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Daylight strategies for architectural studio facilities: the literature review

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Abstract. The implementation of daylighting strategies in buildings is a common aspect in architecture. However, due to the availability of inexpensive electricity, natural lighting strategies became insignificant, and been overlooked by designers. With the current concern over rapid increment on electricity cost, many designers now try to revitalized daylighting strategies in buildings. This includes educational buildings. In Malaysian cases, it is a norm that universities; especially during lecture and studio sessions, used artificial lighting throughout the day. Definitely, this is not parallel with the "green" aim made by the Government in the Malaysian Plan. Therefore, this paper aims to explore the impact of daylight strategies for educational studios in universities, by maximising the penetration of natural daylight into the space towards creating a more green-conducive studio. The paper review literature about the types, criteria and benefits of daylight strategies. This paper also presented a pilot study that has been performed in one university in Perak, Malaysia, by selecting architectural studios as the main subject.

1. Introduction

Nowadays, sustainability and green architecture concept has become the common interest of numerous disciplines [1]. The reason for this popularity is to perform the sustainable development and construct buildings with environmentally friendly features [2] that able to reduce carbon dioxide emission and energy wastage. Green architecture was introduced in order to minimizes harmful effects on human health and the environment [3].

Among the characteristic of green architecture is an energy-efficient lighting and indoor environmental quality (lighting comfort) [4]. The Malaysian Green Building Index (GBI), (2015) for Interiors space assessment, has stated that daylighting is one of the elements to create a good Energy Efficiency (EE) and Indoor Environmental Quality (EQ). In Malaysian Standard (MS 1525), there is also a clause that highlights the importance of daylighting towards achieving an energy efficiency building. The purpose of both act is to encourage the new and existing buildings in Malaysia to comply with energy efficiency approaches [4].

However, despite all the efforts made by the Government in producing green approach for building in Malaysia, the energy consumption is still increased. It is reported that, for the past 10 years, energy usage in Malaysia, has increased to 109,294GWh per year [5].

In Malaysian cases, artificial lighting is switch on even during the daytime and this happened in many buildings, especially government and university buildings. A report made by [6] has mentioned that the government has paid over MYR 2.7 billion for electricity bills for the government buildings, that mainly comes from government offices, particularly universities and hospitals.

For educational building, such as schools and universities, it is reported that the usage of artificial lighting during daytime has increased the electricity bill [7]. This is all due to the weakness of passive daylighting strategies [8] where most of the windows are tinted or blocked with furniture.
According to Malaysian GBI standards, the daylight factor for a classroom or educational studios need to comply within the range of 1.0- 3.5% in the working plane interior. In addition, the working plane interior also must be installed with a blind or screens that are fitted on all glazing to reduce discomfort of glare from natural light [9].
This paper aims to revitalized daylight strategies involving architectural studio in the campus. The key strategy is to create a green space area that reduces the artificial lighting usage in the space and maximize the use of natural lighting. This paper focuses on previous studies on the daylight strategies in academic space.

2. The issue

In architecture education, studio is the most important space where student develop their learning process such as drawing projection, exercises on grammar of design and visual composition. Besides, studio also a place for students sharing information, learning and interacts with their studio mates [10]. Students will spend more time in the studio.
However, there is an issue, as artificial lighting is used actively through day and night which has increased the utilities bill. In electricity data recorded in one of the university in Perak, Malaysia has shown that electricity bills increased by 8% with the increase numbers of architectural studio in that university [11]. This may concurrence with the frequent use of lighting and air-conditioning in those studios through day and night.
Therefore, there is a need to emphasized and empowered natural lighting for these studios; in order to allow energy to be utilized effectively. The proper natural lighting strategies can be made by increasing daylight usage that improve student performance and increase their comfort levels [12]. In addition, high frequency of studio usage will lead to higher consumptions of electricity energy [10]. Daylight is the most obvious contributions for energy saving in building is in exploiting the most abundant source of light available to us [13].
The use of natural daylight in buildings significantly reduces the electric energy consumption by minimizing the use of artificial lighting during the day [8]. Previous research has shown that daylight utilization (replacement of electric light by daylight) can reduce the use of electric lighting by 50%- 80% in office buildings [14]. Malaysian Minister of Energy, Communication and Multimedia, Tan Sri Datuk Leo Moggie said that one of the ways to save energy was through the efficient use of energy in building by the use of extensive day-lighting techniques that would reduce the amount electricity produced by lighting fixtures [15].

