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Tracking Occupant Satisfaction for Improved Energy Efficiency in Campus Buildings

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ABSTRACT

Green buildings incorporate several features to improve energy efficiency, indoor environmental conditions, and occupant satisfaction. However, studies have indicated that green-certified buildings do not always provide occupants with an acceptable level of satisfaction. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) requires that at least 80% of occupants are satisfied with the indoor thermal conditions. Good indoor environmental quality (IEQ) can enhance the health and productivity of occupants. Also, buildings play a significant role in meeting ambitious energy savings and emissions targets in the US. Identifying gaps in operations and integrating occupant needs into building operations can improve energy performance and occupant satisfaction. Occupant feedback surveys are beneficial for building management, commissioning, gathering end-user feedback, and determining occupants' building requirements. They also help facility managers understand how the building performs and whether the occupants' needs are being met. This paper presents the results of an occupant feedback survey administered to occupants in green-certified and non-green certified buildings on a university campus in the United States. About 350 valid responses were collected through the study. Occupant feedback on IEQ parameters (i.e., thermal comfort, lighting, air quality, and noise), occupant access to controls, and the level of importance attached to energy conservation and energy costs are presented. Occupants in green-certified buildings reported significantly increased personal productivity than those in non-certified buildings but, they do not report significantly higher satisfaction with all IEQ parameters.

INTRODUCTION

As many nations continue to develop and reach higher standards of living and working, the expectations of occupants with regard to indoor environmental quality (IEQ) increase (Caetano et al. 2017). The need for good IEQ for building occupants cannot be overemphasized, considering the impact on humans, the environment, and the economy. Several factors contribute to IEQ in buildings, such as thermal conditions, ventilation, lighting, acoustics, visual privacy, office layout and furnishings, and overall cleanliness and maintenance. The impact of these factors on occupant satisfaction with their workspace, job, and productivity has been a focal point for previous studies on IEQ. The impact on an organization's operational costs can be significant as a result of improvements in occupant performance and indoor environmental conditions (Al Horr et al. 2016). Reductions in employee absenteeism, reduced

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turnover, and improved productivity and satisfaction can result from workplaces that have enhanced IEQ (USGBC 2004).

Many green building projects focus on energy-intensive building operations like heating and cooling systems since buildings are collectively a significant contributor to greenhouse gas emissions. There is also a focus on building envelopes and windows to improve energy efficiency. As sustainable building projects have gained more attention over the years, IEQ has become critical for researchers looking at new construction and retrofitting existing buildings. Achieving acceptable IEQ for occupant comfort while maintaining energy efficiency presents unique challenges and opportunities. Studies have shown that thermal, air quality, ventilation, and acoustic factors are important to occupants in various buildings. Poor IEQ has been correlated with increases in absences from work and loss of productivity. In particular, poor indoor air quality can include higher levels of carbon dioxide, airborne contaminants like mold and bacteria (Di Giulio et al. 2009), volatile organic compounds (VOCs) from materials or chemicals in the office, or lingering odors associated with human occupancy of the indoor space. Sick building syndrome (SBS) can lead to significant economic losses as productivity suffers and absences from work increase. SBS symptoms typically manifest as dry, itchy, or burning eyes along with respiratory irritation, headaches, and lethargy (Hodgson 2000; World Health Organization 1982; Al Horr et al. 2016). SBS is largely related to indoor air quality, which can encompass ventilation rates, humidity, and temperature, among other facets. Improvements in IEQ can lead to improvements in work performance and productivity, as well as significant health and economic advantages overall (Fisk et al. 2011). It has been reported that higher ventilation rates can lead to financial returns anywhere from ten to sixty times larger than yearly energy and maintenance costs (Al Horr et al. 2016; Kosonen and Tan 2004; Wargocki et al. 2003; Wargocki et al. 2000).

