A Post-Occupancy Evaluation of the Impact of Indoor Environmental Quality on Health and Well-Being in Office Buildings

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Post-occupancy evaluations have been recognized for documenting occupant well-being and responses to indoor environmental quality (IEQ) factors. Sustainable Post-Occupancy evaluation survey (SPOES), a self-administered and internet-based questionnaire, provides a quantitative analysis of occupants' satisfaction. Employees in Building A (N=75), B (N=69), and C (N=76) rated their satisfaction about 12 IEQ criteria and the impact of built environments on their health. Indoor air quality, furnishings, electric lighting, daylighting, and vibration/movement IEQs ranked highest on the impact on health. These results imply that 12 IEQs are highly related to employees' perception of how the built environment impact their health. The IEQs offer an opportunity for improving occupants' well-being and built environments.

INTRODUCTION

Post-occupancy evaluations (POEs) have been recognized for documenting occupant well-being and responses to indoor environmental quality (IEQ) factors such as thermal, lighting, and acoustic conditions. Sustainable Post-Occupancy evaluation survey (SPOES) developed by an interdisciplinary team at a Midwest University provides a quantitative analysis of occupants' satisfaction and helps direct attention to both successful areas as well as areas that need improvement in the building. The SPOES survey is a self-administered and Internet-based questionnaire that provides a quantitative analysis of occupants' satisfaction in offices, classrooms, and residential spaces. The SPOES questionnaire has identified several IEQ categories that contribute to overall occupant well-being. These categories include acoustic conditions, appearance, cleaning and maintenance, daylighting conditions, electric lighting conditions, function, furnishings, indoor air quality, lighting conditions, personal adjustability, privacy, technology, thermal conditions, vibration and movement and view conditions. SPOES questionnaire has been tested in office, laboratories, classrooms and training center buildings in the State where POEs are

required per B3 guidelines for new buildings. Additional questionnaire modules exist for performance, health, ergonomics, lighting, thermal, privacy and alternative workspace.

LITERATURE REVIEW

Promoting the health and well-being of occupants is important in interior environments (Guerin & Martin, 2010). For example, researchers have studied well-being in healthcare environments (Andrade, Lima, Devlin, & Hernández, 2014; Cama, 2009; Rashid & Zimring, 2008; Ulrich, 1984), classroom environments (Klatte, Hellbruck, Seidel, & Leistner, 2010), residential environments (Burton, Mitchell, & Stride, 2011; Petermans, & Pohlmeyer, 2014, Scott, 2014), and office environments (Bakker, van der Voordt, de Boon, & Vink, 2013; Bluyssen, 2013; Brown, Cole, Robinson & Dowlatabadi, 2010; Gou, Lau, & Shen, 2012; Shafer, 2012; Veitch, 2011). Scott (2014) notes that "well-being is not just the absence of illness, but moving beyond a neutral position of health to flourishing" (p. 3). Peoples' positive and negative feelings towards life have been found to be impacted by their well-being in interior environments (Guerin and Martin, 2010). Furthermore, Kreitzer (2014) reinforces this notion that well-being is a complex concept that is made up of aspects of community, relationships, environment, security, purpose, and health.

Interior designers are responsible for creating environments that protect and enhance the health, safety and well-being of building occupants (ASID, 2013). Therefore, occupant well-being is a goal of all interiors projects (Guerin & Martin, 2010). Occupant well-being has been discussed as a significant predictor of economic success in commercial building types (Bonda & Sosnowchik, 2008). However, occupant well-being is seldom measured in post-occupancy evaluations (POEs), which until recently have focused primarily on building performance.

For example, Leadership in Energy and Environmental Design (LEED) rating system developed by the United States Green Building Council (USGBC) evaluates building performance and promotes sustainable design strategies. Similarly, the Well building standards focuses on advancing health and well-being in buildings. Several universities and organizations have developed POEs that test IEQ in interiors in different ways (Loftness et al 2005/2010; EPA, 2008). But many of these POEs are still focused on physical measurements of the IEQ criteria such as lighting, temperature, and sound, but not the occupants' perceptions, which is what affects their well-being.

