Factors Contributing to Occupants' Comfort: A Survey among Occupants of Academic Buildings in a Public University

S.N.N. Syed Yahya, Ati Rosemary Mohd Ariffin and Muhammad Azzam Ismail
Department of Architecture
Faculty of Built Environment
University of Malaya
Kuala Lumpur, 50603, Malaysia

Abstract

Occupants' comfort is always crucial in determining the quality of performance of an academic building and its facilities management. Factors such as thermal, acoustic, visual comfort and personal control of the building's environmental condition generally contribute to the overall comfort level of its occupants. However, it is important to identify which of the factors contribute most to an occupant's overall comfort. Therefore, this study investigates the relationship between comfort and its contributing factors by utilizing the Building Use Studies (BUS) questionnaire from the UK. The questionnaire was distributed to respondents from one of the earliest and prominent public university in Malaysia. The paper further investigates which type of personal control significantly influences the building occupants' overall comfort. Analysis from 451 responses revealed that there is a significant correlation between overall comfort of the building's occupants with two significant contributing factors which are; air condition (thermal comfort and air quality) and personal control. However, there is insufficient evidence that noise (acoustics) and lighting (visual) have significant correlation with a building occupants' overall comfort level.

Keywords
academic building, occupant comfort, factors of comfort, public university

1. Introduction

Brown and Cole (2009) refer comfort to the most acceptable indoor environment conditions for occupancy and that it is always related to sustainability in building design (Chappells and Shove, 2005; Holopainen et al., 2014). Frontczak and Wargocki (2011) pointed that the indoor environment is perceived to be comfortable when the building occupants do not feel the need to adjust the condition of their environment to suit personal preferences. Therefore, existing buildings especially those built after more than ten years must be evaluated to adhere to occupants' perceptions of comfort inside the building (Arens et al., 2010). Occupants' comfort in academic building is of utmost importance in ensuring efficiency in teaching and learning (Khalil et. al., 2012) which is relevant to all learning institutions. Studies have proven that how occupants perceive their comfort with regard to the environmental conditions in the building affects their ability to teach and learn (Khalil et al., 2012; Puteh et al., 2012; Yang et al., 2013). Khalil et al. (2010) discovered that 40% of students from a Malaysia university claimed that their performance level are affected by poor comfort level of their indoor environment.

Several researchers have identified factors which influence occupants' comfort with the indoor environment condition (Frontczak et al., 2012; Lee et al., 2012). There are three distinctive factors which the occupants find most important namely; air condition (thermal comfort and quality), noise (acoustic comfort), and lighting (visual comfort). These three factors are extensively discussed in studies concerning occupancy evaluation and building performance (Baird & Lechat, 2009; Lai & Yik, 2007; Paul & Taylor, 2008; Yun et al., 2012). With the recent emergence of automated building systems to control indoor environment in building management, the present study includes a fourth factor which is 'personal control' to examine its relationship as another influencing factor with occupants' overall comfort.

2. Research objective

This study evaluates building occupants' overall comfort and the occupants' level of personal control in academic buildings of a public university in Malaysia. A correlational examination between overall comfort and its influencing factors is also performed to identify which factor most influences the occupants' overall comfort. Finally, the study will reveal whether the results are consistent to the findings of many similar studies done on other types of buildings.

3. Methodology

3.1 Questionnaire

An established questionnaire for occupant survey is used with permission under the license of Building Use Studies (BUS) in the UK. A pilot test was conducted on two groups consisting of thirty (30) students each using the primary version of the questionnaire. Thirty-five returned questionnaires indicated that some adjustments are needed before the actual survey is carried out. The adjustments include inserting Malay translation below each English text. Some terms from the primary questionnaire which are unfamiliar to the local respondents are substituted to more suitable and familiar terms, while one section which is found to be irrelevant is eliminated to make up for the final questionnaire used in the study.

