The Sustainable Indoor Environment: Influences on Occupants' Workplace Wellbeing on the Auburn University Campus

By

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science in Interior Design

Auburn, Alabama
December 12, 2015

Keywords: indoor environmental quality, LEED, workplace wellbeing, health, sustainability

Submitted to

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Abstract

Sustainable buildings are believed to provide superior health and comfort to their occupants. However, little empirical research has been conducted to verify this belief. The purpose of this study is to explore if the environmental sustainability of buildings influences occupants' workplace wellbeing through its ability to enhance occupant health. Data were collected using (1) observations of three buildings at Auburn University (AU) certified to be sustainable through the Leadership in Energy and Environmental Design (LEED) certification rating system and three non-LEED-certified AU buildings and (2) an online survey with a sample of 199 occupants of these building. Results indicate that as compared to the non-LEED-certified buildings, LEED-certified buildings provide a higher objective sustainable indoor environmental quality (IEQ), and their occupants are more satisfied with the IEQ. Further, occupants' satisfaction with the indoor air quality and comfort factor of the IEQ enhanced their physical and psychological health, which in turn increased their workplace wellbeing. Further, occupants' satisfaction with acoustics of their building directly influenced workplace wellbeing. This study contributes to the literature by generating empirical evidence for the relationship between sustainable IEQ of a building and its occupants' health and workplace wellbeing.

Acknowledgments

There are several individuals to acknowledge and thank for their endless support, guidance, and generosity through my graduate experience at Auburn University. First and foremost, I would like to mention my parents, Ron and Jodie Ortlieb, of whom I would not have been able move to Alabama on such short notice with the surety in the care of personal affairs. My family's constant love and encouragement made this journey both possible and achievable.

Secondly, I would like to acknowledge my CADS cohort who became my extended family. Your kindness, encouragement and commodore have created wonderful friendships, specifically Dawn Michaelson. You have impacted my life in many positive and lasting ways. Thank you, Abbi-Storm McCann, for ensuring I experienced the South. Also, I would like to thank the Interior Design faculty who provided mentorship as I taught, researched, and sought counsel. We have fostered lasting friendships. This journey started over coffee with Lindsay Tan as she recruited and believed fervently that Auburn University was where I belonged.

I would like to recognize my committee members who were critical to this journey in sharing their time, expertise, and experiences with me. Without each of you, this research would not be possible. I am especially thankful for Dr. Wi-Suk Kwon, who shared her vast knowledge in research design through supervising the development of my research, keeping my work on track and challenging my critical thinking. Your standard of excellence was both challenging and encouraging as I strove each time to provide my best work through this process. Further, I would like to acknowledge Dr. Amanda Gale for her passion and expertise on sustainable design and

for her willingness to conduct the on-site building research. Lastly, I would like to thank Dr. Thomas Fuller-Rowell for his willingness to contribute and provide valuable feedback.

Lastly, I would like to acknowledge the Auburn University Facility Department, (Jim Carroll, Eric Moore, and Anna Ruth Gatlin), who were willing to meet to answer questions, provide guidance, and enable access to the Auburn University building information. Without this information, the research would not have been possible.

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List of Abbreviations

AP	Accredited Professional
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
AU	Auburn University
BD+C	Building Design and Construction
CBE	Center for the Built Environment
EFA	Exploratory Factor Analysis
GBES	Green Building Education Services
HVAC	Heating, Ventilation, and Air Conditioning
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
LEED	Leadership in Energy and Environmental Design
OIT	Office of Information Technology
USGBC	U.S. Green Building Council

CHAPTER 1. INTRODUCTION

Fundamentally, sustainability is based on the preservation of the planet, the people, and global economics (Edwards, 2011; Steemers & Manchanda, 2010), which is sometimes described as "the triple bottom line" (Lynn & Loehr, 2010, p. 270). Each of these three aspects centralizes human preservation as a priority when addressing global environmental issues (Edwards, 2011; Lynn & Loehr, 2010; Steemers & Manchanda, 2010; Tucker, 2010). People spend more than 80 - 90% of their lives indoors in buildings (Evans & McCov, 1998; Lynn & Loehr, 2010). Research shows that the built environment impacts various comfort and health parameters of building occupants (Evans & McCoy, 1998; Fisk & Rosenfeld, 1997; Steemers & Manchanda, 2010). Building occupants' awareness of the positive and negative effects of the built environment has resulted in a demand for better indoor environmental quality as a mechanism to increase their wellbeing and productivity (Heerwagen, 2010; Steemers & Manchanda, 2010). Ultimately, people want to flourish in their environments (Guerin & Kwon, 2010; Heerwagen, 2010; Steemers & Manchanda, 2010).

The premise exists that an environment can affect individuals' physical and psychological health, as well as cognition, behavior, and overall wellbeing (Kopec, 2009; Stokols & Altman, 1987). Vischer (2008) isolates and frames the effects of health and wellbeing on individuals as user-centered theory. User-centered theory is a set of principles that explains the relationship between the environment and occupant by focusing on psychological perceptions an occupant forms about the built environment and their personal wellbeing (Vischer, 2008). This theory identifies the occupant's perception as a critical component to document building performance (Vischer, 2008). Furthermore, user-centered theory ascertains that an occupant's feelings, responses, and coping mechanisms are impacted by their environment (Stokols, 1992;

Vischer, 2008). Applying user-centered theory, this study examines sustainable indoor environmental quality (IEQ) through the lens of the occupant by measuring the level of satisfaction with the indoor environment to pursue its relationship with human wellbeing.

Concerns for sustainability and awareness of the human-environment relationship have increased the necessity to construct green or sustainable buildings (Kopec, 2006; Winchip, 2011). Sustainable buildings should achieve measures that positively affect the triple bottom line of the global and regional systems (Steemers & Manchanda, 2010) through "a) efficiently using energy, water, land, and materials, b) protecting occupant health and improving employee productivity, c) reducing waste and pollution from each sustainable building, and d) continuously looking for ways to improve performance" (Green Building Education Services [GBES], 2011, p. 3). Essentially, good sustainable building design should address the building's entire life from initial design to the end of its use (GBES, 2011). As a result, a number of sustainable building rating systems have been developed as a way to encourage, reward, and quantify achievements of sustainably designed and constructed buildings (Reeder, 2010; Winchip, 2011). Examples of such sustainable building rating systems include (a) the British Establishment Environmental Assessment Method (BREEAM), which was established in 1990 in the UK, (b) Leadership in Energy and Environmental Design (LEED) sustainable building program, which was established in 1993 in the U.S., (c) Green Globes, which was established in 2000 in Canada, and (d) Living Building Challenge, which was established in 2005 in the U.S..

In the U.S., the LEED sustainable building program has continued to grow in popularity as a sustainable building rating system and currently leads the sustainable building movement (Lee & Guerin, 2009). Given the popularity and convenience, LEED-certified buildings were selected to represent buildings that have sustainable indoor environments in this study. The U.S.

Green Building Council (USGBC) established the LEED certification rating system in order to recognize various types of sustainable building strategies and provide levels of achievements through a stringent certification process (Abbaszadeh, Zagreus, Lehrer, & Huizenga, 2006; Katz, 2012; Lee & Guerin, 2009; Reeder, 2010; Winchip, 2011). The overall goal of LEED certification is to achieve high levels of performance in areas of human and environmental health through environmental responsibility. By achieving this goal, the LEED certification rating system aims at increasing human wellbeing, lowering operational cost savings, reducing energy usage, and minimizing resource consumptions (GBES, 2011; Heerwagen, 2010; Lee & Guerin, 2009).

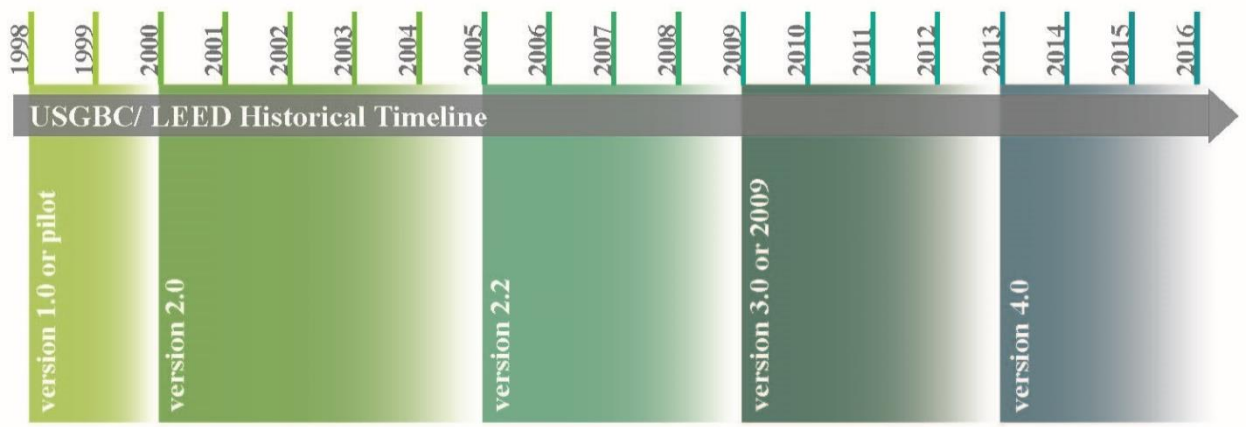


Figure 1.1. Timeline of LEED Rating Systems.

