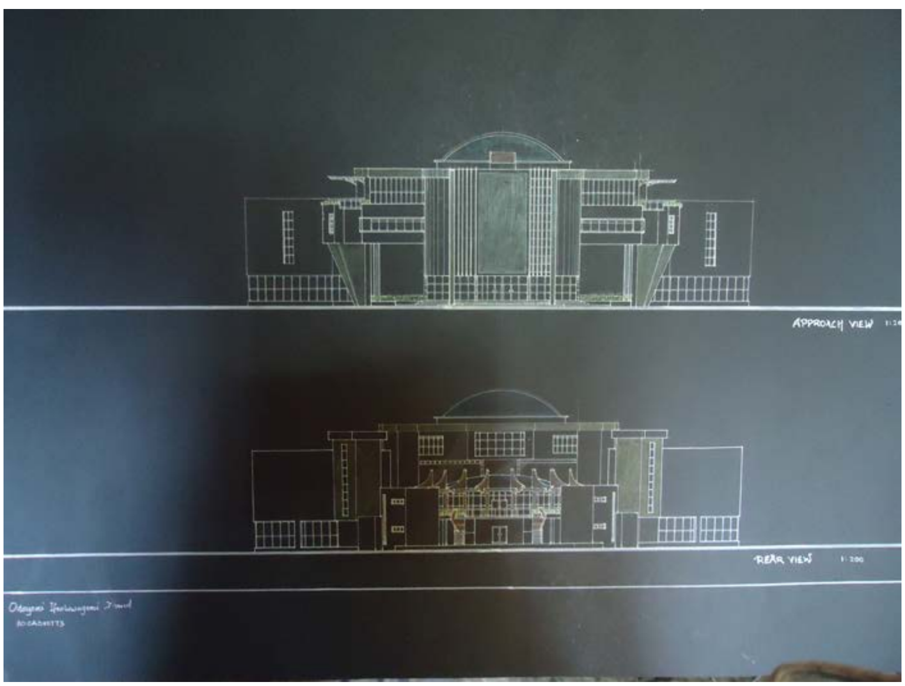

Figure 2: Elevations (Approach and Rear) of the student's design solution

5.0 Results and Discussions of Jury in Relation to Students' Awareness and Performances

The jury scoring guide developed by the module tutors was designed to capture students' mastery of specific design components. Such components and their weights include: preliminaries and analysis (5); site planning (15); creativity (25); technical awareness (15); design development and compliance to brief (10); energy efficiency (15); 3 dimensional images (7) and model (8). These eight components are weighted as the tutors deem crucial to the project to arrive at a 100% total. The above weights describe creativity, site planning, technical awareness and energy efficiency as the most crucial aspects of the students' solution to the project.

The following summations were the results of the review of the studio works:

1. Most students found it difficult to arrive at a well resolved site plan. Many of them made attempts to situate the building correctly on the site but concluded by having more paved external areas than green areas because of the challenge of resolving vehicular movements and parking. The study found that not much time was committed to developing and completing the site planning by the students. Poor time management towards the completion of the studio works adversely affected the quality of site planning.

2. It was discovered that some of the PV panels and windows were designed to be located in along covered terraces and other areas where shading was apparent. This renders the installations ineffective and makes them perform below capacity.

3. Technical awareness was generally on the average. It is believed that the more the students engage with knowledge and its application in this area, the better the results.

4. The battle for aesthetic supremacy of the design solution by many students, created some inadequacies such as spaces that were heavily energy dependent (needing artificial cooling, ventilation and lighting to be functional). Increase in energy demands in such areas may nullify or reduce the savings accruing from the integrated solar energy installations and design.

5. Oral presentation mostly showed high level of mental understanding and use of sustainability terms. However more design input (action) is needed to support the eloquence recorded.

6.0 Pedagogic Suggestions and Proposals

6.1 Architect-Designers and Architecture Passive Design Devices

During the architectural design studio project experiences, a charade of events takes place within and outside the intellectual domains of the students' designers; both the design studio teachers and practioners in the field are concerned with these realities of knowledge construction in sustainability parameters. Certain methods needs to be employed in order to integrate all necessary factors in to the design; thereby offering the entire building systems a completely integrated solar building systems, serving the immediate purpose without jeopardizing its future benefits.

