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Understanding high performance buildings: The link between occupant knowledge of passive design systems, corresponding behaviors, occupant comfort and environmental satisfaction

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ABSTRACT

In the past twenty years, more stringent energy codes and environmental standards have led to many higher performance building designs that use less energy. Oftentimes, high performance buildings that incorporate passive building strategies require active occupant engagement [Brown et al. (2009) [1]] but the people who work in these buildings on a daily basis may not comprehend how their actions (*negatively or positively*) affect the building's energy use [Janda (2009) [2]]. Additionally, minimal research exists surrounding educational strategies for how to best educate building occupants. The purpose of this study was to investigate existing occupant training in high performance buildings to provide recommendations for future occupant education efforts.

A sequential mixed methods study was conducted to better understand the relationships between occupant behaviors, reported environmental satisfaction, and learning in high performance buildings. First, expert interviews were conducted ($n = 3$) to determine the study population. Second, a survey was sent to ten high performance buildings in the United States ($n = 118$), and third, follow-up occupant interviews ($n = 41$) were conducted to better understand the survey responses. It was hypothesized that participants who had received effective training for high performance building features would be more satisfied with their environment than those who had not received training. Results indicated a significant difference between the two groups (those who had received effective training and those who did not), and individuals who reported *effective* training were significantly more likely to be satisfied with their office environment. Follow-up interviews provided additional insight into occupant satisfaction and behaviors.

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1. Introduction

Climate change, rising fossil fuel costs, and a paradigm shift in how we, as a culture, regard sustainability have started to influence how energy use is perceived. In general, the market has seen a rise in more sustainable and energy efficient goods and services over the past two decades within the building sector [3]. Buildings are an ideal sector to target as they account for nearly 40% of total energy use in the United States; lighting (25.5%), heating (14.2%), and cooling (13.1%) are some of the leading energy consumers in commercial buildings [4]. The building and design communities have responded to this issue, and the way in which buildings are conceived is beginning to transform towards sustainability [5].

Specifically, high performance building designs are becoming more prominent. The rationale for many high performance buildings is to increase energy efficiency and to promote health and productivity for building occupants [6]. Energy efficient design strategies have gained traction in the commercial office building industry for a litany of reasons including more stringent building codes, company policies geared toward environmental stewardship, government regulations, cost effectiveness, utility incentives, energy use reduction goals, and occupant productivity and satisfaction [7–11]. However, the success of many of these design strategies is heavily dependent on how occupants interact with the building [12].

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Passive design strategies, such as daylighting or natural ventilation, are intentionally designed to decrease or eliminate the need for energy, but these may also have adverse impacts on the overall building energy use if occupants do not understand how to operate building systems effectively. A window blind left open on the south side of a building during a hot summer day over the weekend may contribute to excess heat gain, requiring additional mechanical cooling. Alternatively, if an operable window were left open overnight during the cold winter months, it would lead to unnecessary building heating; in either scenario, the occupant plays a major role in the overall building's energy-use.

These outcomes are not difficult to understand; it is common sense to most. Growing up at home, many of us were told to turn off our electric lights when we left the room, or to close the windows when it was to cold or hot outside. However, these seemingly common sense ideals are complicated in an office building where occupants are not paying for the energy bills, the office culture may not support these actions, and individuals may not feel the same sense of control over their environment as they might in their own homes [13].

So, who cares if occupants understand how to operate their office building? From a business standpoint, the simplest explanation is that if occupants understand the building and environmental control systems, then they may contribute to lower building energy use, which ultimately costs the owner less money, and they may increase their overall satisfaction with the interior work environment [2]. This is a win/win situation for both the building owner or company and the building occupant. Alternatively, if users do not understand building controls, then energy use may increase if systems are overridden incorrectly, or occupants may be less satisfied with their environment due to decreased thermal or visual comfort.