Since 1998, the LEED certification rating system has undergone several iterations, denoted in Figure 1.1, to include a variety of different project types. This was in effort to align with policy changes and adapt to new technologies and innovations in sustainable buildings (USGBC, 2009; Winchip, 2011). Currently, the LEED certification rating system uses four categories: Building Design and Construction, Buildings Operations and Management, Interior

Design and Construction, and Neighborhood Development (USGBC, 2013c). For the purpose of this study, LEED Building Design and Construction (BD+C): New Construction and Major Renovations version 4 was used to assess the objective quality of the sustainable buildings. LEED BD+C: New Construction has eight credit categories: a) location and transportation, b) sustainable sites, c) water efficiency, d) energy and atmosphere, e) materials and resources, f) indoor environmental quality (IEQ), g) innovation in design, and h) regional priority (Moloney, 2014; USGBC, 2013c). Points can be earned in each of these credit categories toward certification.

As the user-centered theory pertains to the user and their interaction with the environment, this study concentrated on the interior environment, specifically IEQ (Stokols, 1992). From the LEED BD+C: New Construction version 4 credit ratings, the IEQ credit category pertains to dimensions such as indoor air quality, ventilation, control and comfort of lighting, control and comfort of thermal temperature, access to daylight and views, and acoustics (USGBC, 2013a; USGBC, 2013c); therefore, in this study, these dimensions were used to assess the objective quality of the sustainable IEQ as a function of whether the indoor environment is meeting sustainable performance as prescribed by LEED.

Findings in the psychosocial, physical, and psychological aspects of human satisfaction with the sustainable environment research have been consistent. This is especially true for sustainable buildings and occupant satisfaction in relation to wellbeing (Sorrento, 2012; Thatcher & Milner, 2012). For example, Steemers and Manchanda (2010) found that the low level of occupant satisfaction with IEQ directly correlated to low levels of health and wellbeing and that unhappiness and discomfort were connected to poor psychological or physical health. Fisk and Rosenfeld (1997) reviewed the literature of indoor environmental quality and identified the

impact of low IEQ on various diseases such as respiratory disease, infectious disease, allergies and asthma, and acute sick-building health symptoms, as well as worker performance. Fisk and Rosenfeld argued that strong evidence was well established linking IEQ, health, and performance.

Literature also has demonstrated that dimensions of health are impacted, positively or negatively, by the indoor environment through air quality, levels of lighting, acoustics, access to daylight, and comfortable furniture (Bluyssen, 2014; Ghodrati, Samari, & Shafiei, 2012). Poor individual health leads to losses in business operational costs through employee absenteeism, reduced cognitive performance, and increased stress in the workplace (Heerwagen, 2010; Morton, 2002). In the built environment, occupants express satisfaction with the interior environment as a means of conveying their comfort and happiness (Steemers & Manchanda, 2010). The impacts of the indoor environment on occupant health and wellbeing are further supported by the October 2014 launch of the WELL Standard by the International WELL Building Institute which is administered by the Green Business Certification Inc. similar to LEED certification (International WELL Building Institute, 2015). The institute "believe[*s*] that buildings should be developed with peoples' health and wellness at the center of design" (International WELL Building Institute, 2015, para. 1). Similarly to sustainable certification systems, the WELL Standard measures, certifies, and monitors the performance of building features that "impact human health and wellbeing, through air, water, nourishment, light, fitness, comfort, and mind" (International WELL Building Institute, 2015).

The launch of the WELL Standard is one of many shifts towards wellbeing from health and wellness. "Wellbeing is about achieving harmony between your physical, emotional and cognitive self" describes Jim Hackett, CEO of Steelcase (Steelcase, 2014, p.14), broadening the

potential impacts of the built environment beyond the dimensionality of health. In fact, Steemers and Manchanda (2010) defined wellbeing in the indoor environment as the expression of health, comfort, and happiness. As a result, wellbeing research in the workplace environment has devised a parallel construct called workplace wellbeing that measures wellbeing gained from work (Page, 2005). Literature has implied a possible correlation between IEQ and workplace wellbeing; however, the two variables have not been applied in the same study. In previous studies, the relationship between the quality of the indoor environment and occupant satisfaction has often been supported, but these studies have inferred the outcome of this relationship is wellbeing without empirically supporting the inference (Leaman & Bordass, 2007; Schell, Theorell, & Saraste, 2012; Steemers & Manchanda, 2010; Veitch, Charles, Newsham, Marquardt, & Geerts, 2003), a gap addressed in this study.

Purpose Statement

The purpose of this study is to examine how workplace wellbeing is influenced by the sustainability of the workplace indoor environment, specifically by working in a LEED-certified building versus a non-LEED-certified building. This will be considered through physical and psychological health, which is positively influenced by the enhancements in the objective sustainable IEQ and occupants' subjective satisfaction with the IEQ, as visually illustrated in Figure 1.2. Specifically, the objectives of this study are

1. To identify whether the objectively assessed sustainable IEQ is higher in LEED-certified buildings than non-LEED-certified buildings,
2. To examine whether satisfaction with the sustainable IEQ is higher among occupants of LEED-certified buildings than ones of non-LEED-certified buildings,

3. To examine whether the objective, sustainable IEQ of a building is positively linked to occupants' satisfaction with the sustainable IEQ of the building,
4. To examine whether the objective, sustainable IEQ of a building is positively linked to its occupants' (physical and psychological) health,
5. To examine the relationship between occupants' satisfaction with sustainable IEQ and their (physical and psychological) health,
6. To explore whether occupants' satisfaction with sustainable IEQ leads to their workplace wellbeing through enhanced health.

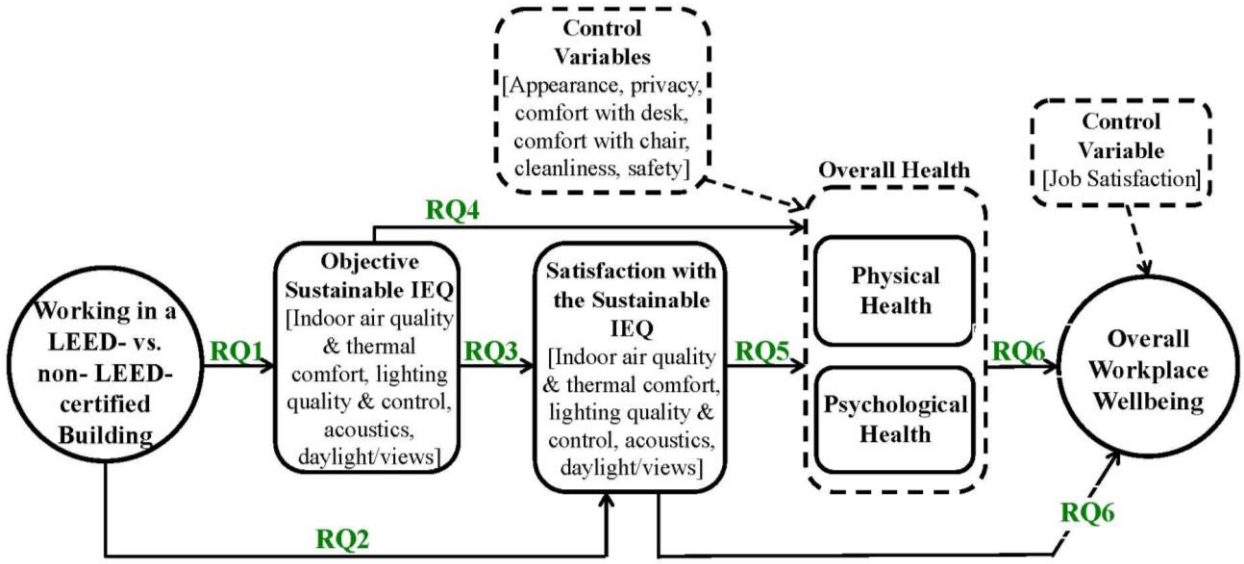


Figure 1.2. A Proposed Research Model. *Note:* The dashed circles indicate control variables.

Assumptions

As noted above, several sustainable rating systems are available to verify the sustainable construction and performance of buildings. In this study, LEED BD+C: New Construction version 4 IEQ credits have been selected to verify the objective sustainable IEQ performance of Auburn University (AU) buildings. The assumption is that LEED criteria is a valid measure of

sustainable IEQ and relates to occupant health and workplace wellbeing. Further, it is assumed that participants will respond honestly and with reflective consideration for each item in the web-based questionnaire. With all instruments utilized, it is assumed they will function properly acquiring data for analysis towards the objectives the study.

Definition of Terms

Acoustics – "effect of sound produced in an enclosed space" (Edwards, 2011, p. 231).

Aesthetics – "the philosophy or theory of taste, or of the perception of the beautiful in nature and art" (Edwards, 2011, p. 231).

Building Occupant – an individual that habitually occupies space in the built environment. In this study, building occupants refer to employees (full-time or part-time) of Auburn University who have their main workspace in one of the selected six buildings.

Cleanliness –a state of an indoor environment to be orderly and frequently maintained free of dirt, stain, and impurities.

Comfort with Workspace Furnishings – a psychological state of mind related to perception of personal comfort considering one's work area furniture, chair, and visual preferences.

Control – the ability to make decisions regarding the appearance, furniture layout, and personalization of one's work area.

Daylight – the system of placing fenestration such as windows, skylights, doors, and openings in such a way that, during the day, natural light provides effective interior illumination (Edwards, 2011).

Indoor Air Quality – "the health conditions of the air within a building" (Winchip, 2011, p. 309) such as humidity, smells, and air movement (Kopec, 2009).

Indoor Environmental Quality (IEQ) – the assessment of the physical and ambient components of the indoor of a building (Kopec, 2009). For the purpose of this study, IEQ refers to the assessment of all indoor environmental factors, which may affect the occupants' health and wellbeing, including sustainable IEQ factors such as indoor air quality, thermal comfort, acoustics, daylight, views, and lighting control and quality,

which are validated through Leadership in Energy and Environmental Design (LEED) Building Design and Construction (BD+C): New Construction and Major Renovation version 4 IEQ, as well as non-sustainability related IEQ factors such as chair comfort, desk comfort, appearance, cleanliness, privacy, and safety (Ghodrati et al., 2012).