The questionnaire establishes the background and credibility of the respondents by enquiring their status and the period they have occupied the buildings. There are twenty 'Likert Scale' questions inquiring on the respondents' comfort when conducting activities in the buildings. One question concerns with the respondent's overall comfort during occupying the building. The section on comfort is further divided into three types consisting of; comfort relating to the air condition (thermal comfort and air quality), noise (acoustics) and lighting (visual). Respondents are offered to leave their comments at the end of each section. A summary of the breakdown is shown in Table 1. The questionnaire was self-administered to 700 respondents from six shortlisted buildings. Electronic version of the questionnaire was not used because previous research demonstrated that the method has lower response rate compared to a self-administered questionnaire (Nulty, 2008).

Table 1: Questionnaire items

Content	No. of 'Likert Scale' items	No. of open ended items
Demographic information	8	0
Comfort level of air condition	8	1
Comfort level of noise condition	6	1
Comfort level of lighting condition	5	1
Overall comfort	1	1
Total	28	4

3.2 Sampling

Eight buildings are shortlisted from 308 building population in the campus. The sampling frame of the study only includes academic buildings, therefore, all non-academic buildings are omitted leaving only 167 buildings in the sampling frame. However, 167 buildings are overwhelming to manage independently, therefore, additional exclusion criterion is introduced. To ensure that responses obtained are heterogeneous (employees, students and visitors), the buildings need to fulfill at least ten of the common academic space criterion derived from Economic Planning Unit (2008 p.36) guidelines. Therefore, 159 buildings are finally excluded based on the exclusion criterion with eight buildings remaining as shown in Table 2. All buildings are identified by codes provided by the facility management department from the university.

Table 2: List of shortlisted buildings

Code	Block	Built up area (m2)	Year completed
J15	Mathematics Block (ISM)**	3,545.48	1971
M16	Administration Building FSKTM	3,953.08	1999
J24	Language Centre	4,945.32	1979
F18	Block R - Pharmacy	7,875.55	1997
I08	Additional Building FSSS	8,314.01	1999
D25	Balai Ungku Aziz**	8,913.24	2002
L01	Main Block APM	11,480.50	1996
G25	Mercu Alam Bina	20,611.50	2012

*** buildings excluded from the study*

A preliminary assessment through visual inspection of all buildings is performed in making the final selection for use in the study. The assessment identified two buildings; D25 and J15 to be hardly occupied with a negligible number of populations. Therefore, these two buildings are withdrawn from the list of buildings for survey.

4. Results

4.1 Demography of Respondents

From the 700 questionnaires distributed, 451 questionnaires are completed and returned making up a response rate of 64.4%, which is satisfactory for the study. The demographic profile of the respondents is presented in Figure 1. The table reveals that 61.7% respondents are below 30 years old and 37.3% are male respondents. The responses received are mainly from the employees, students or visitors with 50% of respondents are students while 40.3% are employees and only 9.7% make up for visitors.

