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Performance Evaluation of Indoor Environment Towards Sustainability for Higher Educational Buildings

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The indoor environmental factors considered in higher educational building must be determined in order to meet the user's requirement. Disruption of indoor environment may constitute to reduce occupants' efficiencies and their learning process and activities. But the question is, how to ensure that the provision of indoor environmental aspects achieves high satisfaction to the building user. Therefore, POE (post occupancy evaluation) is a prominent tool that indicates satisfaction and comfort level needs by the building occupants as lessons learned to identify problems in the indoor environment. The information of the building's condition is gained by reviewing what the occupants' feelings are and how they response to their needs by using and occupying the building. With relation to the title, the main aim of this study is to determine the occupants' satisfaction levels and the probability of learning process, which can be affected due to poor environmental conditions, based on analytical study on concept and process of POE. A survey on occupants' satisfaction of 100 students in University Technology of MARA, Perak, Malaysia, has revealed that there is significance of providing good quality of indoor environmental conditions, that will affect the learning process of the students. It is concluded that POE is effective to be used in evaluating performance of environmental conditions in a building, especially to apply the relative impact of aspects towards the design of future buildings. By introducing POE in evaluating environmental conditions in higher educational buildings, it is hoped that it helps to move the industry towards sustainable, healthy and comfortable learning areas.

Keywords: indoor environment, occupants' comfort levels, higher educational buildings, POE (post occupancy evaluation)

Introduction

According to Fien, Maclean, and Park (2010), back in 1990, there were several universities signed a ten-point action plan for incorporating sustainability and environmental literacy in teaching, research, operations and outreach at colleges and universities. Seeing this importance, hence, the evaluative criteria derived from the occupants in educational buildings needs to be measured in terms of quality of building

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facilities for its general condition and suitability for education. Higher learning institutions generally occupy large land area and a growing populations year by year. Various activities which are not limited to education and research activities alone are conducted in the campus involving students as the dominant occupants of higher institutions. The academic and non-academic activities resulted in two significant ways: direct and indirect impacts on the environment and sustainability. As stated by Sohif et al. (2009), the environmental pollution and degradation caused by the university in the form of energy and materials consumption via activities and operations in teaching and research, provision of support services in residential and hostel areas have raise some serious concerns within the campus community and the various external organizations alike. Over the past decade, thousands of higher educational buildings have been planned, designed and constructed in Malaysia and only a small fraction will ever be evaluated against the building facility needs of students and academicians. In an effort to standardize the evaluation of educational facilities, the evaluative criteria derived from the occupants in educational buildings needed to be measured in terms of quality of building facilities for their general conditions and suitability for education. In the current situation where people concern about sustainable environment, building occupants seeks to obtain comfort and efficiency, especially in higher educational buildings. Occupants demand to have priority in terms of comfortability to use and utilize the facilities and services as it must be fit for the purpose of the user. The educational process and learning activities may be de-motivated and interrupted due to poor environmental conditions. Several questions arise in regards to poor environmental conditions in higher educational buildings. Is there any way in which evaluation of indoor environment aspects might combine to form an occupant's overall assessment? Does the provision of services and facilities in higher educational buildings well function and fit for the purpose of the user? POE (post occupancy evaluation) is one of strategic analyses of building sustainability after occupancy. Natasha and Abdul Hadi (2008) encapsulated POE as an integrated tool that determines the parameters of building environmental performance perceived by the user and provides ways towards improvement. Watson (2003) stated that POE is an assessment of how well the building matches the user's needs and identify ways to improve building design, performance and how it can fit the purpose for which it was built. Information of the building's condition is gained by reviewing what the occupants' feelings are and how they response to their needs by using and occupying the building.

In regards to the performance of environmental conditions in a building, more than one indoor environmental aspects need to be measured. According to Humphreys (2005), occupants' satisfaction with one or more environmental aspect in a building does not necessarily produce satisfaction with the total environment. Several case studies presented by Zagreus, Huizenga, Arens, and Lehrer (2004) indicated that information provided by POE survey can positively influence indoor environmental quality for occupants of existing as well as future buildings. Therefore, this study is purposely conducted to determine occupants' satisfaction in terms of three indoor environment aspects, namely: (1) visual comfort; (2) thermal comfort; and (3) air movement, by using POE method. This study is limited to the end-user of the higher educational building, i.e., the students.