The SPOES questionnaire (see Table 1) has identified, developed and tested several IEQ categories that contribute to overall occupant well-being in B3 buildings in the State of Minnesota. The IEQ categories relate to the overall lighting conditions, cleaning and maintenance, furnishings, technology, view conditions, privacy, function, appearance (aesthetics), indoor air quality, vibration and movement, acoustic quality and thermal conditions. However, determining the contribution each of these conditions makes to an employee's well-being needs to be tested widely in the State of Minnesota B3 buildings, as well as other buildings in the state. The next section of this paper discussed findings from three different office buildings. The goal is to use the statistical analysis of the results to help in the development of a score or scale to measure well-being via various contributions (categories). Since this paper focuses on health two of the SPOES questionnaire six dependent variables are analyzed for the three buildings. The two questions are related to health (i.e., effect of the building on health, and effect of the primary workspace on health).

TABLE 1
VARIABLES, MEASURES, AND SCALES FOR SPOES

Variables	Measures	Scales
Independent variables		
Thermal conditions	Overall thermal conditions [temperature (hot or cold), air velocity (drafty or stagnant), and humidity (dry or moist)]	1=very dissatisfied, 7=very satisfied (for all IVs)
Indoor air quality	Overall indoor air quality (free of odors, staleness, chemicals or irritants)	
Acoustic quality	Overall acoustic quality (ability to hear desired sounds and limit undesired sounds)	
Daylighting conditions	Overall daylighting conditions (amount of daylighting and adjustability of the daylighting)	
Electric lighting conditions	Overall electric lighting conditions (amount of daylighting and adjustability of the daylighting and of your task lighting)	
Privacy condition	Overall privacy (sound and visual privacy) conditions	
View conditions	Overall view conditions (outdoor or distant interior views)	
Furnishings	Overall furnishings (adjustability and function of your furnishings)	
Appearance	Overall appearance (aesthetics)	
Technology	Overall technology (e.g., computer, telephone, etc.)	
Vibration and movement	Overall vibration and movement	
Cleaning and maintenance	Overall cleaning and maintenance	
Dependent variables		
Satisfaction with the building	Overall satisfaction with the physical environment of the building/facility	1=very dissatisfied, 7=very satisfied
Effect of the building on work performance	Overall effect of the physical environment of the building/facility on work performance	1=hinders, 7=enhances
Effect of the building on health	Overall effect of physical environment of the building/facility on health	1=hinders, 7=enhances
Satisfaction with the primary workspace	Overall satisfaction with the physical environment of the primary workspace	1=very dissatisfied, 7=very satisfied
Effect of the primary workspace on work performance	Overall effect of the physical environment of the primary workspace on work performance	1=hinders, 7=enhances
Effect of the primary workspace on health	Overall effect of physical environment of the primary workspace on health	1=hinders, 7=enhances

METHODOLOGY

Instrument

The SPOES tool developed by a research center at the University of Minnesota is a self-administered and internet-based questionnaire. It evaluates employees' perspectives of IEQs in offices, classrooms, and residential spaces. The IEQ criteria includes thermal condition, indoor air quality, acoustic quality, daylighting, electric lighting, privacy, view conditions, furnishings, appearance, cleaning and maintenance, vibration and movement, and technology. Based on the Minnesota B3 guidelines, the questionnaire contains questions related to satisfaction with specific IEQ criteria (e.g., thermal condition, daylighting, electric lighting, and privacy), satisfaction with the building and the primary workspace, and perceived effect of the building and primary workspace on their health and work performance.

The questionnaire uses a 7-point Likert scale to measure satisfaction (1=very dissatisfied, 7=very satisfied) and health and work performance (1=hinders health/work performance, 7=enhances health/work performance). Respondents rate each statement based on their satisfaction and perception. At the end of the questionnaire, respondents are asked several demographic questions such as gender, age, and tenure.

Buildings and Respondents

Data was collected from three workplace buildings in a Midwest region. Building A (see Figure 1) is a three-story building with 111,000 square feet, including private and group offices, classrooms, and conference rooms. There are also support area such as locker rooms, supply rooms, a small commercial kitchen, drill hall (gymnasium), and an underground parking garage. This study included the overall facility and the primary workspaces (approximately 55,000 square feet) which were renovated in December, 2013. Building B (see Figure 2) is a six-story building with 163,820 square feet, including 14,193 square feet of private offices, shared enclosed offices, workstations, and open desk areas for employees. This building was completed and ready for operation in July 2013.