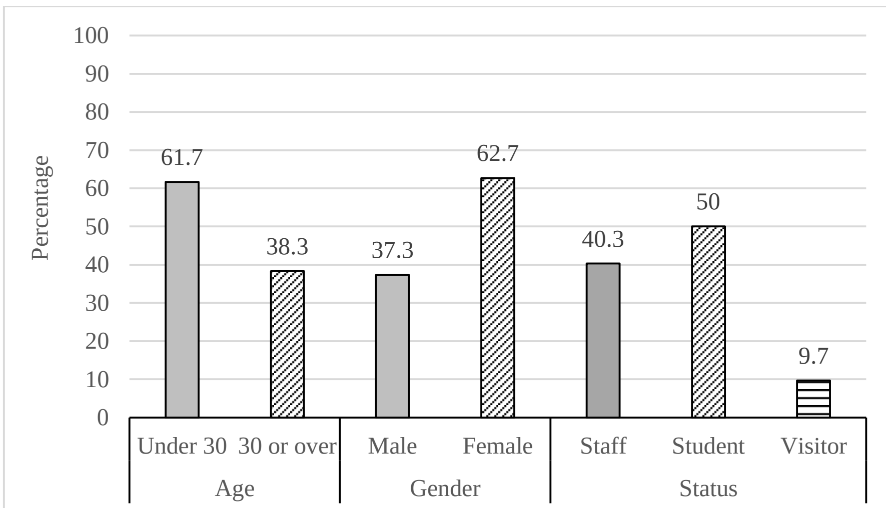

Figure 1: Percentage of respondents by age, gender and status

4.2 Overall comfort and level of personal control

Figure 2 illustrates the mean score for factors influencing the respondents' overall comfort. Mean score for 'overall comfort' is incorporated within the figure with the four factors to show the mean score difference. The Likert scale with measuring unit of 'uncomfortable' (scale '1') and 'comfortable' (scale '7') are used for 'overall comfort', 'air condition', 'noise' and 'lighting'. Meanwhile, the measuring unit for 'personal control' is 'no control' (scale '1') and 'full control' (scale 7). The figure indicates that scoring for three factors (air condition, noise and lighting) are leaning towards 'uncomfortable', while the mean score for 'personal control' leans towards 'full control'. The figure also shows that the respondents are fairly comfortable in 'overall comfort' with the mean score leaning towards 'comfortable'.

Figure 3 presents the mean score of how much control the respondent have over four types of personal control. The measuring unit used is 'no control' (scale '1') and 'full control' (scale 7). The result suggests that respondents have the most control over their lighting with the mean score of 4.43 and have the least control over noise with the mean score of 4.05. Generally, the respondents feel that they have fair control over all environmental conditions with each mean score is higher than the neutral score ('4').

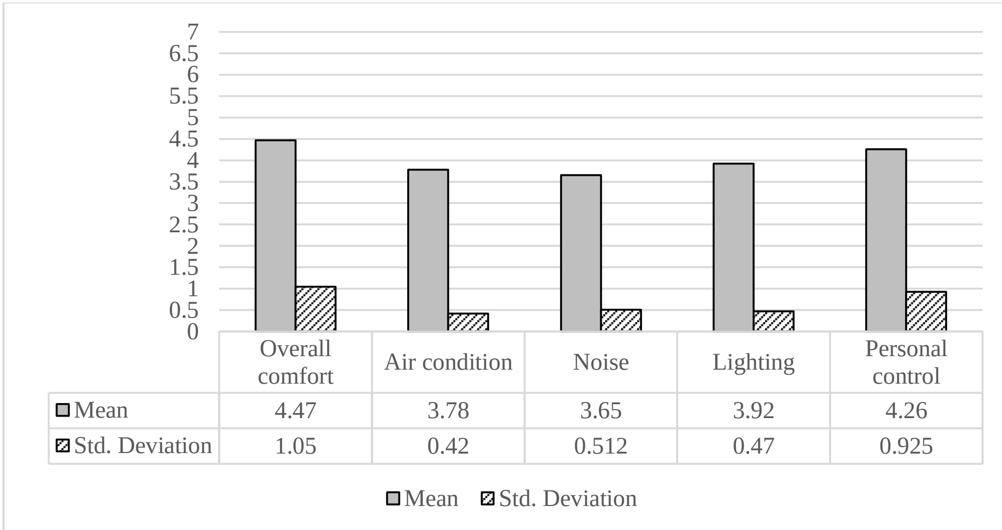

Figure 2: Mean and standard deviation of factors influencing overall comfort (valid *n* = 385)

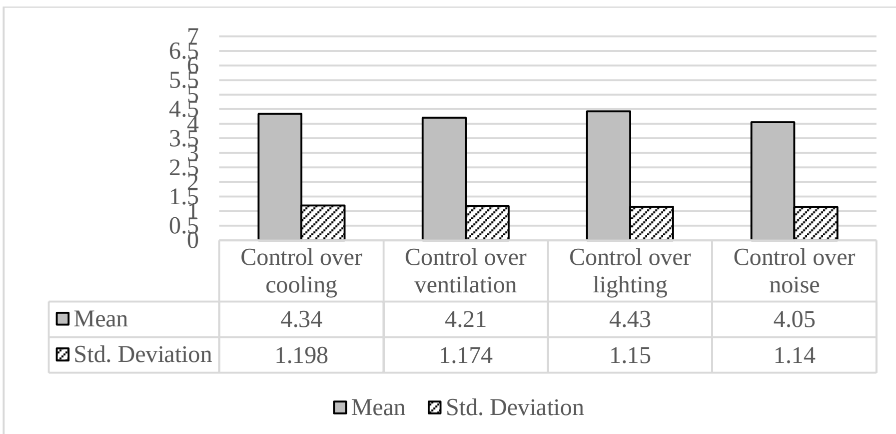

Figure 3: Mean and standard deviation of type of personal control (valid *n* = 435)