Ultimately, passive design strategies in high performance buildings, such as daylighting and natural ventilation, have the potential to greatly reduce energy use, positively impact worker productivity, increase satisfaction, and increase indoor air quality (IAQ) if controls are operated as intended [14–16]. However, negative outcomes can arise from uninformed or unintentional interactions with the high performance building systems. For example, access to natural daylight within the office space has been proven as advantageous to building occupants' psychological and physiological health [17]. Yet, daylight is a dynamic light source that changes on a daily basis, so an understanding of daylight controls and seasonal and diurnal patterns of the sun are crucial to its overall success. If occupants fail to operate blinds when needed, it may lead to issues such as glare, which can have adverse health consequences such as headaches, eye strain or migraines [18]. In this example, it may seem completely unnecessary or even offensive to “teach” people how to use blinds, but other factors may impact the use of blinds. Thermal preferences, visual comfort, social dynamics in the office, and the sheer complexity of the given blind system (many blinds are now automated and one must understand how to override computer controls to even move the blinds) all come into play and influence occupants’ decisions. These challenges are further compounded by poor occupant understanding of building design strategies and their intent and use.

The purpose of this study was to investigate the overall success of existing occupant training in high performance buildings with regard to energy use, corresponding occupant behaviors and environmental satisfaction. It was hypothesized that participants who had received effective training for high performance building features would be more satisfied with their environment than those who had not received training. The hypothesis and research questions were explored through an interdisciplinary and mixed methods approach to identify and assess existing occupant educational strategies and occupants’ comprehension of varying high performance building strategies. Buildings with varying high performance building design strategies were sought out in multiple climate zones, and many other data types were collected including surveys, interviews, and documents. The unit of measurement for statistical analyses in the quantitative phase was based upon individual survey respondents rather than individual buildings.

The remainder of this article is structured as follows: first, a brief review of relevant literature surrounding building energy use, occupant behaviors, thermal and visual comfort, and occupant education is reviewed. This is followed by an explanation of the research methodology used in the study. Next, the results of the study are summarized. The paper concludes with a brief discussion of results, study delimitations and limitations, and recommendations for future research.

2. Literature review

2.1. High performance buildings

High performance buildings use various sustainable strategies to reduce overall energy use, optimize all installed systems, and to promote health and productivity for its occupants [6]. High performance buildings offer many benefits to both employers and employees, which is further discussed in the sections below.

2.1.1. Employer benefits of high performance buildings

There are many reasons owners or companies might choose to build a high performance building including the environmental mission or value of the company, stakeholder pressure, employee attraction and retention, government regulations, and economic opportunities or disincentives [19]. For businesses, one of the major motivators for building a high performance building is the potential to increase profits. Some of the monetary benefits for employers include potential energy efficiency upgrade incentives and rebates, decreased operating costs from energy use, and increased employee productivity [8,15,20,21]. Additionally, in high performance buildings with access to natural ventilation, employers may see monetary benefits in terms of fewer sick/short-term leave from sick building syndrome (SBS) symptoms such as inflammation, respiratory infections, and asthma [22].

Overall, these potential cost savings are very important aspects of high performance buildings to employers, but there are also several equally important benefits to the building occupants, such as the potential for increased occupant satisfaction [23], productivity, and overall well-being.

2.1.2. Employee benefits of high performance buildings

Employee benefits attributed to high performance building strategies include increased performance and productivity, increased environmental satisfaction, and positive impacts on both physiological and psychological health.

Sustainable building strategies, such as daylighting and natural ventilation, have been specifically linked to improved productivity and occupant performance in both schools and offices [8,20,24,25]. Natural ventilation has been found to play an important role in supporting air flow in buildings, which can promote thermal comfort, IAQ, and productivity [15,26]. Many studies have also shown how occupant performance can be affected by the quality of light in a space, and occupants with access to natural daylight perform better when compared to those who only have access to electric light [8,24].

Passive design strategies, when designed properly, can have positive impacts on occupants’ physiological and psychological health. For example, access to natural daylight has been linked to