FIGURE 1
EXTERIOR IMAGE OF BUILDING A, A THREE-STORY OFFICE BUILDING IN MIDWEST, US (Source: NGA-CS)

Building C (see Figure 3) is also new building, which was completed and ready for operation in December, 2014, and serves mental health services for children. This building is a three-story building with 56,000 square feet with classrooms, therapy rooms, an outdoor playground, gym, restrooms, and training rooms for clinicians. In addition, the building provides a large meeting space for clinicians and professionals from the community. Since this project was developed to investigate the impact of indoor environmental qualities (IEQs) in workplaces on employees' perception of their satisfaction regarding well-being, the eligible respondents were employees working in the three buildings.

FIGURE 2
EXTERIOR IMAGE OF BUILDING B, A SIX-STORY OFFICE BUILDING IN MIDWEST, US (Source: University of Minnesota)

FIGURE 3
EXTERIOR IMAGE OF BUILDING C, A THREE-STORY OFFICE BUILDING IN MIDWEST, US (Source: WCC-G)

Procedure

After obtaining institutional review board (IRB) approval, this study collected the quantitative data via the SPOES online survey tool. The data from three buildings were collected for two weeks from February to March in 2016. An invitation email with the survey link were sent to the employees and a reminder email were sent a week later after the initial invitation. For consistently the invitation and reminder emails to recruit the respondents from three different building used identical language. The response rate to the questionnaires were approximately 43% for Building A (N=75), 46% for Building B (N=69), and 47% for Building C (N=76).

RESULTS

The demographic information about the respondents from three buildings is summarized in Table 2. The total number of respondents and the approximate response rates are similar across the three buildings. Building A has more male respondents, while Building C has more female respondents and Building B has fairly even male and female respondents. Since Building B is associated with a university and delivers the finest in university recreation and wellness opportunities, the mean age is lower than other two buildings. Most respondents have worked at the association more than 3 years. The majority of the respondents working at Building A and Building C spend more than 30 hours per week in the building, whereas most respondents spend less than 20 hours per week in Building B. Likewise, majority of the

respondents spends more than 75% of their time in their primary workspace in Building A and Building C, and the respondents in Building B spend less time in their primary workspace. This implies Building B might have a different working atmosphere.

TABLE 2
DEMOGRAPHIC INFORMATION

		Building A (N=75)	Building B (N=69)	Building C (N=76)
Gender	Male	48 (65%)	29 (45%)	8 (11%)
	Female	23 (31%)	36 (55%)	63 (88%)
	Other	3 (4%)	0 (0%)	1 (1%)
	Total	74 (100%)	65 (100%)	72 (100%)
Age	Mean (Range)	41 (26-62)	26 (18-68)	35.5 (23-68)
Tenure at the workplace	Less than 1 year	13 (18%)	24 (36%)	11 (15%)
	1-2 years	22 (31%)	15 (23%)	16 (22%)
	More than 3 years	37 (51%)	27 (41%)	45 (63%)
	Total	72 (100%)	66 (100%)	72 (100%)
Work hours per week at the building	Less than 20 hours	0 (0%)	32 (48%)	9 (13%)
	20-29 hours	1 (1%)	10 (15%)	8 (11%)
	30-40 hours	26 (36%)	13 (20%)	27 (38%)
	More than 40 hours	46 (63%)	11 (17%)	27 (38%)
	Total	73 (100%)	66 (100%)	71 (100%)
Percentage of time per week in their primary workspace	Less than 25%	0 (0%)	17 (26%)	5 (7%)
	25-50%	1 (1%)	10 (15%)	18 (25%)
	50-75%	18 (24%)	22 (33%)	12 (17%)
	More than 75%	55 (74%)	17 (26%)	37 (51%)
	Total	74 (100%)	66 (100%)	72 (100%)

Note. Values in parentheses next to the frequencies are percentage.

Table 3 summarizes how respondents perceive their overall satisfaction, work performance, and health related to the building and their primary workspaces. The mean value between 4.51 and 7.00 indicates that they are satisfied with their building or primary workspace, or that they perceived their work performance or health were enhanced by the building or primary workspace. The results indicate that the respondents were satisfied with their building and primary workspaces and perceived the favorable effects of the building and primary workspaces on their work performance as well as health. The respondents were satisfied or perceived that the building enhanced work performance and health except for the effect of primary workspace of Building B.

Table 4 summarizes the means of respondents' satisfaction related to 12 IEQs. The values below than 3.50 are interpreted as dissatisfied IEQs, while the values above 4.51 are interpreted as satisfied IEQs. The IEQs between 3.51 and 4.50 means the respondents are neither dissatisfied nor satisfied. For Building A, technology got the highest satisfaction followed by electric lighting, vibration and movement, furnishing, indoor air quality, and appearance. However, overall cleaning/maintenance got the lowest satisfaction among 12 IEQs. For both Building B and C, the respondents were satisfied with all 12 IEQs. Electric lighting was the most satisfied IEQ followed by vibration/movement and cleaning/maintenance for Building B, and daylighting was satisfied the most followed by view conditions, appearance, and cleaning/maintenance for Building C.