3. Research objectives and aims

The aim of this research is to propose several daylighting strategies that can be integrated into studio educational building designs, allowing the penetration of natural daylight while creating a comfortable studio environment in order to achieve a green- conducive studio.

4. Literature review

Daylighting is a passive strategy that able to help in improving energy performance and user's visual comfort (Lim *et al.*, 2012). Lighting can be divided into two types such as natural light and artificial light [16]. The good natural lighting strategies will reduce the energy consumption spent on lighting while providing adequate illuminance [8].

4.1. Daylight strategies for educational space

Daylight system can be set-up from simple static features (louvers, light- shelves, fixed overhangs, laser-cut panels, prismatic elements, anidolic systems, etc.) to adaptable dynamic elements (blinds, movable lamellae, advanced glazing, holographic optical elements, etc.) and/ or a combination of these elements. This features can, advance distribution and uniformity, increase daylight penetration indoor spaces, and control direct sunlight and reduce glare [8]. Recently, a study by [17] has suggested that it is wise to reduce the consumption of electricity through the utilization of illumination level. [18] proposed that the usage of daylight factor (DF) is significant in achieving more sustainable design of a building.

One of the most significant strategies for reducing the energy consumption effectively in a building is by the design and selection of a suitable window system[19]. For architecture studio facilities, there are certain window designs to be accomplished such as the window head should be as high as possible; at least 2 meter above the floor level to provide a clearer view and space upon designing a project. Next, the window sill must not be higher than 1 meter from level because it can prevent someone to see out when sitting. Furthermore, the window surface are should be evenly distributed over the outside wall and the window heights and widths must not be too small in relating to the window wall because this reduces the uniformity of lighting and produces undesirable shadows. Shadows in studios will affect students' eye-comfort and may attract them to use artificial lighting. Lastly, better natural lighting can be score with windows on opposite walls since the illumination produced by individual windows are superimposed. The region with the minimum daylighting factor is then displaced towards the centre of the room. The illuminations can increases when the useable depth of the room is increases. These window criteria can enhance an illumination level and reduce heat gain.

This criteria of window design has been determined in BS 8206-2, (2008) to create a good window design than can allows a suitable illuminance inside a space. If the studio is a single sided room; if the depth of room from outside wall is lower than 8 meter, the percentage of window wall as seen from inside should be a minimum of 20 percent. When it is equal or between 8 and 11 meter, the percentage of window wall should be minimum 25 percent. If it is > 14meter, the percentage of window wall should be 35 percent.

Besides of installing a window, the skylight also is one of the daylight strategies. If the studios located at the upper level, a skylight can be considered. The skylight can distribution the light uniformly to the space [20]. A solar shading device is an envelope component of daylight strategies. The application of skylight as the daylight strategies has been supported by [21]. The function of the skylight is to monitor lighting [21]. The solar shading device can control glaring problems and reduce solar gains, and thus avoid overheating. It can overcome the issues of glazing application in building facade such as overcooling, glazing and overheating [22]. Next, the uses of low-E double glazing as the glass facade can help to reduce heat gain [21].

4.2. Visual comfortness in educational space

To produce a good design for natural lighting devices in studios, the natural lighting strategies must be combined with the daylight strategies. [8] stated the natural lighting strategies is spreading out of natural daylight in such a way that it creates a good distribution of the light inside the building and facilitates its penetration in a given space. Next, the design must consider about protection against solar radiation or glaring light. It can produce a negative consequence on the spatial activities, such as reflected sunshine glaring on the desk, chalkboard and walls. Lastly, controlling of the natural daylight can manage the quantity and distribution of the light in order a given space according to the needs of its users.