IEQ is one of the criteria considered in major green building certification systems. IEQ criteria for the most popular green building certification system comprises approximately 15% of the obtainable points and includes minimum indoor air quality performance; environmental tobacco smoke control; enhanced indoor air quality strategies; low-emitting materials; construction indoor air quality management plan; indoor air quality assessment; thermal comfort; interior lighting; daylight; quality views; acoustic performance (Isik 2016). Many studies have assessed the impact of sustainable design approaches on IEQ, occupant satisfaction, productivity, and project cost performance. One such study found thermal comfort was the leading issue for occupant satisfaction, with low-emitting materials being the main parameter for project cost performance (Isik 2016).

Several standards have created goals with regard to thermal comfort and air quality. ISO Standard 7730:2005 recommends conditions where a minimum of 90% of occupants are satisfied with the thermal environment of their office space (Huizenga et al. 2006). ASHRAE Standard 62.1-2004 deems acceptable air quality as environmental conditions where more than 80% of occupants are satisfied (Huizenga et al. 2006). Requirements for the thermal environment are primarily rooted in engineering standards like ASHRAE, International Organization for Standardization (ISO), and Chartered Institution of Building Services Engineers (CIBSE), and green building rating systems advocate for maximum thermal comfort and productivity through occupant control of engineering systems (Gou et al. 2013; ASHRAE 2019). However, data collected from previous studies indicate that satisfaction ratings are well below those established by various standards with regard to thermal comfort. Further, under green building rating systems, post-occupancy auditing rarely takes place for the verification of long-term credit requisites (Driza et al. 2014). This leaves designers, engineers, and other professionals to contend that not tracking building performance and levels of occupant satisfaction results in certified buildings not meeting their established objectives with regard to sustainability and IEQ (Driza et al. 2014). Several opportunities exist to improve building energy efficiency through occupant engagement. One way to identify opportunities for this is through self-reported feedback from the occupants to assess and identify the areas of improvement. Web-based surveys and mobile applications have been used to gather occupant feedback in several studies.

In this study, faculty and staff feedback was solicited during the winter season to get a snapshot of occupant satisfaction with a selection of IEQ parameters on a university campus. In addition, this paper compares the responses of those in green-certified and non-certified buildings. It addresses the impact of IEQ on their perceived health and personal productivity and the occupants' consideration of cost and energy conservation as they make decisions to improve the IEQ to improve their comfort.

OCCUPANT-RELATED FACTORS IN BUILDINGS

Occupant presence has been identified as one of the factors that impact building energy consumption. Other factors are materials, equipment and processes, heating, cooling, ventilation and air conditioning (HVAC) processes, occupant presence, and activity (Tham 2016). Building occupants are normally interacting with building systems directly or indirectly. Occupant behavior can increase or decrease building energy consumption. Energy consumption is also affected by the types of equipment present in the space, the use of the space, and occupant-related factors (i.e., environmental awareness, personal values, and energy costs). Occupant productivity can be attributed to four primary factors in a working environment: personal, organizational, social, and environmental (Clements-Croome 2006; Al Horr et al. 2016). Leading green building councils recognize the importance of occupant productivity to varying degrees (Al Horr et al. 2016). Tham (2016) identified how indoor air quality affected humans from various studies and emphasized the importance of user engagement in managing indoor environmental conditions.

Occupant Feedback Surveys in Buildings

Studies have looked at occupant IEQ surveys to assess IEQ factors in office buildings and measure self-reported occupant satisfaction and productivity (Huizenga et al. 2006; Driza et al. 2014). For example, a study assessed data from a survey administered to 52,980 occupants across 351 office buildings. The majority of respondents had worked at their current workspace for more than a year in a full-time capacity and worked in cubicles close to a non-operable window. Results show that occupants were generally satisfied with their workspace and with the building overall. The highest satisfaction was with the ease of interaction with co-workers and the amount of light (Frontczak 2012). The highest levels of occupant dissatisfaction were related to sound privacy, temperature, noise level, and air quality (Frontczak 2012).