4.3 Relationship between overall comfort and influencing factors

Table 3 exhibits that the correlation coefficient between overall comfort and air condition is .172. The two asterisks indicates that the value of .172 is significant at a 1% level. From the table, control over cooling and control over ventilation have significant correlation with overall comfort, while noise and lighting do not have any significant correlation with overall comfort.

Table 3: Spearman correlation coefficient for factors contributing to overall comfort

Factors	*N*	Coefficient	Sig. (2-tailed)
Air condition (thermal & quality)	400	$.172^{**}$	.001
Noise (acoustic)	421	.037	.444
Lighting (visual)	428	.050	.300
Personal control	431	$.536^{**}$	.000

** Correlation is significant at the 0.01 level

Table 4 shows the multiple regression analysis for the two factors that contributes significantly to overall comfort. An analysis was conducted using 'stepwise' method was reached in two steps with 'overall comfort' as the dependent variable. The results show that the model was statistically significant, F (2,380) = 65.045, p < .001 for 25.1% of the variance of overall comfort (R^2 = .255, adjusted R^2 = .251). Overall comfort is predicted by personal control and lesser by air condition. In the form of :

$$Y = a + b_1(X_1) + b_2(X_2) \quad (1)$$

every unit in increase for personal control, .127 increase in overall comfort is predicted and one unit increase in air condition comfort increases overall comfort by .044.

Table 4: Multiple regression analysis for factors contributing to overall comfort

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
2	(Constant)	.979	.432		2.265	.024
	Personal control	.127	.012	.470	10.570	.000
	Air condition	.044	.013	.151	3.398	.001

4.4 Relationship between overall comfort and types of control

Table 5 shows the multiple regression analysis for the types of control that influence overall comfort significantly. 'Stepwise' regression analysis was reached in three steps with 'overall comfort' as the dependent variable. The results show that the model was statistically significant, F (3,427) = 41.317, p < .001 for 22.5% of the variance of overall comfort (R^2 = .225, adjusted R^2 = .220). Overall comfort is predicted by personal control over cooling lighting, and ventilation. Personal control over noise is does not influence overall comfort. In the form of :

$$Y = a + b_1(X_1) + b_2(X_2) \quad (1)$$

every unit in increase for personal control over cooling, .173 increase in overall comfort is predicted and one unit increase in personal control over lighting increases overall comfort by .166. The model also predicted that one unit increase of personal control over ventilation increases overall comfort by .157.

Table 5: Multiple regression analysis for types of personal control contributing to overall comfort

Factors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.307	.198		11.624	.000
control over lighting	.166	.052	.183	3.164	.002
control over cooling	.173	.048	.198	3.583	.000
control over ventilation	.157	.050	.177	3.131	.002

5. Discussion

The main purpose of the study is to evaluate building occupants' overall comfort and level of personal control in academic buildings at a public university. The study also investigates the relationship between factors which are reported to have influence over occupants' comfort. Findings from this study are crucial for buildings managers in identifying elements to emphasize building maintenance with data collected from 451 completed questionnaires on eight academic buildings at a Malaysia public university.

Analysis on the demographic profile of the respondents suggests that the survey achieved homogeneity in the respondents' status. There is a marginal difference on the percentage of students and employees who responded to the survey while visitors' count is the smallest, as expected. Nearly two-thirds of the respondents are younger than 30 years old because students make up 50% of the total respondents. Approximately two-thirds of the respondents are female because more female students are currently enrolled in public universities in Malaysia compared to male (Ministry of Higher Education Malaysia, 2013). Moreover, the high count of female in employee respondents is due to the fact that public service is more attractive to female than male workers (Ministry of Women Family and Community, 2013).