TABLE 3
COMPARISION OF EMPLOYEES' PERCEPTION OF SATISFACTION, WORK PERFORMANCE, AND HEALTH RELATED TO THE BUILDING AND PRIMARY WORKSPACE

		Mean (SD) 1.00 - 3.50 dissatisfied (hindered) 3.51 - 4.50 neither dissatisfied (hindered) nor satisfied (enhanced) 4.51 - 7.00 satisfied (enhanced)		
		Building A (N=75)	Building B (N=69)	Building C (N=76)
Building (Site, building, and interior)	Overall satisfaction	5.07 (1.31)	6.15 (0.91)	6.32 (0.77)
	Overall work performance	4.67 (1.11)	5.76 (0.98)	5.96 (1.01)
	Overall health	4.48 (1.18)	5.95 (1.08)	5.63 (1.19)
Primary Workspace	Overall satisfaction	4.63 (1.45)	5.74 (1.13)	6.04 (1.11)
	Overall work performance	4.56 (1.39)	5.41 (1.30)	5.91 (1.16)
	Overall health	4.52 (1.45)	5.26 (1.17)	5.51 (1.18)

Note. SD=Standard Deviation, Values in parentheses next to the means are standard deviations.

Table 5 shows the correlations among two health-related questions, which are dependent variables, and 12 IEQs. In terms of the impact of the overall building on health, 11 IEQs for Building A except privacy showed statistically significant correlations. For Building B, only two IEQs about thermal and electric lighting had statistically significant correlations with the impact of the overall building on health. Building C had statistically significant correlations between all 12 IEQs and the impact of the overall building on health. Out of 25 statistically significant correlations, 18 correlations (75%) showed at least moderate relationship ($r \geq 0.35$).

The results indicated that 10 IEQs for Building A except acoustic quality and privacy showed statistically significant correlations on the impact of the primary workspace on health. In Building B, 11 IEQs except technology showed statistically significant correlations on the impact of the primary workspace on health. Building C had statistically significant correlations between all 12 IEQ and the employees' perception of the impact of their primary workspace on their health in two-tailed correlations ($P \leq 0.05$), like their perception of the impact of the overall building on their health. Out of 33 statistically significant correlations, 25 correlations (76%) showed at least moderate relationship ($r \geq 0.35$).

For each health-related question and for each building, the weighted values are given according to the correlation coefficients. Since there are 12 IEQs, the value of 12 is given to the IEQ having the highest correlation coefficient, and the value of 1 is given to the IEQ having the lowest correlation. For example, the indoor air quality got 12 because it has the highest correlation coefficient (r =0.605) with the impact of the overall building on health for Building A. Likewise, the view condition got 1 because it has the lowest correlation coefficient (r =0.244) with the impact of the overall building on health for Building C. Therefore, the total ranks of each health-related question were calculated by the sum of the weighted values for each IEQ category and for each building.

TABLE 4
STAFF' SATISFACTION RELATED TO IEQ CRITERIA

	Mean (SD) 1.00 - 3.50 dissatisfied 3.51 - 4.50 neither dissatisfied nor satisfied 4.51 - 7.00 satisfied		
	Building A (N=75)	Building B (N=69)	Building C (N=76)
Overall thermal conditions	4.11 (1.63)	4.91 (1.53)	4.85 (1.53)
Overall indoor air quality	4.61 (1.61)	5.66 (1.28)	6.01 (1.14)
Overall acoustic quality	3.95 (1.65)	5.45 (1.39)	5.16 (1.78*
Overall daylighting conditions	3.99 (2.03)	5.48 (1.62)	6.22 (1.26)
Overall electric lighting condition	4.95 (1.58)	5.96 (1.15)	5.83 (1.43)
Overall privacy	3.77 (1.93)	4.96 (1.72)	5.47 (1.56)
Overall view conditions	3.73 (2.03)	5.45 (1.76)	6.22 (1.17)
Overall furnishings	4.62 (1.69)	5.42 (1.56)	5.97 (1.34)
Overall appearance	4.53 (1.58)	5.68 (1.43)	6.15 (1.09)
Overall technology	5.26 (1.42)	5.74 (1.21)	5.72 (1.40)
Overall vibration and movement	4.92 (1.60)	5.86 (1.19)	6.00 (1.39)
Overall cleaning and maintenance	3.15 (1.84)	5.84 (1.16)	6.15 (1.05)

Note. SD=Standard Deviation, Values in parentheses next to the means are standard deviations.