Post-occupancy evaluations and web-based surveys can show how results are being used to improve IEQ for occupants, identify how building technologies impact occupant comfort, and serve as a benchmark for building quality (Zagreus et al. 2004). By assessing building performance from occupants' perspectives, problems can be identified and addressed accordingly. Combining surveys with physical measurements of indoor spaces provides researchers with a more thorough understanding of the building's IEQ and levels of occupant satisfaction (Zagreus et al. 2004; Abraham et al. 2017; Abraham 2017).

Occupant Satisfaction and Behavior in Buildings

The level of occupant comfort and satisfaction can influence behavior indoors. Some occupants may voice their concerns relating to the IEQ to facility management or change the indoor conditions by interacting with building systems and controls. Occupants can also alter their level of comfort and satisfaction within the space through behavior modifications. Choice of clothing materials or layers can be a response to dissatisfaction with the thermal environment, as can manual adjustment of thermal control devices such as thermostats or operable windows. Space heaters and small fans may be used in an occupant's workspace in an effort to adjust to or improve their immediate thermal environment (Abraham 2017). Modification of window shades or reorientation of workstations can be a response to excessive glare or inadequate natural light. Some occupants may also choose to wear headphones to help block ambient, undesirable sounds and improve their focus. Speech privacy can be improved by using barriers or partitions between workstations to block out sounds. Work activities should be considered when determining office layout to prevent disruption (Sakellaris et al. 2016). Occupant behavior modifications for the purpose of improving satisfaction and productivity can be an indicator of unsatisfactory workplace conditions and low occupant perceptions of IEQ. Readily accessible controls like thermostats and operable windows can potentially improve occupant perceptions of air quality (Sakellaris et al. 2016). Zhang et al. (2018) showed that the energy-saving potential of occupant behavior in commercial buildings is between 5 and 30%.

METHODOLOGY

This study compares occupant responses to their perception and satisfaction with different IEQ parameters based on the certification status of the occupant's building. First, a literature review was completed to identify gaps in studies relating to occupant satisfaction in buildings and the key parameters that should be analyzed. Second, the survey instrument was developed from various sources in the literature, and a few questions were added based on the author's observations and feedback from potential participants. Surveys were adopted since they have been successfully used in similar studies. A pilot test was completed to assess the readability of the questions, the content of the questionnaire, and the time taken. The survey was modified after a few iterations and feedback from experts and peers for the content and readability of the questions. Third, the questionnaire was submitted to the institutional review board at the author's institution for review and approval. The questionnaire survey was administered through a survey development platform. The estimated completion time for the survey was 10-15 minutes.

Participants took part in the survey voluntarily and anonymously. The response rates were difficult to determine since the email was sent to a faculty and staff listserv that does not include all faculty and staff. Also, not everyone on the listserv met the eligibility criteria, for instance, if they worked off-campus. The survey contained both open and close-ended questions. The questions pertained to occupants' perception of IEQ parameters, satisfaction with these parameters, behavior, indoor control preferences. Also, some demographic data was collected. They were asked to provide their building name so that the researcher could identify the green-certified buildings. The building certification is according to Leadership in Energy and Environmental Design (LEED), but the level of certification was not considered. Occupants of the certified buildings comprised about 18% of all the participants. The data collected were cleaned in a spreadsheet program and analyzed using a statistical tool. Responses of occupants who did not indicate their building name were excluded from the analysis.