One of such methods could be day lighting; in terms of exposing the architectural design geometry to the sky by top lighting or sky lighting and side lighting with the application of appropriate glazed openings or fenestration. Other forms of integrating passive solar systems are found in the use of solar dryers, and passive water heating systems which are designed to be part of the building solution. These methods derive the nomenclature 'passive method' due to the fact that design-problem solving are inherent in the building itself. It also include the use of solar shading devices like cantilever, louvers, window hood, fin blades, vertical, horizontal devices and egg crates which combines both qualities of the two latter devices especially at the south elevations/façade of buildings.

6.2 Engaging Architecture as Driving Force for Sustainability and Renewable Energy Options

The main aim of sustainability in this way is to make architectural design a driving force for the use of solar energy. Solar energy utilization can be an important part of the building design and the building's energy balance to a much higher extent than it is done now.

6.2.1 The Need for Integrated Design Methods and Installation Strategy

The development towards zero energy emissions and the elimination of the use of fossil fuels to generate power in buildings will demand a recommendation of integrated solar energy building systems. Due to the complexity of such systems in relation to the scale of the building envelope, the architectural design of such integration has a major impact on the final architectural composition of the building.

6.2.2 Designing with Purpose and Solar Energy Installation Characteristics

It is almost a common knowledge that the designing with the solar systems do exist on the world market with better energy performance, but, if they are not designed to be integrated into buildings in a purposive manner, it may results to dysfunction, develop design problems and probably fail to meet the approval requirements as stipulated by planning or metropolitan development board for its implementation. Solar energy is not only sustainable but renewable and characteristically inexhaustible; it is a natural source of power as it is possible to generate electricity from it. In addition, it is gladdening to know that there is just little maintenance about the creation of solar energy.

Solar integration and installation produces energy in a silent mode. There is absolutely no noise made from photovoltaic panels as they convert sunlight into usable electricity. There are continual research and developments in solar panel technology which increases the energy efficiency and lowering the cost of production; during operation, solar electricity power is cost effective and produces zero emissions in its effective use.

6.2.3 The Need for 'Energy design' in Solar Integration and Installation

Energy design refers to the minimization of energy consumption of the building envelope, the use of appropriate technical supporting systems for air-conditioning (heating, cooling and ventilation) and lighting, and to the installation of advanced monitoring equipment for controlling and providing management of the technical systems; it also refers to the installation of systems exploiting renewable energy sources, such as systems utilizing solar radiation, soil thermal inertia and, more rarely in building applications, wind energy (Michael and Phocas, 2012). This study places particular emphasis on how designers can maximize the natural aspect of energy production (day lighting, heating, ventilation, cooling and drying) while applying Solar energy as an integrated alternative energy source.

6.3 Advocating the Efficacy of Daylighting in Solar Energy Integration and Optimization

Asides the benefits of electrical energy produced from solar building systems which may be controlled actively; another design problem-solving approach is to engage day lighting passively into the building design and systems. Day lighting emanated from the biblical story of creation; as light opposed to darkness, and land rose from primordial waters- these are the fundamental components of many creation myths from all over the ancient world (Garnham and Thomas 2007). For centuries, daylight was the only efficient source of light available. Architecture was dominated by the goal of spanning wide spaces and creating openings large enough to distribute daylight to building interiors (Nikpou et al., 2012; Dumortier, 1995).

Advanced daylighting systems and control strategies are alternative source of energy generation in building systems. They provide day lit, user-friendly, energy efficient building environments. It needs to be integrated into building’s overall architectural strategy and incorporated into the design process from its earliest stages. It is determined to place emphasis on design considerations associated with enhancing a building’s daylight utilization while achieving maximum energy efficiency and users’ satisfaction.

6.3.1 Daylight Planning

Daylight and architectural design strategies are inseparable. Daylight not only replaces artificial lighting, reducing light energy use, but also influences both heating and cooling loads. When it is appropriately engaged into the building systems, it ensures thermal comfort, user satisfaction and meets physiological needs. Planning therefore involves integrating the perspectives and requirements of various professionals and acumen of specialties. This activity starts with the selection of a building site and continues as long as the building is occupied.

Daylighting planning has different objectives at each stage of building design. They are (i) conceptual design stage (ii) design phase (iii) final/ construction planning stage and (iv) commissioning and post occupancy stage.

6.3.2 Conceptual Stage

During conceptual stage of daylight planning, the building scheme is created, this has influence (s) on basic design decisions. At this stage, a designer is fully engaged in design thinking by intuition or imagination methods. Sudden illumination may come in form of rough ideas, dreams, imagination and a flip of fantasies. The architect needs to start thinking as a client and user before thinking as architect. This will allow all round consideration of sustainability parameters without taking side. This may probably covers the phase of initiation and preparation where a designer is required to identify the source of design problems and define them meaningfully and measurably.