Job Satisfaction – an employee's psychological state of mind regarding the work demands, leadership, cooperation, and realistic goals at work (Warr, Cook, & Wall, 1979; Wilks & Neto, 2013).

LEED Sustainable Building Program – a voluntary program created by the U.S. Green Building Council (USGBC) to provide strategies, standards, and recognition of sustainable building design for 21 different project (building) types within four main rating systems. Projects (buildings) that pursue LEED certification must meet minimum program requirements, complete an adequate number of points (more than 40) and complete all credit category prerequisites as required for the selected rating system (USGBC, 2009).

LEED-Certified Building – a building that has been designed, constructed, renovated or operated sustainably, meeting LEED certification requirements developed by USGBC of location and transportation, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation in design and regional priority to attain one of four LEED certification categories (USGBC, 2013a). For the purpose of this study, AU buildings that have been recognized as LEED-certified or are currently "registered-in progress" with a minimum occupation of a year were considered in the LEED-certified building selection.

Lighting Control – one's ability to adjust the lighting quantity, quality, and direction of work area lighting. In this study, task lighting, functioning light switches, and operable window coverings are considered to provide occupant lighting control.

Non-LEED-Certified Building – a building of conventional construction that did not pursue or achieve sustainable building certification at the time of initial construction or through a major renovation. For the purpose of this study, non-LEED-certified buildings are AU buildings that were not designed and constructed with an intention to pursue a LEED certification.

Non-Sustainability Related IEQ – factors of indoor environmental quality besides the sustainable IEQ factors addressed by the LEED credits. In this study, chair comfort, desk comfort, appearance, cleanliness, privacy, and safety are the specific non-sustainability factors being considered.

Objective Sustainable IEQ – objective, sustainable quality of the physical and ambient indoor environment based on sustainability standards from LEED BD+C: New Construction version 4 IEQ prerequisite and credits.

Overall Health – a state of being sound in body and mind extending beyond the absence of disease (World Health Organization, 1948).

Physical Health – a state of being sound in body; free from physical disease or pain (Health, n.d.).

Privacy – the state or condition of being free from being observed, over-heard, or disturbed by other people in the work environment through interpersonal, or self-boundary to regulate interactions with others (Altman, 1975).

Psychological Health – a state of health of the mind where an "individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community" (World Health Organization, 2013).

Safety – a sense of one's security while coming to and from work (Leaman & Bordass, 2007).

Satisfaction with IEQ – a happy or pleased feeling resulting from the evaluation of the occupant's workplace interior environment (Oliver, 1981).

Satisfaction with the Sustainable IEQ – occupant perception and evaluation of the sustainable IEQ in their workplace environment. In this study, this term specifically indicates satisfaction with indoor air quality, thermal comfort, acoustics, lighting control and quality, and daylight and views of the workplace environment.

Sustainable IEQ -- the degree to which the (physical and ambient) indoor environment is environmentally responsible and resource-efficient throughout the building's life-cycle, consequently reducing the negative impacts on the building's occupants and natural environment (GBES, 2011).

Thermal Comfort – a psychological state of mind related to perception of personal comfort considering temperature, humidity, air speed, and air movement.

Thermal Control – the ability of the occupant to adjust the temperature in their work area.

Views – the ability to see out of one's work area window at an appealing view.

Workplace Environment – the environment where an occupant performs work responsibilities of his or her employment external to his or her home environment.

Workplace Wellbeing – an individual's subjective consideration for the quality of their work life through perceptions, thoughts, and feelings (Muruvi, 2012).

CHAPTER 2. LITERATURE REVIEW

This chapter presents a review of existing literature on sustainable buildings, Leadership in Energy and Environmental Design (LEED) certification, indoor quality of the built environment, health, and workplace wellbeing and proposes research questions based on the literature.

Sustainable Buildings

A systematic search of sustainability in any social media or Internet search engine will produce a multiplicity of articles, videos, images, and documentaries describing the need for action, the destructive nature of mankind, and futuristic views of where the continued course will take the planet (Kellert, 2005; Winchip, 2011). Since the United Nations Conference on Environment and Development at the 1992 Earth Summit, sustainability has increased in importance and global awareness (Lynn & Loehr, 2010). Sustainability operates on an individual, local, regional, and global level to address environmental issues relating to the triple bottom line of the planet, people, and global economy (Edwards, 2011). Sustainability is a global phenomenon that will continue to take precedence due to the degrading global challenges of pollution, climate change, endangerment of species, population increases, and resource consumption (Brooker & Stone, 2010; Kellert, 2005; Tucker, 2010).

In 2002, at the World Summit on Sustainable Development in Johannesburg, South Africa, the framework of sustainability was formalized as 1) “change from unsustainable patterns of consumption and production” (United Nations, 2002, p. 13), 2) “protecting and managing the natural resource base of economic and social development” (United Nations, 2002, p. 20), and 3) “health and sustainable development” of human beings as they are “at the center of concern” and “entitled to a healthy and productive life, in harmony with nature” (United Nations, 2002, p. 39).

People spend more than 80-90% of their lives in buildings and 72% of the U.S. electrical energy are consumed by buildings (Evans & McCov, 1998; Lynn & Loehr, 2010). Therefore, in order to provide a healthy and productive life, a focus on sustainable building research and strategies has developed.

As the awareness of sustainability grows, so does the recognition of the largest offenders of environmental destruction (Brooker & Stone, 2010; Kellert, 2005). Building design, construction, and maintenance heavily impacts the global environment and natural resources, as articulated in Table 2.1 (Brooker & Stone, 2010; Kellert, 2005). Buildings consume a staggering percentage of global resources and generate an enormous amount of waste (Brooker & Stone, 2010; Kellert, 2005; Steelcase, 2007). Through sustainable certification systems, builders can make conscious site selections, employ energy efficient strategies, minimize heating, ventilation, and air conditioning (HVAC), integrate day lighting, reduce water consumption, minimize waste and pollutants, select local materials and renewable materials, and ensure the integration of human services (Jones, 2008; Thatcher & Miller, 2012).

To accomplish building sustainability goals, a variety of sustainable building strategies have been identified and may include 1) becoming carbon neutral, 2) creating net water productions, 3) implementing net energy production, 4) eliminating waste, 5) improving occupant health, and 6) designing with intent (Lynn & Loehr, 2010). Through these strategies, building stakeholders try to minimize the consumption and waste generation that is detrimental to the planet (Brooker & Stone, 2010; Winchip, 2011). The best opportunity to impact sustainability is during the planning process as the decisions made at the project onset have outreaching effects on the environment, occupants, and long-term building maintenance and operations (Green Building Education Services [GBES], 2011; Morton, 2002).

Table 2.1

Global Impact from Buildings

Consumption of resources	Creation of pollutants and waste
40% of all energy resources	40% of air emissions
25% of all freshwater resources	20% of freshwater effluents
30% of all natural resources	25% of solid waste
	60% of ozone depletion emissions
	30% of greenhouse gas emissions

Note. Adapted from "Building for Life", by S. R. Kellert, 2005, p. 91 Washington, DC: Island Press. Copyright 2005 by Stephen R. Kellert.

High levels of performance in areas of human and environmental health can be achieved through building construction and operations (GBES, 2011; Heerwagen, 2010; Lee & Guerin, 2009). From a business perspective, it is estimated that 82% of operational business costs are associated with employees, such as costs for salaries, benefits, training, and rehires. The remaining portions of operational costs are spent in maintaining the building through rent, technology usage and upgrades, operations, and maintenance (Morton, 2002). The relationship of users and their environment suggests financial advantages if employee satisfaction, health, productivity, and wellbeing are improved through environmental quality (Heerwagen, 2010; Morton, 2002; Vischer, 2008).

Leadership in Energy and Environmental Design (LEED)

LEED certification provides "an independent, third-party verification that a building . . . was designed and built using strategies aimed at achieving high performance in key areas of human and environmental health" including "sustainable site development, water savings, energy efficiency, materials [and resource] selection, and indoor environmental quality" (Katz, 2012,

para. 5). As established by the World Summit on Sustainable Development, the overall goals of the U.S. Green Building Council (USGBC) align the LEED certification rating system by promoting high levels of performance in sustainable buildings in areas of human and environmental health (GBES, 2011; Heerwagen, 2010; Lee & Guerin, 2009; United Nations, 2002).

LEED sustainable building program establishes a portfolio of rating systems to accommodate the wide range of building types, levels of construction and operations, and building use (USGBC, 2013a; Winchip, 2011), as described in Table 2.2. Each rating system establishes specific project applications with relevant credits for sustainable achievements in the eight categories, described in Table 2.3. Prior to any project being eligible for LEED certification, the project must meet the minimum program requirements and credit category prerequisites (USGBC, 2013c; Winchip, 2011).

A commercial building project intended for LEED certification will be designated 'Registered- in Progress' at the time of initial registration (GBES, 2011). This standing persists through the duration of construction and initial occupancy until the project administrator completes and submits documentation for final review by the Green Building Certification Inc. For the purpose of this study, AU buildings that were LEED-certified as well as those that were 'registered- in progress' and occupied for a minimum of a year were considered in the LEED-certified building selection. Once the Green Building Certification Inc. conducts the final review, a formal ruling is determined based on the number of points achieved (GBES, 2011). A project (building) can be denied LEED certification when it does not achieve 40 points or does not meet all minimum program requirements and/or credit category prerequisites as required for the selected rating system (USGBC, 2013a; USGBC, 2013c).