RESULTS AND DISCUSSION

Occupants' Satisfaction with IEQ Parameters in Certified and Non-certified Buildings

The building occupants' satisfaction with thermal conditions, air quality, lighting, and noise were determined through the survey. Occupants were also asked about their overall satisfaction with their personal workspace. Satisfaction was measured on a scale of 1 to 6, with 1 being very dissatisfied and 6 being very satisfied. The mean satisfaction score was determined from the descriptive statistics obtained from a statistical software package. Generally, occupants of certified buildings reported higher mean satisfaction ratings with all the parameters than those in non-certified buildings (Table 1). However, an independent-samples t-test was conducted to compare occupant satisfaction with IEQ parameters between the two groups and, at the 95% confidence interval, there was no significant difference in the thermal satisfaction for occupants in certified ($M=3.72$, $SD=1.099$) and non-certified ($M=3.43$, $SD=1.299$); $t(80.514)=1.717$, $p=0.090$. There was no significant difference in the air quality satisfaction for occupants in certified ($M=3.91$, $SD=1.114$) and non-certified buildings ($M= 3.62$, $SD=1.332$); $t(81.285)=1.690$, $p = 0.095$. There was no significant difference in the lighting satisfaction for occupants in certified ($M=4.08$, $SD=1.141$) and non-certified ($M=3.96$, $SD=1.282$); $t(346)=0.617$, $p=0.538$. There was no significant difference in the noise satisfaction for occupants in certified ($M=4.04$, $SD=1.192$) and non-certified ($M=3.83$, $SD=1.319$); $t(346)=1.068$, $p =0.286$. Finally, there was no significant difference in the overall satisfaction for occupants in certified ($M=4.17$, $SD=1.221$) and non-certified ($M=3.88$, $SD=1.248$) $t(346)=1.573$, $p=0.117$. Although all the mean satisfaction ratings were higher for the certified building occupants than the non-certified building occupants, the results suggest no statistically significant difference in satisfaction with any of the parameters for occupants in certified and non-certified buildings.

Table 1. Occupants' Satisfaction with IEQ Parameters

	Thermal satisfaction		Air quality satisfaction		Lighting satisfaction		Noise satisfaction		Overall satisfaction	
Satisfaction scales	**C (%)**	**NC (%)**	**C (%)**	**NC (%)**	**C (%)**	**NC (%)**	**C (%)**	**NC (%)**	**C (%)**	**NC (%)**
Sample size (N)	53	295	53	294	53	295	53	295	53	295
Very dissatisfied	3.8	8.8	1.9	9.9	0.0	5.8	3.8	6.4	1.9	6.4
Dissatisfied	9.4	17.3	7.5	12.2	9.4	9.8	7.5	10.5	7.5	6.8
Moderately dissatisfied	24.5	22.4	28.3	17.7	22.6	14.6	15.1	20.0	18.9	20.0
Moderately satisfied	37.7	27.5	26.4	28.2	28.3	27.8	35.8	26.1	28.3	31.5
Satisfied	22.6	22.0	32.1	30.6	30.2	36.6	30.2	30.5	30.2	29.8
Very satisfied	1.9	2.0	3.8	1.4	9.4	5.4	7.5	6.4	13.2	5.4
Mean satisfaction	3.72	3.43	3.91	3.62	4.08	3.96	4.04	3.83	4.17	3.88

Impact on Perceived Health and Personal Productivity of Occupants in Certified and Non-certified Buildings

This study also explored the impact of the indoor environmental conditions on the perceived health and personal productivity of building occupants in certified and non-certified buildings. Figure 1(a) shows that 48.8% of the occupants of certified buildings reported that the IEQ increases their perceived health, while 33.3% of those in non-certified buildings reported the same. 24.4% of those in certified buildings reported that it decreased their perceived health, while a higher percentage, 37.8%, of those in non-certified buildings reported the same. In Figure 1(b), we observe that 53.2% of the certified building occupants reported that the IEQ increased their personal productivity, while 37.8% of those in non-certified buildings reported the same. Further analysis showed that there was no significant difference in the perceived health for occupants in certified (M=2.22, SD=0.852) and non-certified buildings (M=2.04, SD=0.789); $t(264)=1.290$, $p=0.198$ but, there was a statistically significant difference in personal productivity for occupants in certified (M=2.43 , SD=0.683) and non-certified buildings (M=2.17, SD=0.746); $t(298)=2.150$, $p=0.032$.