Problem Statement

According to YUAN (1987), Malaysia's climate can be classified as warm-humid equatorial, characterized by high temperatures and humidity. Air temperature averages within 22 and 32 degree Celsius with small annual and diurnal ranges. It is continually near but seldom exceeds normal skin temperature. Malaysia which is located in tropical climate region is naturally hot and humid. Because of this situation, the majority of

buildings in Malaysia served air-conditioning and mechanical ventilation systems to maintain a thermally comfortable indoor environment. The rapid development of higher institutional building which is normally located in the sub-urban or city area, incorporates issues in terms of cleanliness, noise and air pollution. Cheong and Chong (2001) pointed out that the provision of comfortable indoor environment for the occupants is the only aspect in achieving better indoor air quality. Chemical pollutants, volatile organic compound, noise pollution or pollutant contaminants are factors that can have impact on the quality of indoor environment. Pollutant emissions from human activities, building materials and air handling units in the form of both living and dead material take place continuously in any type of buildings. Over the last 20 years, a range of POE methods have been developed and their systematic applications have demonstrated a huge potential not only to reduce the financial and environmental costs, but also to improve the quality of life, comfort and sustainability of building (Nicol & Roaf, 2005).

However, building condition assessments do not explicitly address educational adequacy of the academic buildings that is the relationships between physical condition of the school and various educational goals and activities that take place within the building. Problems in higher educational buildings include lack of design aspects, building elements, inadequate room spaces, facilities, safety aspects, indoor and outdoor environmental problems, noise pollution and many more. Comments from occupants should be recorded and the value placed on the particular issue is relative to other issues. The economic plan to develop higher educational buildings is served based on the programmes offered by the university. Therefore, the majority of higher institutions must provide lecture halls, class/lecture room, library, studio, computer labs and others. Delivery of knowledge to students, their learning process and activities by face-to-face interactions are generally conducted at lecture halls or class/lecture rooms. Seeing those vital areas, the provision of indoor environmental aspects must be adequate to encourage students to learn in an effective way.

In Malaysia, Ambu, Chu, Mak, S. F. Wong, Chan, and S. T. Wong (2008) developed a general guideline of indoor environment quality to any type of building and analysed its impact on health purposes, but the study did not relate the specific guideline to be used towards students' learning efficiency. Another similar study conducted by Sohif et al. (2009) addressed the concept of indoor environment and its sustainability in campus by reviewing used practices, the organizational approach and measurement of technical improvement towards sustainability. He suggested that universities must preserve the environment, stimulate economic growth and improve the well-being of the surrounding community, but the study does not provide a new method to achieve the sustainability concerns.

Research Objectives

The introduction and the problem statement above led to the formulation of the research objectives. The objectives for this study are:

(1) To determine occupants' satisfactions and perception levels in higher educational buildings in terms of indoor environmental aspects;

(2) To determine the probability of learning process that may be affected by poor environmental conditions.

The Concept of POE

POE in the 1960s and 1970s involved in individual case studies of public and student housing sector (Vischer, 2002) in Britain, France, Canada and US. The evaluation primarily involved collecting information

about occupants and buildings through questionnaires, interviews, site visits and field observation. It was then spread widely to other facilities, such as army barracks, hospitals, prisons, courthouses and hospital. With the logical step and beneficial results of POE, it was later applied to commercial real estate and office buildings by the mid-1980s. The information from POE has been used by the public agencies in support of the design criteria and guidelines. POE programmes were conducted by a number of project teams after construction in order to identify lessons learned by analysis of findings.

Generally, there are three phases and steps involved in conducting POE, namely: (1) planning; (2) conducting; and (3) applying (Preiser, Rabinowits, & White, 1988). For this study, a prototype guideline adopted from Natasha and Abdul Hadi (2008) was used to fulfill the objectives of study. It consists of activities under each step and the survey commenced from step 1 until step 6. Figure 1 depicts the proposed guideline.