For the impact of the building on health, electric lighting, furnishing, and indoor air quality IEQs ranked highest. IEQs about daylighting, thermal conditions, vibration and movement, and appearance ranked second, followed by IEQs about acoustic quality, technology, cleaning and maintenance, and view conditions. For the impact of the primary workspace on health, indoor air quality, daylighting, vibration and movement, and furnishing IEQs ranked highest. IEQs about view condition, electric lighting, cleaning and maintenance, and appearance ranked second, followed by IEQs about privacy, acoustic quality, thermal conditions, and technology.

TABLE 5
COREELATIONS AMONG TWO DEPENDENT VARIABLES AND 12 IEQS

	Building A (N=75)		Building B (N=69)		Building C (N=76)		Total Rank	
	1	2	1	2	1	2	1	2
1. Overall building to health	1	-	1	-	1	-	-	-
2. Primary workplace to health	.671**	-	.328**	-	.859**	-	-	-
3. Overall thermal conditions	.380** (4)	.288* (4)	.307* (11)	.261* (2)	.340** (3)	.355** (3)	5 (18)	11 (9)
4. Overall indoor air quality	.605** (12)	.517** (11)	.156	.337** (5)	.535** (12)	.500** (12)	3 (24)	1 (38)
5. Overall acoustic quality	.303** (3)	.206	.140	.278* (3)	.498** (10)	.437** (7)	8 (13)	10 (10)
6. Overall daylighting conditions	.482** (8)	.570** (12)	-.025	.401** (8)	.533** (11)	.466** (10)	4 (19)	2 (30)
7. Overall electric lighting condition	.447** (7)	.370** (7)	.327** (12)	.369** (6)	.446** (8)	.439** (8)	1 (27)	6 (21)
8. Overall privacy	.197	.142	.129	.514** (10)	.441** (7)	.393** (5)	10 (7)	9 (15)
9. Overall view conditions	.414** (5)	.470** (10)	-.023	.527** (11)	.244* (1)	.355** (3)	12 (6)	5 (24)
10. Overall furnishings	.554** (10)	.414** (8)	.072	.387** (7)	.381** (6)	.471** (11)	2 (26)	3 (26)
11. Overall appearance	.597** (11)	.449** (9)	.006	.331** (4)	.371** (4)	.378** (4)	7 (15)	8 (17)
12. Overall technology	.422** (6)	.346** (6)	-.096	.168	.327** (2)	.340** (1)	9 (8)	12 (7)
13. Overall vibration and movement	.503** (9)	.304** (5)	.061	.584** (12)	.475** (9)	.453** (9)	5 (18)	3 (26)
14. Overall cleaning and maintenance	.289* (2)	.238* (3)	.122	.433** (9)	.374** (5)	.430** (6)	10 (7)	7 (18)

Note. Value in parentheses under correlation coefficient is the weighted value sorted by higher correlation coefficient. Value in parentheses under total rank is sum of the weighted values.
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

To investigate the perception of how the physical environment at workspaces impacts the employees' health, the 12 IEQs were analyzed. According to the Table 3, employees satisfied were with the buildings and perceived enhanced work performance and health through the building except the employees in Building A. Even though they were satisfied with the building and perceived that their work performance was enhanced, they perceived their health was neither hindered nor enhanced through the building. In terms of the impact of the primary workspaces on satisfaction, work performance, and health, employees satisfied with their primary workspaces and perceived that their work performance and health were enhanced by the primary workspaces from all three buildings. With the exception of the impact on the perception of health, employees were satisfied more with the building than their primary workspaces and they perceived that their work performance and health were more enhanced through the building than through the primary workspaces.

Based on the results from the Table 4, the employees from Building B and C were satisfied with all 12 IEQs, since the value above 4.51 means satisfaction with the IEQ criteria. However, employees from Building A were satisfied with technology, electric lighting, vibration and movement, indoor air quality,

and appearance. They were dissatisfied with cleaning and maintenance. They were neither dissatisfied nor satisfied with thermal conditions, acoustic quality, daylighting, privacy, and view conditions. These results imply that employees recruited for this project were satisfied with most IEQs.