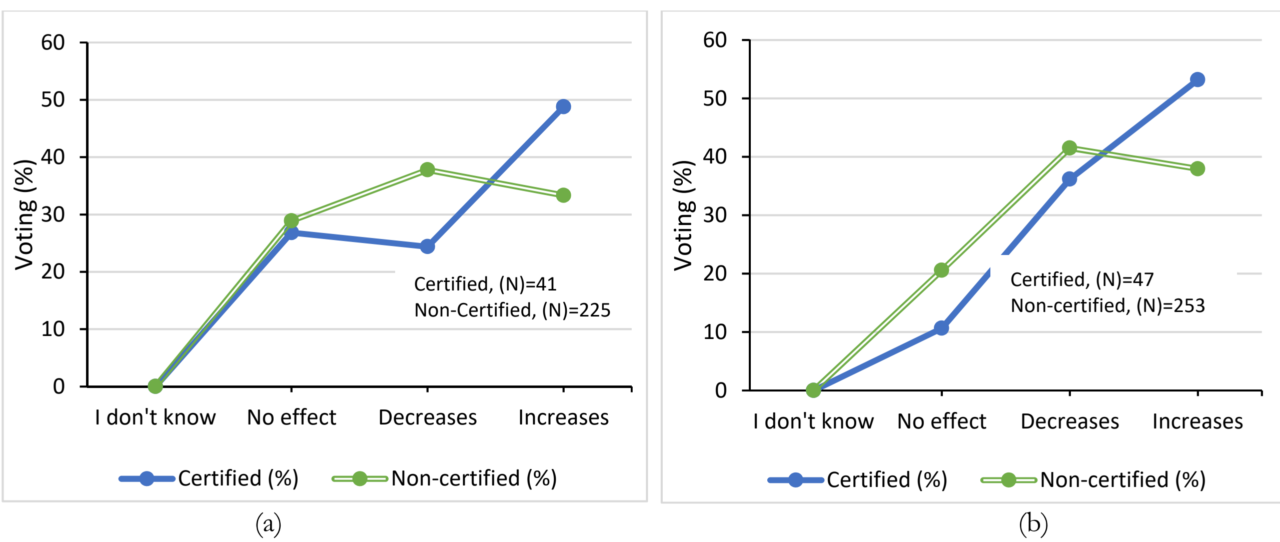

Figure 1 (a) Impact of IEQ on perceived health and (b) impact of IEQ on personal productivity

Studies have indicated the positive benefits of green buildings in relation to perceived health and personal productivity. In this study, further statistical analysis only showed a statistically significant difference in the impact of the IEQ on personal productivity. However, a higher percentage of certified building occupants voted that the IEQ improved their personal productivity and perceived health than non-certified building occupants indicating that occupants of certified buildings are likely to be more productive.

Consideration of Energy Conservation and Cost in Certified and Non-certified Buildings

A higher percentage of non-certified building occupants considered energy conservation in efforts to improve their comfort indoors "to some extent" and "to a moderate extent" than those in certified buildings (Figure 2(a)). They might have opted for options/activities that would save energy. In terms of cost, a higher percentage of those in certified buildings would not take cost into account at all in efforts to improve their comfort indoors (Figure 2(b)). There was no significant difference in considering energy conservation for occupants in certified (M=3.02 , SD=1.232) and non-certified (M=3.14, SD=1.157); t(346)=-0.689, p=0.491. Also, there was no significant difference in considering cost while improving comfort for occupants in certified (M=2.04 , SD=1.160) and non-certified (M=2.28, SD=1.256); t(346)=-1.315, p=0.189. Occupants of certified green buildings may assume that the building is already energy efficient and their actions would not severely negatively impact the building energy costs. This highlights the need for occupant education, especially for those in green buildings. Occupants should be educated on the proper use of building systems and the impact of certain behaviors on costs and energy consumption, especially in office buildings where they are not directly responsible for paying for utilities.