The daylight strategies can be planned by determined the floor plan with an east- west axis, and south-facing windows and roof monitor and skylight for daylighting. [23] said the overhangs and interior baffles to shield direct sunlight while using daylight. There are various act (BSI, 1992; BS 8206, 2008) regulations (Hong Kong Government, 1997; Building Department, HKSAR, 2005) and design handbooks (Illuminating Engineering Society (IES) of North America, 1993) that present the precautions and conditions for good daylighting in building. USGBC, LEED-NC (2009), green building rating system from the US Green Building council, suggest a DF is 2 percent for the minimum daylight level a minimum illuminance level of 269 lux on the equinox at 9am and 3pm under the International Commission on Illumination (CIE) clear sky conditions. The environmental rating system BREEAM awards a credit where occupied spaces have an average DF of over 2 percent. The [24] stated that an illuminance level of 300lx for offices, classrooms and library type's space, occupied hours from 8am to 6pm. According to Chartered Institution of Building Services Engineers (CIBSE), in educational buildings context, the minimum illuminance level is 300 lx for classrooms and computer practice where the minimum illuminance level is 750lx for technical drawing classrooms and 500lx for conference and meeting rooms [25]. Figure 1 and 2 shows the types of daylight strategies. Figure 1 stated that the different of devices and features can be installed to the educational building window. Figure 2 showed daylight strategies by used a material application, opening (windows) devices, roof features and volume space.

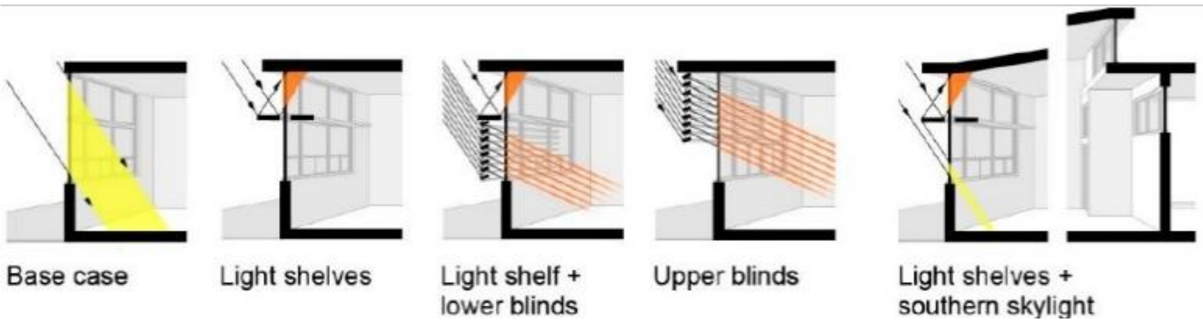

Figure 1. Daylight strategies for educational space
Source: Moreno & Labarca (2015)