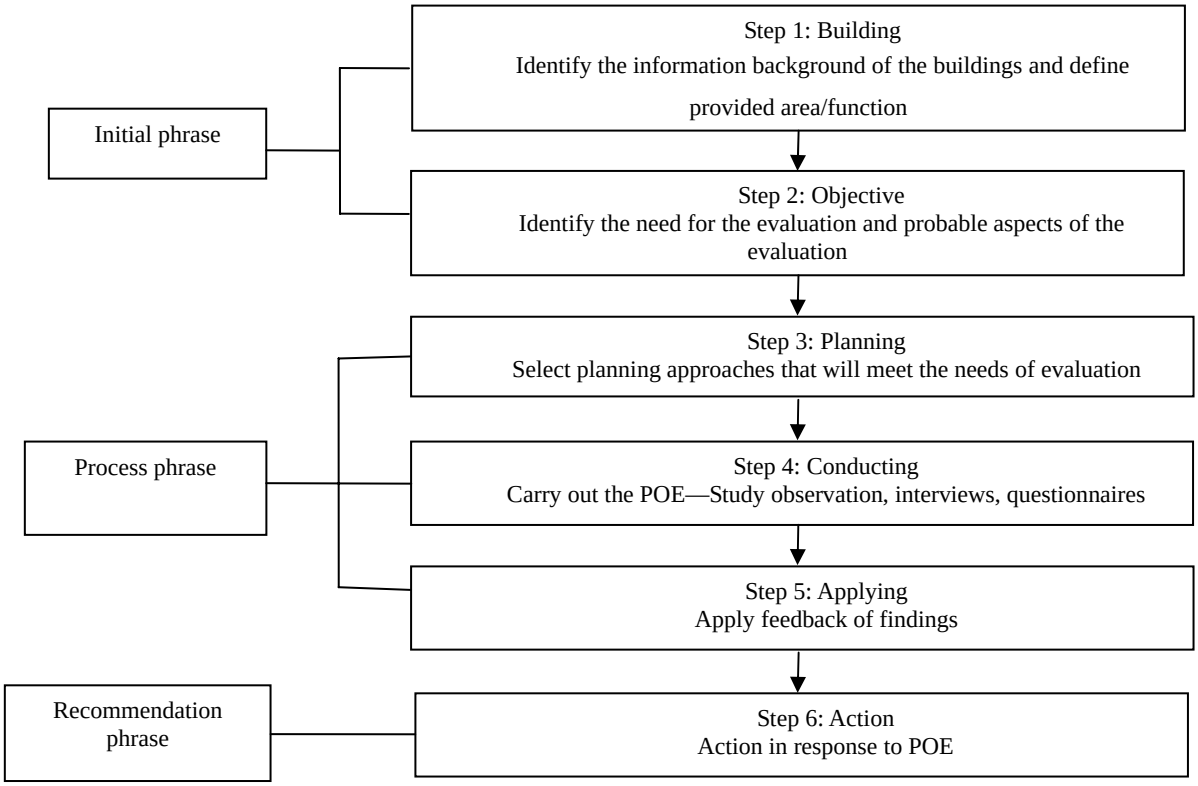

Figure 1. Prototype guideline of POE. Source: Natasha & Abdul Hadi, 2008.

Analysis and Findings

This study was conducted at one of the higher educational buildings in Malaysia, i.e., University Technology of MARA which is located in Seri Iskandar, Perak, Malaysia. Currently, there are about 10,000 students who are studying in various programmes in this institution. The respondents who were randomly sampled are the end-users of the institution. One hundred questionnaires were distributed to the respondents and a self-administered questionnaire which is based on Likert scale was prepared to be rated by the respondents. The Likert scale consists of five numerical nomenclatures on each question, ranging from “1” to “5”. They need to rate their perception levels of three parameters of indoor environmental aspects:

(1) Visual comfort—natural day lightings vs. artificial lightings;

(2) Thermal comfort—cooling system vs. fan system;

(3) Air movement—provision of openings vs. indoor ventilation.

Figure 2 shows comparison of respondents' rate in terms of visual comfort, i.e., natural daylight and artificial light. The majority of the respondents stated that the artificial lightings were bright (54%) while 36% respondents (highest percentage) claimed that the provision of natural daylight was dark. This result shows that the provision of natural daylight is still inadequate, which needs artificial lightings to improve the visual view in their building units. This may constitute more usages of energy consumption since artificial lightings are widely used.