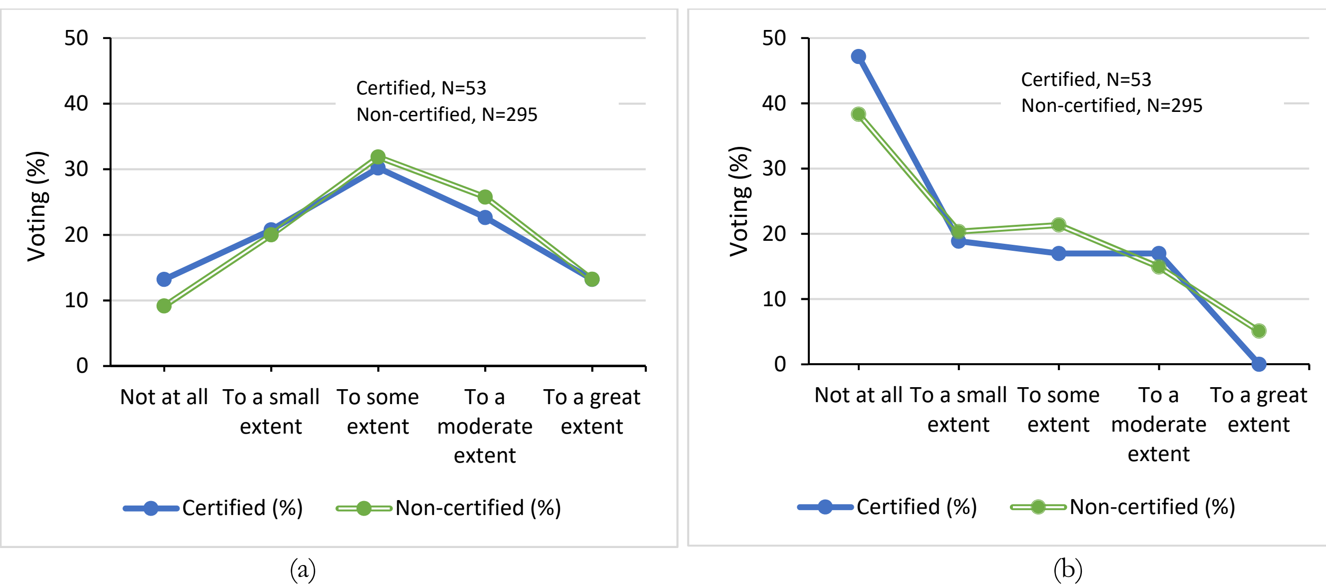

Figure 2 (a) Extent of considering energy conservation in efforts to improve IEQ and (b) extent of considering cost in efforts to improve IEQ.

Comparison of Occupants' Control Preferences in Certified and Non-certified Buildings

The occupants rated the importance of having control over thermal conditions and lighting in their workspaces on a scale of 1-6, from "not at all important" to "extremely important." The results indicate that occupants of non-certified buildings felt it was more important for them to have control over their thermal and lighting conditions than the occupants of certified buildings (Figure 3). There was no significant difference in the importance rating of thermal controls for occupants in certified (M=3.92, SD=1.089) and non-certified buildings (M=4.04, SD=1.119); t(346)=-0.719, p=0.473, but there was a significant difference in the importance rating of lighting controls for occupants in certified (M=4.49 , SD=1.137) and non-certified buildings (M=4.81, SD=1.024); t(346)=-2.035, p=0.043. Thus, the results indicate that access to thermal controls is important for both certified and non-certified building occupants. However, lighting control seems more critical for occupants in non-certified buildings than those in certified buildings.