Table 2.2

LEED Version 4: Rating Systems by Project Types

Rating Systems	Description and Project Types
Building Design and Construction (BD+C)	Designed to guide and distinguish high-performance new construction or major renovation. "At least 60% of the projects gross floor area must be complete by the time of certification" (USGBC, 2013c, p. 7): LEED BD+C: New Construction and Major Renovations LEED BD+C: Core and Shell Development LEED BD+C: Schools LEED BD+C: Retail LEED BD+C: Data Centers LEED BD+C: Warehouses and Distribution Centers LEED BD+C: Hospitality LEED BD+C: Healthcare LEED BD+C: Homes and Multifamily Lowrise LEED BD+C: Multifamily Midrise
Buildings Operations and Management (O+M)	Provided for "existing buildings that are undergoing improvement work or little to no construction" (USGBC, 2013c, p. 7): LEED O+M: Existing Buildings LEED O+M: Retail LEED O+M: Schools LEED O+M: Data Centers LEED O+M: Warehouses and Distribution Centers LEED O+M: Hospitality
Interior Design and Construction (ID+C)	Designed for the tenant improvement market to make sustainable choices once the building exists and a new tenant wants to move in. LEED ID+C: Commercial Interiors LEED ID+C: Retail LEED ID+C: Hospitality
Neighborhood Development (ND)	Integrated as the principles of smart growth, urbanism and sustainable building for development. LEED ND: Plan LEED ND: Built Project

Note. Adapted from "*LEED v4 User Guide,"* by USGBC. Copyright 2013 by USGBC.

Table 2.3

Credit Categories and Point Distribution for LEED BD+C: New Construction (Version 4)

Credit Categories	**Description**	Points
Location and Transportation	Sustainable achievements in bicycle facilities, access to quality transit and sustainable vehicles	16
Sustainable Sites	Building site location factors including energy use, land use and preservation, development density, erosion and rainwater management, habitat protection, site development maximizing open space, community connectivity, and reduction of heat island effect and light pollution	10
Water Efficiency	Sustainable water use by the building and site, which includes reduction of quantity of water needed both in the building and for landscaping, reduction of municipal water use, and reduction of the need of treated water	11
Energy & Atmosphere	Sustainable energy use by the building, which includes reduction of energy use, support of environmentally friendly energy sources (sustainable power), enhanced refrigerant management, on-site renewable energy, and optimal energy performance	33
Materials & Resources	Sustainable materials and resources used in the building construction and operations, which includes reduction of waste, waste diversion, reuse of building, reuse of materials, utilizing materials with recycled content, purchasing materials from the region, using rapidly renewable materials, use of certified wood, and sustainable purchasing program	13
Indoor Environmental Quality	Sustainable quality of the air and environment of the building, which includes strategies of outdoor air monitoring, increased ventilation, indoor air quality management, use of low-emitting materials, controllability of thermal comfort and lighting, acoustics, and optimizing daylight and views	16
Innovation in Design	Achievement through exemplary or creative performance and having one LEED Accredited Professional (AP) participant on the project team	6
Regional Priority	Specific environmental priorities in the project's region	4

Note. Adapted from (1) "*LEED: Green Associate Study Guide," by* GBES, LLC. Copyright 2011 by GBES and (2) "*LEED v4 User Guide,"* by USGBC. Copyright 2013 by USGBC.

Based on the total points achieved on a 100-point scale from the first six credit categories plus 10 "bonus points" available through the remaining credit categories of regional priority and innovation in design (or operations), a project that receives LEED certification can be granted one of four levels: *Certified* (40-49 points), *Silver* (50-59 points), *Gold* (60-79 points), and *Platinum* (80 points or above) (USGBC, 2009). LEED certification versions 1 and 2 were based on a 69-point scale with levels as follows: *Certified* (26-32 points), *Silver* (33-38 points), *Gold* (39-51 points), and *Platinum* (52-69 points) (USGBC, 2006).

The LEED certification rating systems contain a set of prerequisites and scoring criteria for each credit category in order to accumulate points towards a certification level (GBES, 2011; USGBC, 2009). Prerequisites do not receive points, but must be fully met as mandatory characteristics for a project to move forward to receive certification as noted in Table 2.4 (GBES, 2011; USGBC, 2009). Essentially, the point distribution for credits is based on the environmental impact of the sustainable strategy to both humans and the environment (GBES, 2011; USGBC, 2009). The credit category point distribution is described in Table 2.3.

At the on-set of a new project (building), the building owner sets the goals and budget and assembles a design team (GBES, 2011; USGBC, 2009). USGBC refers to the design team as the integrated project team and advocates for the team to be fully engaged at the start of the project (GBES, 2011). The integrated project team may include owners, general contractors, project managers, interior designer, architect, mechanical engineer, electrical engineer, structural engineer, facility manager, landscape architect, energy consultant, lighting designers, janitorial staff, and occupants (GBES, 2011). USGBC admonishes the integrated design team to follow the LEED work plan for certification: (1) discovery through research and analysis, (2) select LEED rating system, (3) check minimum program requirements, (4) establish project goals, (5) define

project scope, (6) develop LEED scorecard, (7) further research and analysis, (8) continue iterative plans, (9) assign roles and responsibilities, (10) develop consistent documentation, and (11) perform quality assurance (USGBC, 2013c; USGBC, 2013d). As part of the work plan, the integrated project team selects the applicable LEED rating system and develops the LEED scorecard to prioritize the project's sustainable goals and select the credits the project (building) will attempt to achieve (USGBC, 2013c; USGBC, 2013d). The LEED BD+C: New Construction version 4 score card is provided in Figure 2.1.

Table 2.4

LEED BD+C: New Construction (Version 4) Prerequisites

Credit Categories	**Prerequisite**
Location and Transportation	NA
Sustainable Sites	SS 1: Construction Activity Pollution Prevention
Water Efficiency	WE 1: Outdoor Water Use Reduction WE 2: Indoor Water Use Reduction WE 3: Building-Level Water Metering
Energy and Atmosphere	EA 1: Fundamental Commissioning and Verification EA 2: Minimum Energy Performance
Materials and Resources	MR 1: Storage and Collection of Recyclables MR 2: Construction and Demolition Waste Management Planning
Indoor Environmental Quality	IEQ 1: Minimum Indoor Air Quality Performance IEQ 2: Environmental Tobacco Smoke (ETS) Control
Innovation	NA
Regional Priority	NA

Note. NA = not applicable
Note. Adapted from "*LEED v4 User Guide,"* by USGBC. Copyright 2013 by USGBC.

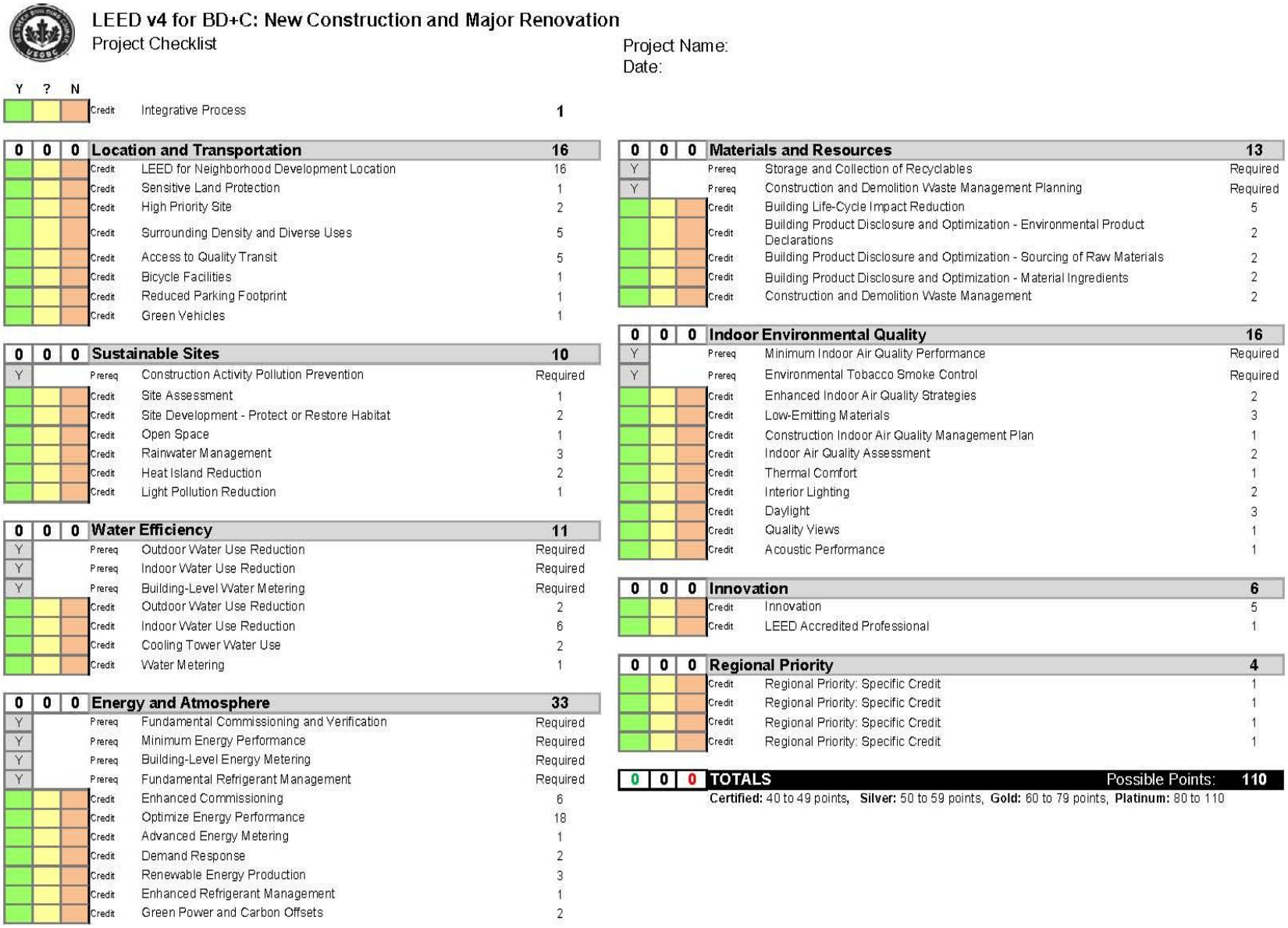


Figure 2.1. LEED for BD+C: New Construction (Version 4) Project Scorecard (USGBC, 2014).