It means that if a problem is not clearly identified, a wrong prescription or specification may be recommended. In essence, before reaching a consensus in design decision making, the role daylighting is going to perform must fit in properly to the geometry of forms and utility of such design spaces. One may say that these types of agreement will dictate on the building's shape, proportions, and apertures as well as the integration and the role of building energy systems.

6.3.3 Design Phase

After conceptualization of architectural designs, the architect-designers need to be actively engage in the design evolution. Since building systems are in component parts, it imperative for one to think in parts, analyze in parts and develop design modular units in parts because of the differences in structural, materials, and technological purposes. The the design of facades and interior finishes would inform designers at this stage on passive methods to employ in admitting daylight into the interior spaces of the building.

This stage will also consider the workable parameters of fenestration sizes i.e the size, position, and orientation of windows; this may have to relate to whatever factor that affect ventilation, as cross ventilation is desirable for physiological cooling.

Also, the glass qualities especially when special glasses are needed like heat absorbing and reflecting purposes. In addition, to control excessive heat in order to achieve maximum comfort, architect-designers need to incorporate into the design phase devices that can enhance daylight planning in an ordered form. Such devices include fin walls or blades, overhangs, cantilevers (Aderonmu and Adewale, 2014)

6.3.4 Final and Construction Planning Stage

The selection of materials and products is affected by the building's daylighting strategy; final details of the daylighting scheme must be worked out when construction plans are created.

6.3.5 Commissioning and Post Occupancy

When a building is fully constructed and occupied, maintenance and operational manuals need to be developed in order to effectively utilize equipment and component parts of the buildings. In the same manner, lighting controls must be calibrated and ongoing operation and maintenance of the system begins.

6.4 Daylight Availability

Luminance distribution from the sky, sun, buildings, and ground plays a major role in daylighting strategy. This depends on the availability of natural light, which is determined by the latitude of the building site and the conditions immediately surrounding the building, ie the presence of obstructions. The identification of seasonal, prevailing climate conditions, particularly ambient temperatures and sunshine probability, is a basic in daylight design. For architect-designers to effectively render acceptable services, accurate understanding of both climate and daylight availability at a construction site, for a designer is a key to understanding the operation conditions of the building's façade.

In the tropics, where daylight levels are high throughout the year, the design emphasis is usually on preventing overheating by restricting the amount of daylight entering the building. Therefore, solar shading devices are recommendable. But at high altitudes where winter daylight levels are low, designers opt to maximize the daylight penetration into the buildings under desirable conditions can also be redirected into Daylight availability also strongly depend latitude and orientation; each orientation will require a different emphasis. Also, going back to the traditional background of vernacular architecture and past successful daylighting designs is a good way to understand the relationship between climate and building daylight design.

7.0 Conclusion

The synergy of enumerated factors that contribute to the designers' methods of architectural design enables a pragmatic design problem-solving formula. These are perquisites to the improvement of the comfort conditions of the indoor spaces, reducing energy consumption, optimizing natural daylighting resources and preventing the consequences of discomfort of varying degrees in and out of the building. Essentially, the application of the active and passive controlled design principles aims to minimize the engagement of artificial means of energy and maximize the natural energy (daylighting) in design spaces and to improve the users' comfort conditions. The field of energy design is inseparable from the entire integrated process of architectural design. The alignment of the building envelope with the constant environmental changes and the ability to face dissimilar climatic conditions may constitute the most complex and challenging requirement of bioclimatic design. In the design projects presented, the application of solar energy design principles has pragmatically contributed to the alternative energy production process of the building systems and has redefined the architectural composition (energy design concept, geometric form, materiality, equipment, and construction of energy efficient buildings).

Energy production, architectural design and the energy design equipment and construction details, directly affects the integration of function, installation of equipment and expression of geometric forms for each architectural design proposal. Finally, integrated energy design aims at ensuring the relevant technical support of the building and to minimize the use of conventional energy sources. The examination of the integration of renewable energy sources and integrated-technical systems approach into the building envelope infuse values to the architectural design and offers opportunities to delineate and redefine the contemporary architectural expression. Knowledge pattern in the empathy of designers as architects, clients, and the user application of aspects discussed ensures a holistic framework for all stakeholders at all levels. This is evident and relevant in the design of buildings and environments with a view to appropriate the sustainability of architectural masterpieces and built-up spaces.

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