There are different points of view when it comes to providing occupants with access to controls. While providing control allows for flexibility, there is a concern of possible abuse and others feel that not providing control pushes occupants to engage in behavior that wastes energy.

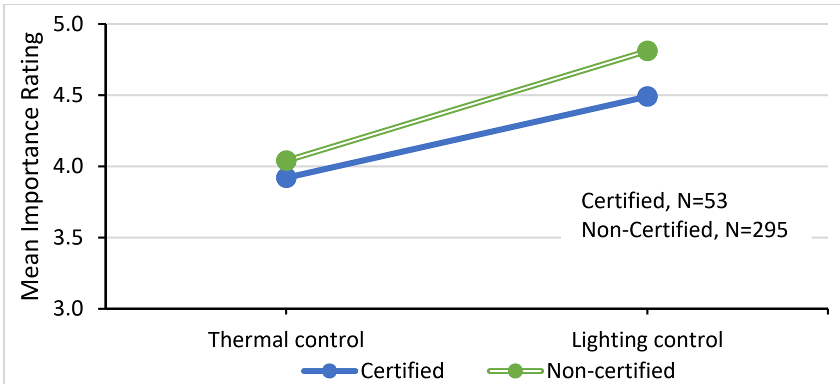

Figure 3 Mean importance rating for thermal and lighting controls in workspaces

Occupants in the certified buildings perceived a higher positive impact of the indoor environmental conditions on their productivity even though they did not report higher satisfaction with all the IEQ parameters at a statistically significant level than non-certified building occupants. Also, they were less concerned with the cost and energy conservation impact of their actions. It is unclear if the occupants were aware of the certification status of their buildings and the impact on building operation, which could imply an incorrect expectation of green buildings.

CONCLUSION

Occupant feedback surveys provide some insight into the building's performance. Providing valuable feedback routinely to relevant stakeholders can provide positive outcomes for the occupants and enable them to diagnose and address problems quickly. IEQ parameters such as thermal comfort, acoustics, air quality and ventilation, lighting, and others can be optimized to achieve maximum occupant comfort and productivity while meeting sustainability goals. It appears that certification provides some value to building occupants since certified building occupants reported significantly increased personal productivity but did not score those buildings as having significantly higher satisfaction in relation to the IEQ parameters investigated. Also, occupants of certified buildings did not value energy conservation and cost in efforts to improve their comfort as much as those in non-certified buildings. Occupants of non-certified buildings felt lighting control is more important than occupants in certified buildings. Building owners, facility managers, and operators who pursue certification should explore its potential benefits in relation to building occupants and their perceptions about the certification status and the building operations.

The main limitation of this study is the small number of occupants from certified buildings, but this number also reflects the small percentage of certified buildings at the institution. These findings should be further investigated with a larger sample size exploring the perception and behavior of occupants in certified and non-certified buildings especially relating to IEQ, energy cost, and energy conservation. In addition, this study was only completed in the winter season. Therefore, a study on warmer weather conditions could determine if similar trends would be observed.

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REFERENCES

Abraham, Yewande S. "Integrating Occupant Values and Preferences with Building Systems in Conditioned Environments." (2017).

Abraham, Yewande S., Chimay J. Anumba, and Somayeh Asadi. "Data Sensing Approaches to Monitoring Building Energy Use and Occupant Behavior." *In Computing in Civil Engineering 2017*, pp. 239-247. 2017.

Al Horr, Yousef, Mohammed Arif, Amit Kaushik, Ahmed Mazroei, Martha Katafygiotou, and Esam Elsarrag. "Occupant productivity and office indoor environment quality: A review of the literature." *Building and environment* 105 (2016): 369-389.

ASHRAE. (2019). *2019 ASHRAE Handbook - Heating, Ventilation, and Air-Conditioning Applications*. Atlanta: American Society for Heating, Refrigeration and Air-Conditioning Engineers.