Indoor Environmental Quality (IEQ)

Indoor environmental quality (IEQ) refers to the assessment of the distinct attributes of the interior of a built environment that positively or negatively affects an occupant's physical and psychological health and wellbeing (Ghodrati et al., 2012). From the user-centered theory, the environment influences human behavior and identifies the ways the user interfaces with the environment (Vischer, 2008). Given the amount of time users spend within the built environment and the theoretical connection between user and environment, this study focused specifically on IEQ. IEQ may consist of factors pertaining to the sustainability (e.g., daylight, enhanced indoor air, views, and lighting quality) of the indoor environment (hereafter, *sustainable IEQ factors*) as well as many other non-sustainability related indoor environment factors (e.g., desk comfort, appearance, cleanliness, and safety) that may influence occupants' wellbeing (hereafter, *non-sustainability related IEQ factors*). Sustainable IEQ refers to the degree to which the (physical and ambient) indoor environment is environmentally responsible and resource-efficient throughout the building's life-cycle, consequently reducing the negative impacts on the building's occupants and natural environment (GBES, 2011).

Sustainable Indoor Environmental Quality Factors

Ghodrati et al. (2012) argued that buildings with sustainable IEQ features have better IEQ than conventional buildings. This argument is supported further by Newsham et al. (2012) where sustainable buildings exhibited superior indoor environments. Newsham et al. (2012) studied 24 buildings in the U.S. and Canada where both objective on-site measurements and subjective occupant surveys were obtained. The objective IEQ on-site measurements of 974 workstations across the 24 buildings resulted in recorded data for thermal conditions, air quality, acoustics, lighting, ceiling height, window access and shading, and surface finishes. Newsham et al.'s

analysis of the objective IEQ data indicated that the indoor environments of the sustainable buildings demonstrated few differences in the number of airborne particulates and had lower noise from HVAC than the conventional buildings with all other IEQ dimensions having no difference between the building types. Moreover, the analysis of the occupant surveys (n = 2545) resulted in substantially higher performance with the sustainable buildings in satisfaction with the overall environment, thermal conditions, and view to the outside.

The LEED certification rating system establishes IEQ as one of the eight credit categories of a sustainable building (GBES, 2011). The IEQ credit category of the LEED BD+C: New Construction (Version 4) addresses various sustainable IEQ factors such as indoor air quality, tobacco smoke control, access to daylight, quality views, interior lighting, acoustical performance, thermal comfort, and low-emitting materials (Heerwagen, 2000; USGBC, 2013d). These factors extend into specific features of building design such as 1) healthy indoor air quality through low-toxicity in finishes and furnishings, tobacco smoke control, increased ventilation, and filtrated indoor air, 2) occupant control through lighting adjustability at multiple levels, adjustable window treatments, and thermostat and vent locations; and 3) access to daylight and views through proximity to windows and obstructed views (USGBC, 2013d). In LEED BD+C: New Construction (Version 4), 16 out of the possible 110 points are accounted for by the nine sustainable IEQ features, in addition to two prerequisites, as indicated in Table 2.5 (USGBC, 2013d). For this study, LEED BD+C: New Construction (Version 4) IEQ credit category constructs the sustainable IEQ dimensions. Therefore, the subsequent literature review pertains to the dimensions provided by LEED IEQ: (1) indoor air quality, (2) thermal control and comfort, (3) lighting, (4) access to daylight, (5) access to views, and (6) acoustics (USGBC, 2013a; USGBC, 2013d).

Indoor air quality. People spend 80-90% of their lives inside buildings, resulting in the vast majority of breathable air coming from mechanical systems that ventilate, purify, and humidify the inside air (GBES, 2011; USGBC, 2013d). Spread of disease, stagnation of air, indoor air pollution, and uncomfortable indoor breathing conditions are fallouts of a poorly designed and operating HVAC mechanical system (Bluyssen, 2014; Kellert, 2009; USGBC, 2013d). Further, poor indoor air quality may result from lack of cleaning, toxic cleaning agents, off gassing materials, chemical pollution, or periods of high humidity (Ghodrati et al., 2012; Roper & Beard, 2006).

Table 2.5

LEED BD+C: New Construction (Version 4) Indoor Environmental Quality (IEQ) Credits

Credits	Points	Description	Potential Sustainable IEQ Factor
Prereq. 1		Minimum Indoor Air Quality Performance	Indoor air quality
Prereq. 2		Environmental Tobacco Smoke Control	Indoor air quality
Credit 1	2	Enhanced Indoor Air Quality Strategies	Indoor air quality
Credit 2	3	Low Emitting Materials	Indoor air quality
Credit 3	1	Construction Indoor Air Quality Management Plan	Indoor air quality
Credit 4	2	Indoor Air Quality Assessment	Indoor air quality
Credit 5	1	Thermal Comfort	Thermal comfort
Credit 6	2	Interior Lighting	Lighting quality and control
Credit 7	3	Daylight	Daylight and views
Credit 8	1	Quality Views	Daylight and views
Credit 9	1	Acoustic Performance	Acoustics

Note. Adopted from "*LEED for BD+C: New Construction IEQ Credits",* by USGBC. Copyright 2013 by USGBC.

To protect human health, indoor air quality standards and guidelines have been established to govern the quality of air in the indoor environments (GBES, 2011). Two main strategies embraced by the LEED certification rating system, include 1) improving ventilation

and 2) decreasing the introduction of pollutants to indoor spaces through source control (GBES, 2011; USGBC, 2013d). Essentially, source control is managing the contaminants at the entry point into the mechanical system (Bluyssen, 2014; GBES, 2011). Contaminants may include dust, allergens, secondhand smoke, CO_2, material off-gassing, radon, chemicals, particles, and mold (GBES, 2011; Kellert, 2009). Poor air quality is reduced when fresh air is mixed into the indoor air systems through operable windows, mixed mode vents, and increased air exchange rates (Bluyssen, 2014; GBES, 2011; Kellert, 2009).

Indoor air quality accounts for two prerequisites and eight points of the LEED BD+C: New Construction version 4 IEQ credit category (USGBC, 2013d). The 2010 version of American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) 62.1 is the adopted standard for the LEED certification rating system in regards to indoor air quality (USGBC, 2013d). The ASHRAE 62.1-2010 standard provides the minimum ventilation rates, outdoor intake flow, and contaminant quantities (USGBC, 2013d). The features set forth by LEED BD+C: New Construction for indoor air quality credits include CO_2 monitoring, increasing outdoor air ventilation rates by 30%, construction monitoring of air quality (during and before occupancy), indoor air quality management plan implementation, and reduction of indoor air contaminants through reduction of volatile organic compounds (VOCs) that off gas from materials (USGBC, 2013d). Due to the adoption of the ASHRAE 62.1-2010 standard in the LEED certification rating system, LEED-certified buildings often have better indoor air quality than non-LEED-certified buildings (Green-Buildings, n.d.). In the U.S., indoor air pollution is not regulated, resulting in no implementation of air quality standards (Green-Buildings, n.d.). Therefore, buildings that follow any rating system that requires indoor air quality standards may have better air quality than ones that do not.

Thermal control and comfort. Control over one's environment is strongly linked to productivity, happiness, and comfort (Leaman & Bordass, 2007; USGBC, 2013d; Zagreus, Huizenga, Arens, & Lehrer, 2004). Temperature is one of the areas an occupant can control within their environment (Leaman & Bordass, 2007; USGBC, 2013d). At a minimum, most occupants can achieve temperature control through managing their clothing choices, opening operable windows, and utilizing portable heating/cooling devices where appropriate in the indoor environments (GBES, 2011). At a higher level of control, buildings may provide the occupants the ability to adjust the temperature of a space to their preference and task requirements (GBES, 2011). LEED BD+C: New Construction IEQ Credit 5 addresses individual temperature controls for a minimum of 50% of building occupants and meet thermal comfort design requirements of ASHRAE Standard 55-2010 (USGBC, 2013d). To achieve this credit, a building should be designed with thermostats for individual (private offices) or groups (open offices) for a minimum of 50% of building occupants to adjust the temperature to their preferred comfort levels, meeting the ASHRAE 55-2010 standard (USGBC, 2013d). Regardless of the strategy taken, the design of personal control should be intuitive and simple to operate for occupants (Steemers & Manchanda, 2010).

Thermal comfort is more than how hot or cold a space may feel (GBES, 2011). Temperature (air and radiant), humidity, and air speed are components of occupant thermal comfort that are addressed by LEED BD+C: New Construction credits for IEQ (GBES, 2011). In LEED BD+C: New Construction Credit 5, ASHRAE 55-2010 is the adopted standard for the thermal environmental conditions of an indoor environment (USGBC, 2013d). Specifically, ASHRAE specifies that a minimum of 80% of a building's occupants should find the thermal comfort acceptable for their activities and clothing choices (USGBC, 2013d). ASHRAE's

definition of thermal comfort asserts comfort as a state of mind and an expression of thermal satisfaction (ASHRAE, 2004). For this reason, the design of the thermal comfort system in LEED-certified buildings implements the ASHRAE 55-2010 standard with IEQ Credit 5 to verify design compliance of the HVAC system (USGBC, 2013d).

Lighting. The quality of luminance from both artificial and natural light in an indoor environment can enhance or degrade IEQ and impact occupants (Leaman & Bordass, 2007). High quality lighting enables performance of tasks, provides visual comfort, ensures safety moving throughout the space, and enhances the aesthetic qualities of the architectural designs (Brooker & Stone, 2010; Fisk & Rosenfeld, 1997; Winchip, 2011). Similar to thermal comfort, individuals have different lighting needs based on their visual comfort preferences, tasks to be achieved, and personal health conditions (Kopec, 2009). For this reason, controllability of the levels of illumination and adjustability of location or placement of the lighting is important to an interior environment and occupant health and wellbeing (GBES, 2011; USGBC, 2013d).