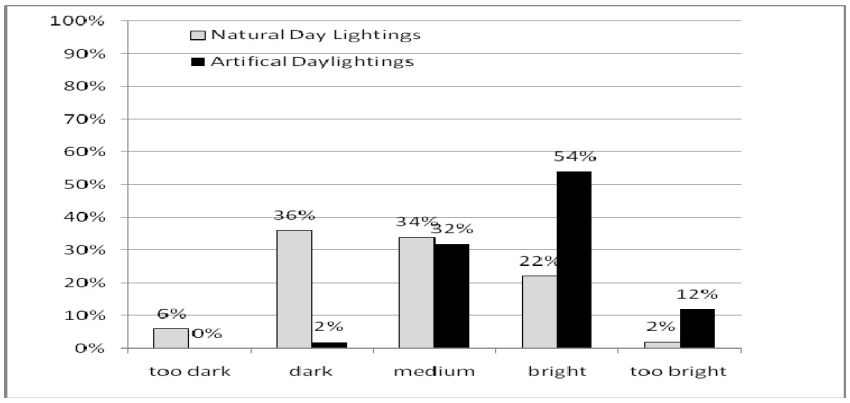

Figure 2. Occupants' perception level on visual comfort.

Figure 3 shows comparison of thermal comfort provision, i.e., air-conditioning and fan system. The majority of the respondents indicated that they were at medium level of comfort for both parameters. It may be caused by self-controlling of the system that can be suited to the conditions in the building unit; the occupants may adjust the needed temperature, therefore, it constitutes the thermal comfort not to be too cold or too hot. Figure 4 shows that the majority of the respondents indicated that the provision of air movement was poor (36% for provisions of openings; 38% for indoor ventilation).

Apart from rating their perception levels for the above indoor environmental aspects, the respondents also stated that the learning process could be affected by poor environmental conditions. The result is shown in Figure 5, whereby 40% of the respondents who constitute the highest percentage stated that their learning processes and productivity decreased due to poor environmental conditions.

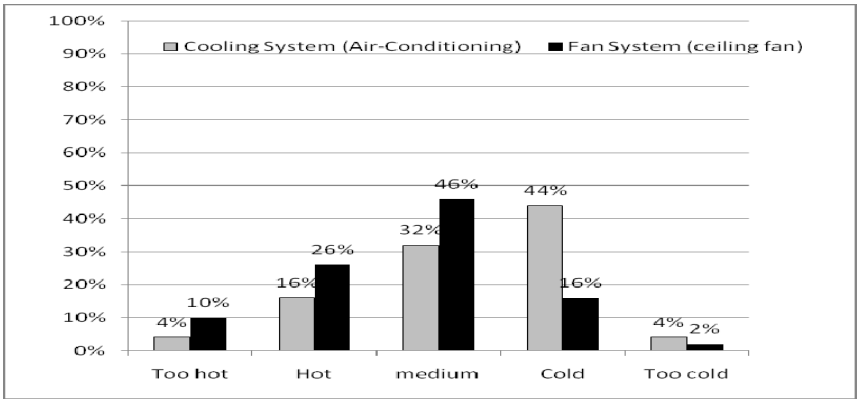

Figure 3. Occupants' perception level on thermal comfort.

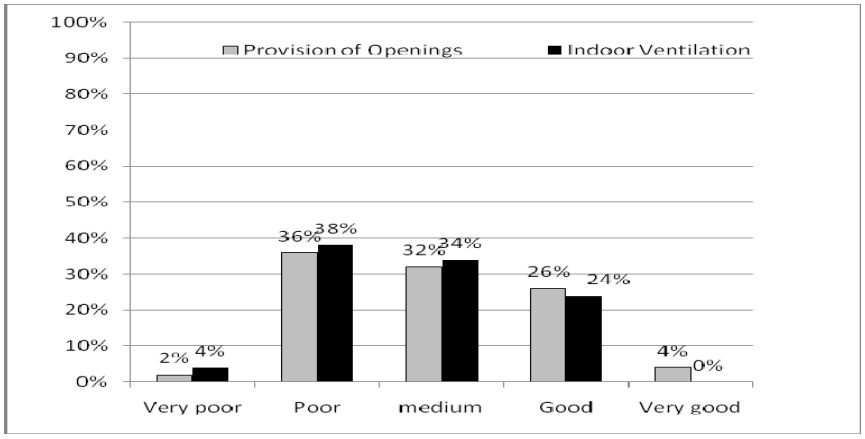

Figure 4. Occupants' perception level on air movement.