Caetano, Diego S., Doreen E. Kalz, Louise LB Lomardo, and Luiz P. Rosa. "Evaluation of thermal comfort and occupant satisfaction in office buildings in hot and humid climate regions by means of field surveys." *Energy Procedia* 115 (2017): 183-194.

Clements-Croome, Derek, ed. *Creating the productive workplace*. Taylor & Francis, 2006.

Di Giulio, Mara, Rossella Grande, Emanuela Di Campli, Soraya Di Bartolomeo, and Luigina Cellini. "Indoor air quality in university environments." *Environmental monitoring and assessment* 170, no. 1 (2010): 509-517.

Driza, Pamela-Jean N., and Nam-Kyu Park. "Occupant satisfaction in LEED-certified higher education buildings." *Smart and Sustainable Built Environment* (2014).

Fisk, William J., Doug Black, and Gregory Brunner. "Benefits and costs of improved IEQ in US offices." *Indoor Air* 21, no. 5 (2011): 357-367.

Frontczak, Monika, Stefano Schiavon, John Goins, Edward Arens, Hui Zhang, and Pawel Wargocki. "Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design." *Indoor air* 22, no. 2 (2012): 119-131.

Gou, Zhonghua, and Stephen Siu-Yu Lau. "Post-occupancy evaluation of the thermal environment in a green building." *Facilities* (2013).

Hodgson, Michael. "Sick building syndrome." *Occupational medicine (Philadelphia, Pa.)* 15, no. 3 (2000): 571-585.

Huizenga, Charlie, Sahar Abbaszadeh, Leah Zagreus, and Edward A. Arens. "Air quality and thermal comfort in office buildings: results of a large indoor environmental quality survey." *Proceeding of Healthy Buildings 2006* 3 (2006): 393-397.

Isik, Zeynep. "Assessment of LEED Green Building Certificate Indoor Environmental Quality Parameters from the Perspective of Occupant Satisfaction and Cost Performance." *Megaron* 11, no. 4 (2016).

Kosonen, R., and F. Tan. "The effect of perceived indoor air quality on productivity loss." *Energy and Buildings* 36, no. 10 (2004): 981-986.

Sakellaris, Ioannis A., Dikaia E. Saraga, Corinne Mandin, Célina Roda, Serena Fossati, Yvonne De Kluizenaar, Paolo Carrer et al. "Perceived indoor environment and occupants' comfort in European "modern" office buildings: The OFFICAIR study." *International journal of environmental research and public health* 13, no. 5 (2016): 444.

Tham, Kwok Wai. "Indoor air quality and its effects on humans—A review of challenges and developments in the last 30 years." *Energy and Buildings* 130 (2016): 637-650.

USGBC (US Green Building Council). "Making the business case for high performance green buildings." *US Green Building Council, Washington, DC* (2004).

Wargocki, Pawel, K. W. Tham, S. C. Sekhar, and D. Cheong. "Estimate of an economic benefit from investment in improved indoor air quality in an office building." In *7th International Conference on healthy buildings 2003*, pp. 382-387. University of Singapore, Department of Buildings, 2003.

Wargocki, Pawel, David P. Wyon, Jan Sundell, Geo Clausen, and P. Ole Fanger. "The effects of outdoor air supply rate in an office on perceived air quality, sick building syndrome (SBS) symptoms and productivity." *Indoor air* 10, no. 4 (2000): 222-236.

WHO (World Health Organization). "Indoor Air Pollutants Exposure and Health Effects Report on a WHO Meeting Nördlingen, 8–11 June 1982." *EURO reports and studies* 78 (1982).

Zagreus, Leah, Charlie Huizenga, Edward Arens, and David Lehrer. "Listening to the occupants: a Web-based indoor environmental quality survey." (2004).

Zhang, Yan, Xuemei Bai, Franklin P. Mills, and John CV Pezzey. "Rethinking the role of occupant behavior in building energy performance: A review." *Energy and Buildings* 172 (2018): 279-294.