Only one credit, IEQ Credit 6, exists in LEED BD+C: New Construction IEQ for lighting quality and control (USGBC, 2013d). For lighting control (1 point), the credit requires 90% of occupants to have individual controllability of lighting to perform tasks and suit preferences, with at least three lighting levels (on, off, mid-level) (USGBC, 2013d). Additionally, all shared multi-occupant spaces require controllability and adjustability (USGBC, 2013d). This is measured based on the number of occupant workstations and the number of workstation with individual controllability to determine the compliant percentage (USGBC, 2013d). Lighting control solutions may include task lights, local switching controls for individual offices, handheld remotes, and PC integrated control (USGBC, 2013d; Winchip, 2011).

The second point of IEQ Credit 6 may be achieved by meeting at least four of the eight lighting quality options (USGBC, 2013d). The credit strategy is to provide fixtures and/or lamps with extended life (at least 24,000 hours), good color rendition (CRI or 80 or higher), and have the majority with indirect light distribution (greater than 75%), as well as meeting surface reflectance thresholds for furniture, walls, and ceilings (USGBC, 2013d). For the specific credit, one or both, of the credit strategies may be met. The number met equates to the number of points (up to 2) earned (USGBC, 2013d).

Baylon and Storm (2008) compared performance characteristics (i.e., HVAC systems, energy usage, lighting control, lighting systems, glazing percentage, and glazing performance) of 24 LEED-certified buildings to those of a random sample of new non-LEED-certified regional buildings that comparatively matched in floor area, mechanical equipment, lighting, and exterior construction. For lighting, the LEED-certified buildings had a reduced lighting power density, thus using less energy than non-LEED-certified buildings. Baylon and Storm suggests the difference occurs because linear fluorescent fixtures account for 75% of the lighting power in LEED-certified buildings as compared to 60% in non-LEED-certified buildings. Further, Baylon and Storm identify that lighting control is twice as common in LEED-certified buildings as it is in non-LEED-certified buildings. The LEED-certified buildings utilized occupancy and daylight sensors, interior photocells, daylight zoning, and centralized lighting control systems in an effort to reduce the energy usage to meet the LEED certification credits (Baylon & Storm, 2008).

Access to daylight. Occupants are positively impacted by access to daylight and exterior views in their indoor environments (GBES, 2011; Kellert, 2005). Daylighting is a strategic inclusion of natural light through building penetrations with the purpose of reducing electric lighting (USGBC, 2013d). The inclusion of daylighting design can impact energy costs, lighting

loads, lighting quality, and visual appeal of a building (GBES, 2011). This is achieved by consciously designing building penetrations that permit the best natural light considering the geographical location, climate, building site and orientation, sun path, floor depth, furniture placement, and building use factors (GBES, 2011; Winchip, 2011). Beyond the location of fenestration, daylight designs may include high-performance glazing, skylights, tubular devices, solar shading devices, daylighting controls, automated window treatments, and furniture layout and design (GBES, 2011; Winchip, 2011).

For LEED BD+C: New Construction, one credit, IEQ Credit 7, is designated for daylight, which requires all occupied spaces to have glare-control devices and 75% of the occupied spaces to receive the denoted quantity of daylighting (USGBC, 2013d). Three options are provided to verify that the building design achieves the credits. The options include a) demonstrating that the occupied floor area has spatial daylight autonomy through annual computer simulations, b) constructing a computer simulation model that demonstrates a minimum daylight illumination level between 300 and 3,000 lux, and c) recording indoor light measurements at work plane height between 9 a.m. and 3 p.m. twice a year between 4 to 9 months apart to ensure minimum daylight illumination has been achieved between 300 and 3,000 lux (USGBC, 2013d). In all cases, the daylighting design should include controllability features to reduce high-contrast lighting levels which could result in discomfort (USGBC, 2013d).

Access to views. In conjunction with daylight, occupant access to exterior views is important as it reinforces the connection between people and the natural environment (Kellert, 2005; USGBC, 2013d). From the perspective of LEED BD+C: New Construction, IEQ Credit 8, 75% of occupants should have a direct line of sight to the outdoors that is not obstructed (e.g. no frits, fibers, patterned glazing or tints to distort color balance) and meets two of the four

prescribed types of views noted in Table 2.6 (USGBC, 2013d). For credit verification, the percentage is derived from a study of the building plans and sections to quantify the occupied spaces that meet the 75% requirement (USGBC, 2013d).

Table 2.6

LEED BD+C: New Construction (Version 4) IEQ Credit 8: Quality Views Optional Strategies

Strategy	Description
1	Multiple lines of sight to vision glazing in different directions at least 90 degrees apart
2	Views that include at least two of the following: (1) flora, fauna, or sky, (2) movement, and (3) objects at least 25 feet from the exterior of the glazing
3	Unobstructed views located within the distance of three times the head height of the vision glazing
4	Views with a view factor of 3 or greater, as defined in "Windows and Offices: A Study of Office Worker Performance and the Indoor Environment."

Note. Adopted from "*LEED for BD+C: New Construction IEQ Credits",* by USGBC. Copyright 2013 by USGBC.

Acoustics. In the indoor environment, acoustics include noise from conversations, equipment and fixtures, workplace activities, outdoor noises, and HVAC systems (Leaman & Bordass, 2007). Disruptive noise can cause reductions in mental alertness, problems focusing, increases in annoyance, and difficulties in communicating with coworkers (Kroemer & Grandjean, 1997). Especially susceptible to sporadic or continuous noise are those who are engaged in high concentration tasks (Kroemer & Grandjean, 1997). LEED IEQ Credit 9, acoustic performance, is a new credit in BD+C: New Construction version 4 (USGBC, 2013d). The credit requires occupied spaces to meet three requirements: (a) HVAC background noise, (b) reverberation time, and (c) sound reinforcement and masking systems (USGBC, 2013d). Sound

masking is the addition of background sound with the intent to reduce distractions and provide confidentiality (Winchip, 2011). The intent of the acoustic performance credit is to enhance and "promote occupants' wellbeing, productivity, and communications" (USGBC, 2013d).

Based on the above literature that argues the superiority in sustainable IEQ in LEED-certified buildings, we ask the following research question (RQ).

RQ1: Is the objective sustainable indoor environmental quality higher in a LEED-certified building than in a non-LEED-certified building?

Non-Sustainability Related Indoor Environmental Quality Factors

From the user centered theory, multiple factors construct the indoor environment and occupant relationship (Danielsson, & Bodin, 2008; Vishcer, 2008). For this reason, a number of other IEQ factors besides the sustainable IEQ factors addressed by LEED sustainable building program are included as control variables in this study to predict occupant health. They include 1) aesthetics (Schell et al., 2012), 2) furniture and workstation comfort (Brennan, Chugh, & Kline, 2002; Danko, Eshelman, & Hedge, 1990; Frontczak & Wargocki, 2011), 3) privacy (Lee, 2010), 4) personal control (Lee & Brand, 2005), 5) safety (Veitch et al., 2003), and 6) cleanliness (Veitch et al., 2003). In a study on open office plans, Veitch et al. (2003) had office occupants rank the indoor environmental parameters. The study discovered that occupants ranked air quality and ventilation as most important followed by privacy, noise level, temperature, lighting, size of workstation, and window access (Veitch et al., 2003). It is important to recognize the varying factors in the indoor environment as occupant health and wellbeing may be impacted by both sustainable and non-sustainability related IEQ factors.

Aesthetics. Aesthetics refers to perception and appreciation of beauty (Edwards, 2011). Schell et al. (2012) determined aesthetics to be an independent indoor environmental factor

through a mail questionnaire of 1,961 employees from the Public Service Broadcasting Company for Television and at the Radio Symphony Orchestra in Sweden. The questionnaire included work environment, health (such as sick-leave, stress-related symptoms and musculoskeletal pain), and demographic data developed by Statistics Sweden (Schell et al., 2012). Further, the questionnaire included items on the perceived need for aesthetics and ergonomics (Schell et al., 2012). The study found that individuals in different occupations had varying degrees of need for aesthetics in the indoor environment, in that individuals working in a more demanding and psychologically strenuous work, which may cause pain, stress, sleep disturbances, disturbing noise, and overall work demands, needed a higher level of aesthetic. Through this study, Schell et al. (2012) established the relationship between health and work environment aesthetic and postulated the notion that workplace aesthetic improvements would increase job productivity, recommending further research in worker health and workplace aesthetic assessments.

Comfort with workspace furnishings. Comfort is defined as a psychological state of mind related to perception of personal comfort considering one's work area furniture, chair, and visual preferences, which encompasses ergonomics. Schell et al. (2012) also identified a strong relationship between sick leave and pain, and comfort with office furnishing including the occupant's desk and seat. The one-size-fits-all model of workspace design is counterintuitive to the reality in which each occupant has individual physical proportions and work styles and requires adaptability through work activities (Leaman & Bordass, 2007).