The first objective of the present paper is to examine the overall comfort and level of personal control of the respondents as building occupants. The mean score calculated for both measurements (overall comfort and personal control) revealed that despite feeling less comfortable for all three environmental conditions (air, noise and lighting) they still rated that they are comfortable with the building in overall. This outcome shows that the buildings occupants' overall comfort is not greatly affected by the air condition, noise and lighting comfort. However, the opposite can be said for personal control. Respondents rated that they have some control over their environmental conditions as occupants. The mean score for personal control is higher than 'neutral' and is more consistent with the mean score for the respondents' overall comfort. This result suggests that the occupants' ability to control their surrounding personally may be the factor influencing their overall comfort level as occupants.

This assumption is further investigated by calculating the mean score for each type of personal control. There is a fringe difference in the mean score over the four types of personal control and it is apparent that most respondents rate that they have more control over lighting and cooling. This is because, almost all artificial lighting in the buildings surveyed are installed with light switches that are accessible to the occupants. Some lighting is centrally controlled and is usually just for common areas like corridors and lobbies. Many windows and openings that permit sunlight fenestrations are installed with blinds for control. These blinds are usually accessible to occupants.

Respondents rated that they have less control over the cooling of the building. Although some rooms are equipped with non-centralized air-conditioning system that can be manually controlled by the occupants (lecturer's rooms and lecture rooms), the larger rooms like lecture halls and auditoriums are installed with centralized air-conditioning system. The centralized air-conditioning systems are controlled by the building technician and the controls are only accessible to him. The situation is different with split-unit air-conditioning system where it allows occupants to control and adjust the temperature of the room according to their comfort.

Ventilation within a building is usually controlled by fans, air-conditioners and openings on the external wall of the building. The buildings surveyed are mostly mechanically ventilated except for the toilets. Rooms that have external walls with windows can only control its ventilation by windows that can be opened. Some windows, especially in old buildings are malfunctioned with the windows jammed or wedged for safety. These two factors may be the cause for lack of personal control over ventilation. Also, the amount of ventilation for rooms with natural ventilation usually depends on how drafty the day is, where a still day will not provide natural ventilation for the room. This situation is entirely out of the occupants' control.

Respondents rated that they can control noise the least compared with other types of control. Noise control is usually dependent on the physical condition of the building, such as, type of wall used (sound-proof or not), proximity of each room, and more importantly the source of noise. These are conditions where building occupants have no control at all, hence returning the survey result as reported in the previous section. This result agrees with the finding of other research which also highlight that noise comfort is the most difficult type of environmental condition to control (Baird & Lechat, 2009).

The next objective of this study is to examine whether there is any significant relationship between the four factors of air condition, noise, lighting and personal control with the overall comfort of building occupants. The findings revealed that there is a significant relationship only between two factors; air condition and personal control, with overall comfort. These findings are consistent with the result from the previous section where it is found that overall comfort score is high despite having low mean score for the remaining two factors (noise and lighting). This survey has proven that noise and lighting does not have significant influence on overall comfort. This is probably because most respondents perceive that they have little control over noise and lighting. Therefore, they have a higher tolerance for the two factors.

In a hot and humid country such as Malaysia, an air conditioner is perceived to be very important by building occupants. It is an important factor because Malaysia often experiences drastic weather change and it affects indoor temperature. In addition, air conditioner which consists of thermal comfort and air quality, directly affects the physical comfort of the occupants. However, noise and visual comfort have more direct effects on the psychological comfort of the occupants (British Standards Institution, 2013). This result is consistent with previous researches reporting that building occupants consider thermal comfort and indoor air quality to be the most important factor influencing overall comfort (Frontczak & Wargocki, 2011; Paul & Taylor, 2008).