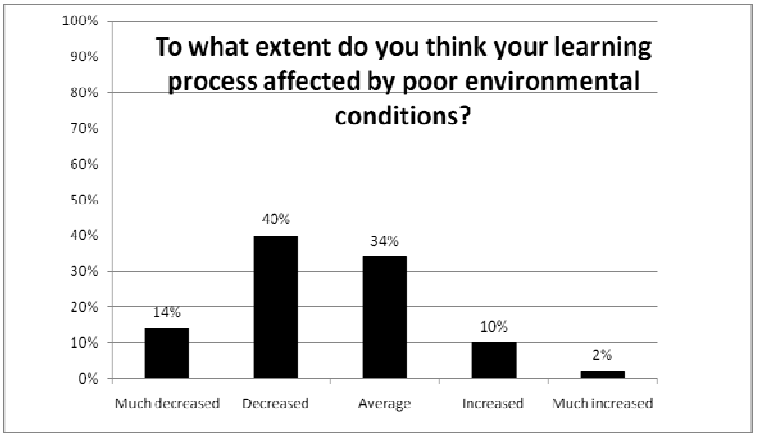

Figure 5. Assessment of students' learning process can be affected by poor indoor environment.

Based on the result and analysis of the survey, two related dependant samples were tested in NPar (non-parametric test) using SPSS (Statistical Packages for the Social Sciences) version 16.00 (see Table 1). The analysis was undertaken to see which hypothesis can be accepted based on the following hypothesis:

H_0: The learning process is not affected due to occupants' comfortability in terms of poor environmental conditions.

H_1: The learning process is highly affected due to occupants' comfortability in terms of poor environmental conditions.

Table 1
Statistic Tests Between Two Related Dependant Samples (NPar Test)

	Overall comfort level in the building area—Learning process is affected by the poor indoor environmental conditions in the building
Z	-2.127[a]
Asymp. Significance. (2-tailed)	0.033

Note. [a] based on negative ranks.

It was statistically tested with a 2-tailed alpha level of 0.05. Based on the results shown in Table 1, since *p*-value is $p = 0.033$ (2-tailed test) which is less than 0.05, it is reported that there is enough evidence to

conclude that the learning process is highly affected due to occupants' comfortability in terms of poor environmental conditions. With this significance finding, the value of indoor environmental aspects should be incorporated into the preliminary planning of a higher educational building, in terms of occupants' perceptions and comforts.

Research Conclusions and Recommendations

It can be concluded that POE provides significant impact on creating change in terms of improving building environment by providing lessons and feedbacks for the owner or those involved in the environment improvement works. The analysis has shown that if a higher educational building experiences poor environmental conditions, it will demotivate the students during learning process, thus, reduce the quality of students' achievements. POE can lead towards enhanced quality of indoor environment by being sensitive to change needs of occupants. It empowers the end-users as an evaluation that provides benchmark and a pool of analysis to show how the end product (the building design and its environment management) meets the needs of client and users. By effective implementation of POE, it enables the relevant stakeholders to shorten the learning time of the positive and negative environment changes. In general, quality of indoor environment in higher educational buildings can be improved by:

(1) Using recyclable or renewable materials to avoid emission of chemical or microbial contaminants, for example, materials for furniture, floor finishes, wall finishes or ceiling finishes;

(2) Using environmental-friendly products, for example, energy saver lights, which can reduce the usage of energy consumption;

(3) Instilling public awareness to practice a healthy and sustainable environment and promote more campaigns through community service;

(4) Emphasizing energy-efficient design in higher educational buildings.

Ideally, POE must be a continuous activity to evaluate the performance of building in certain duration of time. It is suggested that POE should be implemented as a practice in Malaysia as a benchmarking towards sustainable environment. Continuous programmes of POE are not only able to identify problems constituted to disruption in environmental performance, but also are able to avoid emergence of defect or deterioration. By providing lesson learned from the application of POE, it should be incorporated in the early design phase and planning of any buildings. All building players should prioritize the application of POE as decision-making at strategic level to maintain sustainable environment.

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