Privacy. Privacy is the state of not being disturbed or being free from unwanted intrusion to personal visuals, conversations, or information through construction of an interpersonal or self-boundary to regulate interaction with others (Altman, 1975). A balance between the ability to interface with colleagues in workgroups and the personal perception of separation and

seclusion is a difficult achievement in workplace privacy (Leaman & Bordass, 2007). Moreover, privacy is tied to both acoustics, as interruption may occur through earshot contact (e.g., noise), and visual line-of-sight contact (e.g., physical office arrangement, panel heights, and open plan workstations) (Leaman & Bordass, 2007). Ding (2008) interviewed 42 managers and employees from three separate companies in the Midwest of the U.S., all using open plan offices. The results confirmed a lack of privacy (visual and acoustical) still exists in the open plan offices (Ding, 2008). Further, Ding's study identified that employees and managers have the same opinion of acoustical privacy, but differ with the application and need for visual privacy. Ding postulates that the difference may be a consequence of a manager's role to monitor the whole team or space. Although the environment often requires a fostering of team work through seeing and hearing each other closely and precisely, at times occupants require a place to work uninterrupted (Leaman & Bordass, 2007). Hence, privacy is tied to an occupant's sense of psychological health and wellbeing at the workplace (Altman, 1975).

Personal control. A sense of control in our workplace environment is critical to occupant psychological health and wellbeing (Kopec, 2006; Leaman & Bordass, 2007). Psychologically, the perceived level of control an occupant has over their work environment directly affects their feelings about it and their degree of investment (Kopec, 2006). Personal control is linked to territorialism, ownership, and personal space (Altman, 1975). Therefore, in a workplace environment, personal control may exist in an occupant's choices regarding furniture placement, aesthetic qualities, work activities, and options for personalization (Veitch et al., 2003).

Safety. Safety encompasses work area orientation to points of access including windows or office entrances, approach to the building and work areas, security of personal belongings and work files (such as informational privacy), spatial mindfulness, permanency, and placement in an

open office (Leaman & Bordass, 2007). A sense of safety in one's surroundings positively affects an occupant's psychological health, through a feeling of security, and orientation (Leaman & Bordass, 2007). The lack of safety, therefore, disorientates and negatively impacts an occupant's health and satisfaction with the work environment (Leaman & Bordass, 2007).

Cleanliness. This factor is directly tied to the spread of infectious disease and perception of employer values in regards to the indoor environment (Kopec, 2009). Unclean indoor environments contribute to poor physical and psychological health through the spread of disease, exposure to environmental pollutants, and development of hypersensitivity illnesses (Kopec, 2009). Further, unclean environments are perceived as being unhealthy and result in low productivity and low job satisfaction (Leaman & Bordass, 2007).

Satisfaction with the Indoor Environmental Quality

The interaction between the user and the indoor environment is dynamic (Vischer, 2008). The interactions and experiences change with the active participation of occupants as they act on and in their spaces (Vischer, 2008). Essentially, occupant satisfaction measures how users feel about the quality of their space and indoor environment to meet workplace needs (Vischer, 2008) and enables the identification of the effects of building systems on users (Vischer, 2008).

Brennan et al. (2002) conducted a longitudinal study of employees who were relocated to a new office. In this study, surveys were conducted three times during the transition to the new space, including before, one month after, and six months after the relocation, to determine if occupants adapted to the new space and assess their satisfaction in four areas (the physical environment, team member relations, job performance, and physical stress of the office environment). Brennan et al. determined that occupant satisfaction scores changed over the 1-to-6-month time period and concluded that the occupants did not attempt to adapt to the new

environment. In fact, the study indicated that the occupants found further dissatisfaction with the physical environment as time progressed and recommended that the dissatisfactory features be improved.

Several studies (e.g., Altomonte & Schiavon, 2013; Frontczak et al., 2012; Kim, de Dear, Candido, Zhang, & Arens, 2013) utilized the large database of research in the area of IEQ and occupant satisfaction established by the Center for the Built Environment (CBE). The CBE occupant satisfaction survey is web-based and assesses occupants' evaluation of IEQ and building features and their self-reported productivity (Frontczak et al., 2012). The survey consists of a core module of items and optional modules that can be added by the building owner or survey administer. Further, the CBE survey collects background information including gender, age group, type of work performed, office type, proximity of workstation to window, and how long one has worked in the building. Lastly, the building facility manager completes an information form about the building's age, location and size, number of floors, number of occupants, type of HVAC system, solar shading and controls, building's LEED certification level achieved, energy use, and cost of building construction (Frontczak et al., 2012).

Frontczak et al. (2012) evaluated occupants' satisfaction in U.S. office buildings utilizing the CBE web-based IEQ database available in 2011 of 351 office buildings from 52, 980 occupants who 1) performed office work and 2) worked in a single office, shared office, cubicle, or open-space office. Frontczak et al. reported that occupants were satisfied with their work area and the overall building, but expressed high dissatisfaction with aspects of their work environment including acoustical privacy, noise level, temperature, and air quality. Further, sound privacy was connected to the type of office, with private offices providing the greatest satisfaction (Frontczak et al., 2012). On the other hand, Kim et al. (2013) also utilized the post

occupancy CBE database of 38,257 occupants (after excluding respondents that missed gender or other core survey factors) from 351 office buildings to examine gender differences in occupants' IEQ satisfaction and found that female occupants' satisfaction with IEQ was significantly different from that of male occupants. Particularly, female occupants had a lower overall IEQ satisfaction with specific dissatisfied factors in thermal environment, indoor air quality, and cleanliness (Kim et al., 2013).

Ghodrati et al. (2012) argued that theoretically a sustainable building should produce measurably higher degrees of satisfaction with IEQ. Altomonte and Schiavon (2013) addressed this relationship by comparing LEED-certified and non-LEED-certified office buildings. Altomonte and Schiavon began with the same CBE database as used by Frontczak et al. (2012) and Kim et al. (2013). However, Altmonente and Schiavon further controlled the variables by eliminating buildings from the sample that did not provide demographic location and building information or were older than 1998, the year LEED Certification initiated (Altomonte & Schiavon, 2013). The building sample was further narrowed by removing buildings that were reported as LEED-certified but their certification status could not be verified through the USGBC project directory. This process resulted in a finalized sample of 144 buildings (65 LEED-certified) and 21,477 occupants (10,129 LEED occupants). Altomonte and Schiavon found that the occupants of the LEED-certified buildings had higher satisfaction with indoor air quality, building maintenance, building cleanliness, workspace, and building overall and lower satisfaction with the amount of light. However, the occupants in LEED-certified buildings were slightly dissatisfied with privacy and temperature than those in non-LEED-certified buildings (Altomonte & Schiavon, 2013).

An earlier comparative analysis of the CBE database establishes occupants of LEED-certified buildings having higher satisfaction with aspects of their built environment in the areas of office furnishings, thermal comfort, air quality, cleaning and maintenance, and overall satisfaction with workspace and building (Abbaszadeh et al., 2006). It is important to recognize that initially the CBE comparison of LEED-certified versus non-LEED-certified buildings did not consider the age of the non-LEED-certified buildings to the newer LEED-certified buildings. When the comparison was conducted after controlling for building age, the LEED-certified buildings exhibited higher satisfaction only with air quality and indicated no higher satisfaction in any other aspects (Abbaszadeh et al., 2006). Thus, the following research question is asked:

RQ2: Is occupants' satisfaction with the indoor environmental quality higher in a LEED-certified building than a non-LEED-certified building?

Objective Sustainable Indoor Environmental Quality and Satisfaction with Sustainable Indoor Environmental Quality

User satisfaction is not sufficient as a single measure in conducting the user-centered research of office spaces because many other factors must be considered in the relationship between the objective IEQ and subjective satisfaction of the IEQ (Vischer, 2008). Several of the aforementioned satisfactions with IEQ studies neglect the objective quality of the building performance as a factor of the user-centered relationship between the user and their environment. Numerous studies utilizing the CBE database are lacking the verification of the actual building characteristics and objective performance. Therefore, they have not considered the number of IEQ credits or the level of certification earned by the LEED-certified buildings. Since not all LEED-certified buildings have the same level of sustainable IEQ, without verifying their actual sustainable IEQ level, drawing conclusions about the IEQ in LEED-certified versus non-LEED-

certified buildings lacks validity. Further, through a review of literature, Heinzerling, Schiavon, Webster, and Arens (2013) identified eight studies that evaluated the building performance as a whole-building construct of both subjective (occupant satisfaction) and objective (objective quality verification) methods but concluded that further research needs to consider the weighting and the interrelationship between IEQ variables and revealed a lack of consensus among findings with regard to occupant satisfaction of IEQ and the use of objective measurements of the building performance. For example, no consensus exists on the objective measurement as the various studies use an array of tools, perform the assessments at various times through the day and year, measure different IEQ objective factors, inconsistently weight the IEQ factor data, and apply different data analyze functions to correlate to occupant satisfaction scores (Heinzerling et al., 2013).

Thus, to address the above gap in the literature, the present study considers both objective quality of the sustainable indoor environments and subjective occupant satisfaction with IEQ, while utilizing the IEQ features addressed by the LEED BD+C New Construction (version 4) IEQ credits for both the objective and subjective investigations. Specifically, in this study, the objective sustainable IEQ is a measurement of the quality of building performance in regards to the LEED Certification IEQ credits. Essentially, the objective sustainable IEQ assesses the capacity of the building to achieve the IEQ credits following post-occupancy. The satisfaction with the sustainable IEQ measures the occupant perceptions of the sustainable IEQ factors (thermal control and comfort, lighting control, indoor air quality, access to daylight, and views), along with satisfaction with other non-sustainability related IEQ factors (acoustics, aesthetics, privacy, comfort with workspace furnishings, control, cleanliness, and safety) as control

variables. The satisfaction measurement provides assessment from the user perspective of the IEQ.