Nonetheless, the result showed that the ability of the occupant to personally control individual environmental conditions influences the overall comfort more than air condition alone. According to the positive correlation of the Spearman rank analysis, the more personal control that they have over their environmental condition, the more occupants perceive the building as comfortable. This research outcome contradicts with the finding of another research by Baird and Lechat (2009) who suggested that the overall comfort of the occupant has a negative correlation with personal control. Baird and Lechat (2009) interpreted that the better the occupant's perception of the overall comfort, the lesser the occupant needs to control the environmental condition personally. This is of course, another way to look at the result of the survey where it can be interpreted that, because occupants can control their environment condition, they are able to increase their overall comfort. As suggested by another researcher, occupant's ability to control their environmental condition, especially temperatures, should be included in the approach towards sustainability (Holopainen et al., 2014). Ability to personally control the environment condition highly influence the occupants overall comfort because, as summarized by Arens et al. (2010), the acceptable temperature band for occupants differ according to clothing insulation and metabolic rate. Therefore, Arens et al. (2010) recommended that occupant feedback should always be incorporated in building operations.

Extending from the significant relationship between personal control and overall comfort, this study further investigates the relationship between each type of personal control with overall comfort. The investigation is important to know the level of personal control that the occupants currently have on their environmental conditions. Building managers can use this information to improve the current level of personal control in buildings.

It is apparent from the result presented in the previous section that overall building occupants' comfort would vary and much influenced by the types of control the occupants have on their environment. The result indicates that control over cooling has the most significant relationship with overall comfort. As previously explained, cooling condition affects the occupant physically especially during a hot day, the room temperature increases, causing uncomfortable environment condition to the occupants. Their ability to control cooling significantly influences their perceptions on the comfort level of the building. Although other types of control have lesser influence on the overall comfort of a building occupant, their correlation is still statistically significant except control over noise.

6. Conclusion

To guarantee efficiency in teaching and learning experience, an educational institution must ensure that its students are comfortable in its premises. This study indicates that personal control over indoor environment and indoor air condition are important factors that influence a building occupant's comfort. This is an important finding for building managers to identify which element to focus in building maintenance. Now that the building managers know that personal control and indoor air environment have the highest influence, he can focus on ensuring that the occupant has the ability to control his environment and the occupant's thermal comfort and air quality is at its optimal conditions. For example, the occupants could be allowed to have access to the cooling system temperature adjuster, or as simple as opening the window.

However, the fact that data for the relationship of personal control and overall comfort was interpreted differently by another researcher invites further investigation. It was found that 'personal control' can either be the independent variable or the dependent variable. For this research, 'personal control' is inserted in the statistical analysis program as independent variable, whereas the opposite is for 'overall comfort'. Does 'personal control' influence 'overall comfort' or does 'overall comfort' influence the need to have 'personal control'? It is suggested that further research should use a different set of questionnaire that clearly probes into the respondents perceptions on whether personal control influences overall comfort or not.

Acknowledgements

This research was made possible by University Malaya’s Postgraduate Research Fund (Project no. PG098-2013A) and Adrian Leaman of Building Use Studies for licensing the BUS questionnaire for the use of the survey.

References

Arens, E., Humphreys, M. A., de Dear, R., and Zhang, H., Are ‘class A’ temperature requirements realistic or desirable?, *Building and Environment*, vol. 45, no. 1, pp. 4-10, 2010.

Baird, G., and Lechat, S., Users' perceptions of personal control of environmental conditions in sustainable buildings, *Architectural Science Review*, vol. 52, no. 2, pp. 108-116, 2009.

British Standards Institution, BS EN 12665:2011 -Light and lighting. Basic terms and criteria for specifying lighting requirements, *Standard*, 2013.

Brown, Z., and Cole, R. J., Influence of occupants' knowledge on comfort expectations and behaviour, *Building Research & Information*, vol. 37, no. 3, pp. 227-245, 2009.

Chappells, H., and Shove, E., Debating the future of comfort: Environmental sustainability, energy consumption and the indoor environment, *Building Research & Information*, vol. 33, no. 1, pp. 32-40, 2005.

Economic Planning Unit, Division B: Education, Section B5: Academic buildings dan non-academic HEIs, *Garis Panduan dan Peraturan bagi Perancangan Bangunan*, pp. 36, 2008.

Frontczak, M., Andersen, R. V., and Wargocki, P., Questionnaire survey on factors influencing comfort with indoor environmental quality in Danish housing, *Building and Environment*, vol. 50, pp. 56-64, 2012.