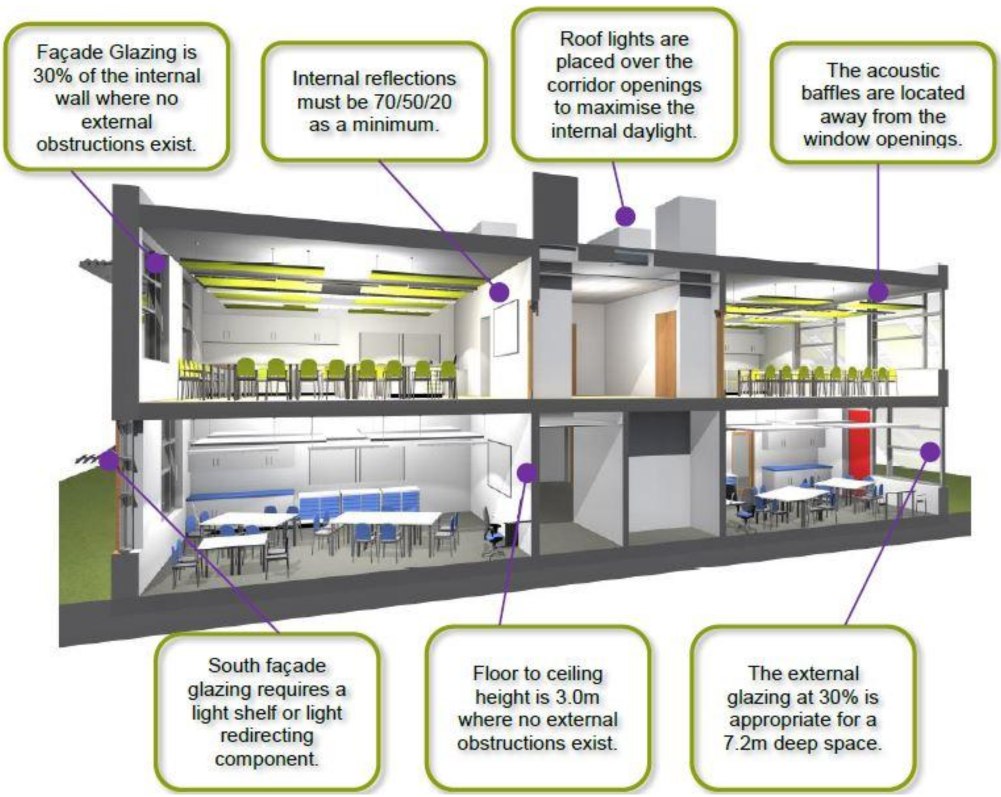

Figure 2. Daylight strategies for educational space
Source: Education Funding Agency (2014)

4.3. Measurement

In order to obtain suitable visual comfort in the studio, two variables need to measure:

- illumination (E)
- daylight factor (DF)

Illumination = illuminance

Illuminance is a total of illumination on a bright surface. Its defined as the luminous flux. Standard unit for illuminance is lux which is lumens per square meter (lm/m^2):

- $E = \frac{F}{A}$
- . E = illuminance of a surface (lm/m^2 or lx)
- F = luminous flux incident on the surface (lumen)
- A = the area of the surface (m^2).

Daylight can be measure in two calculation:

- Using luminous quantities (flux, illuminance), i.e. by a set of outdoor conditions and calculating the resulting interior illuminances.
- Using relative values (the DF) that compare indoor to outdoor regarding illuminance. For a given position, this factor is constant under widely varying outdoor lighting conditions.

The lighting design for illumination normally takes into consideration diffuse light only. The most common metric for measuring daylight- the DF- is valid under the CIE overcast sky model.

- The DF is = the relation between the indoor illuminance at a point on working plane (E_i) and the outdoor horizontal illuminance (E_o) for a CIE overcast sky conditions (Commission Internationale de I'Eclairage (CIE), 1970):
- $DF = (E_i / E_o) \times 100\%$

The DF can be effect by various parameters such as:

- Size and orientation of the glazing.
- The dimensions of the space.
- The reflectance of the surfaces.
- The external obstruction.

No electricity lighting is needed if the space has an average DF of 5 percent or more. The space needs more electric lighting if it is below 2 percent [26]. The DF of 5 percent or more will make an interior looks great daylight and DF below 2 percent will produce a dull interior (BS 8206-2, 2008).

5. Conclusions

This paper review previous studies on the effect of daylight strategies on the educational space in terms of types, criteria, and benefits of daylight strategies. Daylight strategies can reduces the building energy consumption (electrical energy), glare effect, reduce the heat gain (natural overcooling system) and increase daylight penetration indoor spaces. This study provides valuable information for academic institutions on development of green educational space by using natural light in studio. Moreover, this review can help architect and designers in designing daylight strategies in kindergarten, school and universities, which generally provides inadequate natural light.

6. References

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