To find out the relationship between the impact of the physical environment on the perception of health, correlations among satisfaction with 12 IEQs and two health-related questions were analyzed (see Table 5). First of all, the notable thing was the correlation between perception of the impact of building on health and the perception of the impact of primary workspace on health for Building B. The correlation for Building B ($r = 0.328$) is much weaker than the correlation for Building A ($r = 0.671$) and Building C ($r = 0.859$). This might be due to the demographic difference in the three buildings (see Table 2). Employees from Building B spend much less hours per week at the building and much less percentage of time per week in their primary workspace than employees from both Building A and C. Therefore, this difference of the amount for being at the building or the primary workspace might lead to the much weaker correlation between the perceptions of the impact of the building or the primary workspace on health. This difference also might cause that majority of correlations between 12 IEQs and the perception of the impact of the building on health are statistically insignificant, whereas the majority of correlations between 12 IEQs and the perception of the impact of the primary workspace on health are statistically significant.

For both Building A and C, the IEQ about indoor air quality has the strongest relationship with the perception of the impact of the physical environment on health. This result supports the existing findings that the indoor air quality has direct impact on occupants' health (e.g., symptoms of sick building syndrome) as well as occupants' performance (Sundell, 2004; Wargocki, Wyon, Baik, Clausen, & Franger, 1999). Furnishing is also one of the most important IEQ related to the employees' perception on their health. This finding also supports Lee and Guerin (2009)'s conclusion of the significant effect of furnishing. According to Lee and Guerin (2009), the IEQ about office furnishing significantly affects only occupants' satisfaction but also work performance. Moreover, since employees spend most of their time indoor, the furnishing has an intimate relationship with occupants' well-being such as musculoskeletal discomfort (Foley, Engelen, Gale, Bauman, & Mackey, 2016).

Daylighting as well as electric lighting are highly related to employees' perception of how their workplace building and primary workplaces impact their health. Electric lighting has a significant impact on the occupants' perception on their health regarding the building; however, daylighting has a more significant effect on their perception regarding the primary workspaces than the building. The impact of IEQ about lighting on occupants' health and work performance has been well known by previous literature (Mills, Tomkins, & Schlangen, 2007; Veitch, Newsham, Boyce, & Jones, 2008). Vibration and movement is another important IEQ influencing the perceived occupants' health related to the building and the primary workspaces.

Some limitations of this study are as follows. First, the data were collected through a self-administrated online survey system. In addition, the occupants' perception and satisfaction were measured by using 7-point Likert scale. The same point value of responses does not necessary mean the same satisfaction and perception across the respondents. Therefore, the instrument might have low reliability. The second limitation is that the demographic information and the building features across three buildings is different, even though the total response rate and respondents are similar. Therefore, the differences of the findings across the buildings may be impacted by different demographic information and/or the built environment. The last limitation is the responses about satisfaction and perceptions are subjective. Since the IEQs are measured subjectively not objectively, the actual impacts of each IEQ on their actual satisfaction and perception of health and work performance were unable to be measured.

CONCLUSION

As occupants' well-being is an important factor to improve their performance in the built environments, and employees' wellness is highly related to job satisfaction as well as work performance. The importance of the built environment at workplaces has been explored in many disciplines from

organizational psychology to interior design (Guerin et al, 2011b; Lee & Guerin, 2009). Post-occupancy evaluation (POE) is a well-known method to investigate occupants' satisfaction toward the built environment and to document occupants' well-being in the built environment. This study accessed 12 IEQs' impacts on employees' perception of their health about the physical environment across three office buildings and discussed how 12 IEQ criteria contribute to a quantitative measure of occupants' satisfaction in buildings. The 12 IEQ criteria explored in this study included thermal condition, indoor air quality, acoustic quality, daylighting, electric lighting, privacy, view conditions, furnishings, appearance, cleaning and maintenance, vibration and movement, and technology.

The findings from this study imply that indoor air quality impact significantly how occupants perceive their health being affected by the built environment at workplaces. Another important indoor environmental quality is furnishing, since employees spend most of their time at work. Electric lighting as well as daylighting are also influencing factors on the occupants' perception of health related to the built environment. The way the built environment support vibration and movement at workplaces also affects how occupants' perceive the impact on their health. These results indicate that 12 IEQs are highly related to employees' perception of how the built environment impact their health. The IEQs in this study offer an opportunity for improving occupants' well-being and the built environment.

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