Frontczak, M., and Wargocki, P., Literature survey on how different factors influence human comfort in indoor environments, *Building and Environment*, vol. 46, no. 4, pp. 922-937, 2011.

Holopainen, R., Tuomaala, P., Hernandez, P., Häkkinen, T., Piira, K., and Piippo, J., Comfort assessment in the context of sustainable buildings: Comparison of simplified and detailed human thermal sensation methods, *Building and Environment*, vol. 71, pp. 60-70, 2014.

Khalil, N., Husin, H. N., and Nawawi, A. H., Evaluation and concept of building performance towards sustainability in Malaysia higher institutions, *Asian Journal of Environment-Behaviour Studies*, vol. 3, no. 8, pp. 14, 2012.

Khalil, N., Husrul, N. H., and Siti, R. Z., Performance evaluation of indoor environment towards sustainability for higher educational buildings, *Proceedings of 8th International JTEFS/BBCC Conference "Sustainable Development. Culture. Education"*, 2010.

Lai, J. H. K., and Yik, F. W. H., Perceived importance of the quality of the indoor environment in commercial buildings, *Indoor and Built Environment*, vol. 16, no. 4, pp. 311-321, 2007.

Lee, M. C., Mui, K. W., Wong, L. T., Chan, W. Y., Lee, E. W. M., and Cheung, C. T., Student learning performance and indoor environmental quality (IEQ) in air-conditioned university teaching rooms, *Building and Environment*, vol. 49, pp. 238-244, 2012.

Ministry of Higher Education Malaysia, Table 2.1: Number of student's entrants, enrollment, graduants by gender in public HEIs, *National Education Statistic: Higher Educational Sector 2012*, pp.10-10, 2013.

Ministry of Women Family and Community, Chart 7.4: Public sector personnel by service group and sex 2012, *Statistics on Women, Family and Community 2012, Malaysia*, pp. 82, 2013.

Nulty, D. D., The adequacy of response rates to online and paper surveys: What can be done, *Assessment & Evaluation in Higher Education*, vol. 33, no. 3, pp. 15, 2008.

Paul, W. L., and Taylor, P. A., A comparison of occupant comfort and satisfaction between a green building and a conventional building, *Building and Environment*, vol. 43, no. 11, pp. 1858-1870, 2008.

Puteh, M., Ibrahim, M. H., Adnan, M., Che’Ahmad, C. N., and Noh, N. M., Thermal comfort in classroom: Constraints and issues, *Procedia - Social and Behavioral Sciences*, vol. 46, pp. 1834-1838, 2012.

Yang, Z., Becerik-Gerber, B., and Mino, L., A study on student perceptions of higher education classrooms: Impact of classroom attributes on student satisfaction and performance, *Building and Environment*, vol. 70, pp. 171-188, 2013.

Yun, G. Y., Kong, H. J., Kim, H., and Kim, J. T., A field survey of visual comfort and lighting energy consumption in open plan offices, *Energy and Buildings*, vol. 46, pp. 146-151, 2012.

Biography

Sharifah Noor Nazim Syed Yahya is currently a postgraduate student in sustainable design at the University of Malaya, Malaysia and holds a Bachelor of Architecture (Hons.) Degree from MARA University of Technology, Malaysia. She has nine years' experience in facilities and building management as a fulltime practicing architect in the University of Malaya, Malaysia.

Muhammad Azzam Ismail (PhD. in Built Environment UNSW) is a Graduate Architect and an expert in green home/building rating and teaches architecture at the University of Malaya, Malaysia. His current research through awarded grants includes building energy consumption management, operational carbon footprint of residential properties and low carbon cities.

Ati Rosemary Ariffin is the 5th year studio coordinator and a senior lecturer at the Department of Architecture, University of Malaya. She has 18 years of teaching experience in Malaysia and Australia. She has obtained her Diploma in MARA Institute of Technology. Her Postgraduate Diploma and Masters was obtained from Oxford Brookes, United Kingdom. She is currently finishing he PhD degree. Her specialization is on sustainable design and energy efficiency buildings.