Through a survey with customers of the international private banking industry, Lasser, Manolis, and Winsor (2000) found that service quality significantly predicts customer satisfaction (Lasser et al., 2000). Veitch et al. (2003) conducted a study to explore the relationship between objective measurement and occupant satisfaction of the IEQ of nine office buildings with a total of 779 workstations. The buildings were located in either Canada or the U.S. and occupied by either public or private organizations. The objective measurement analyzed the physical IEQ conditions of acoustic, illuminance, temperature and air movement, humidity, concentrations of carbons, size of the workstation, height of panel systems, and the openness of the work space. This was conducted by the researcher observing and situating a customized measurement cart in place of the occupant's chair. Simultaneous to the objective measurement, the occupants completed a 27-item satisfaction questionnaire consisting of IEQ factor satisfaction, overall IEQ satisfaction, job satisfaction, and ranked order of IEQ factors. Through this study, Veitch et al. found that satisfaction with indoor air quality was lower when concentrations of carbon dioxide and other contaminants were higher and that satisfaction with lighting and ventilation had the greatest influence on occupant overall IEQ satisfaction. Further, Veitch et al. revealed that if the occupant was within 15 feet (5 meters) of a window or daylight, their satisfaction with lighting improved, although their satisfaction with thermal conditions was reduced. In addition, in terms of privacy, occupant satisfaction was higher in open-plan environments when occupants had a larger workstation size. Veitch et al. concluded that the most influential factor to improvements in satisfaction with the overall IEQ would be access to daylight, within 15 feet, as it is significantly correlated with both lighting and ventilation

occupant satisfaction in the work area. All these findings of Veitch et al.'s study provide strong evidence for the relationship between objective IEQ and subjective assessment of the IEQ through occupant satisfaction measures. Based on this literature, the following research question is asked:

RQ3: Is there a relationship between the objective sustainable IEQ and occupants' satisfaction with the sustainable IEQ?

Sustainable Indoor Environment Quality and Health

According to the framework of the World Summit on Sustainable Development and user-centered theory, sustainable buildings should promote healthy, productive lives of their occupants (United Nations, 2002; Vischer, 2008). The individual or group has the capacity to change "their own health behavior and wellbeing" through ownership of personal behavior (Stokols, 1992, p. 8). Yet, the built environment significantly impacts human health especially when indoor environment quality is low (Blyussen, 2014; Kopec, 2009; Stokols, 1992).

The concept of health is composed of both physical and psychological factors (Bluyssen, 2014; Danko et al., 1990). The World Health Organization (1948) describes health as a state of being sound in body and mind extending beyond the absence of disease. Physical health is diverse as it incorporates all the biological dimensions of the body including measures of functionality, bodily pain, and general overall physical health (Roysamb, Tambs, Reichborn-Kiennerud, Neale, & Harris, 2003; Ware, Kosinski, & Keller, 1996). Psychological health is a state of mind extending into vitality, social function, emotional maturity, and mental illness (Ware et al., 1996; World Health Organization, 2013). Ghodrati et al. (2012) explained that poor psychological health may include depression, anxiety, low energy, and overall low spirits.

Two different approaches exist to measure the physical and psychological health of individuals: (1) self-rated subjective health, and (2) objective external assessments (Mülunpalo, Vuori, Oja, Pasanen, & Urponen, 1997). Mülunpalo et al. (1997) conducted an investigation in Finland of 1340 men and 1500 women to explore the validity of self-reported health as a valid health status indicator in middle-aged populations (35-63 years of age). The study used data from physician contacts, mortality and questionnaires (Mülunpalo et al., 1997). The statistical analysis and subsequent conclusions resulted in self-reported subjective health as an appropriate and valid measure of health in human science research (Mülunpalo et al., 1997). Therefore, this study utilized self-rated subjective health to measure occupant physical and psychological health.

Good IEQ may lead to better physical and psychological conditions (Ghodrati et al, 2012). For example, sustainable buildings with the design of high IEQ could increase occupant health through low-emission materials, access to natural light and views, thermal control resulting, and quality lighting for work activities (Ghodrati et al., 2012). Using a post-occupancy survey of 319 employees in two LEED-certified buildings and one conventional building on a University campus, Hedge, Miller, and Dorsey (2014) conducted an investigation on occupant health and the range of indoor environmental issues of sustainable buildings and reported that low quality electrical office lighting resulted in increased headaches and eyes strain with the frequency higher in conventional buildings. Further, back ache and neck/shoulder symptoms were associated with dissatisfaction with the comfort of workstations and chairs, which extended further into discomfort with wrist and hand pain associated with poor workstation comfort (Hedge et al., 2014).

Singh, Syal, Grady and Korkmaz (2010) investigated the effects of occupants who moved from a conventional building to a LEED-certified building and how the improved IEQ impacted

the perception of perceived health and productivity, employing two longitudinal case studies conducted through pre-move and post-move surveys. Overall, the researchers found substantial perceived improvements in health and wellbeing, specifically in a reduction in the number of self-reported absences. Singh et al. argued the building move resulted in concrete reductions in self-reported asthma and allergies symptoms, increases in work hours per year, and decreases in depression and stress levels, although the findings may lack generalizability, given the limitations of the study (e.g., length of time, sample size, and limited buildings).

Fisk and Rosenfeld (1997) postulated the relationship between the indoor environment and occupant health and estimated the links between indoor environments and business costs in four health domains: 1) infectious disease transmission, 2) allergies, 3) asthma, and 4) sick building syndrome. From the review, Fisk and Rosenfeld (1997) argue that substantial evidence exists to link rates of respiratory disease, allergies, asthma symptoms, and sick building symptoms to the indoor environment qualities. Specifically, the study demonstrates how poor indoor air quality affects respiratory health, spread of disease, and decreases in productivity (Fisk & Rosenfeld, 1997). Fisk and Rosenfeld (1997) postulate that each of these factors negatively impact financial business portfolios due to losses in productivity and performance from absenteeism or from distractions due to poor physical and psychological health.

Steemers and Manchanda (2010) explored the relationship between sustainable building design and occupant wellbeing through considerations of energy use, occupant satisfaction, self-reported health, and comfort in workplace environments of 12 office buildings in the UK and India. They found a positively linear relationship between occupant thermal and ventilation control and overall occupant satisfaction and between occupant satisfaction and self-reported health. Steemers and Manchanda also revealed that dissatisfaction related to unhappiness and

discomfort with IEQ factors was correlated to self-reported poor health (psychological or physical). Further, they argued that occupants highly satisfied with their workplace IEQ are productive, comfortable, and happy and have a high quality of health.

Newsham et al. (2012) investigated performance of LEED-certified and non-LEED-certified buildings through objective building data and occupant satisfaction surveys. The sample included 12 LEED-certified and 12 non-LEED-certified buildings in Canada and the northern U.S., resulting in a total of 2,545 survey participants. The objective building data included thermal conditions, air quality, acoustics, lighting, workspace size, ceiling height, window access, material finishes, energy performance, and monthly utility readings. A custom instrument, called the 'NICE' cart, was used for the measurement of physical work area conditions. The survey specifically focused on satisfaction with the LEED certification rating system IEQ factors of lighting, thermal comfort, privacy, and acoustics as based on the Cost-effective Open-Plan Environments (COPE) items. The COPE questionnaire contains satisfaction with environmental features (18 items), satisfaction with an occupant's environment (1 item), environmental impacts to productivity (1 item), and job satisfaction (2 items), all rated on a 7-point scale (Newsham et al., 2012). Newsham et al. concluded that LEED-certified buildings perform better in IEQ both objectively and in occupant satisfaction than did non-LEED-certified buildings. Occupants of LEED-certified buildings reported better night-time sleep quality, mood, and physical health symptoms as compared to occupants of non-LEED-certified buildings (Newsham et al., 2012). Based on the above literature, the following research questions are asked related to the relationship between sustainable IEQ and health:

RQ4: Does workplace buildings' objective sustainable IEQ positively predict the building occupants' (a) physical health and (b) psychological health?

RQ5: Does occupants' satisfaction with sustainable IEQ positively predict the occupants' a) physical health and b) psychological health?

Health and Workplace Wellbeing in Sustainable Indoor Environments

Wellbeing has a vast spectrum of definitions hinged on the discipline and application being discussed. For the purpose of this study, wellbeing is specifically considered in the workplace context and in relation to the indoor environment. Steelcase (2014) defines wellbeing as "sustaining a healthy physical and mental state over time, in a supportive material and social environment" (p. 15). This definition underscores the relationship between the material environment, which is the indoor environment in this study, and occupants' health and wellbeing.

Heerwagen (1998) postulates that wellbeing is a product of the interrelationship of quality of work life, psychological health, and social support and conducted a study on the hidden benefits of sustainable buildings using survey data from a sample of 262 people working at Miller SQA (the Herman Miller Greenhouse), a wholly owned subsidiary of Herman Miller, Inc, in Holland, Michigan, collected before and nine months after the move into a new sustainable facility. The survey instrument assessed a range of satisfaction with work and environmental experiences including ambient, aesthetic, social and functional features, as well as their behavioral, physical, social, and psychological experiences. In Heerwagen's study, occupants perceived they were healthier and had a better quality of work life in the new building. The natural features of the building such as access to daylight, connection with nature, and opportunities for environmental enjoyment were found to draw a strong connection to the building (Heerwagen, 1998). Further, access to daylight and nature provided by the new building were found to reduce health symptoms specifically in regards to headaches and fatigue (Heerwagen, 1998).

Further, from the Steemers and Manchanda (2010) study mentioned earlier, health, comfort, and satisfaction were interrelated parameters that contributed to workplace wellbeing. In the built environment, occupants expressed satisfaction with the interior environment as a means of conveying their comfort and happiness which extended to occupant wellbeing (Steemers & Manchanda, 2010).

Given the potential relationship between satisfaction with sustainable IEQ and health, as suggested in RQ5, and the contribution of IEQ and health to human wellbeing supported in the above literature, the following research question is asked in this study:

RQ6: Does occupants' satisfaction with sustainable IEQ positively predict the occupants' workplace wellbeing through its influence on the occupants' physical and psychological health?

Job Satisfaction: A Control Variable for Workplace Wellbeing

Job satisfaction is a cognitive assessment of one's employment through intrinsic and extrinsic evaluation of working conditions and work features such as work demands, leadership, cooperation, and realistic goals at work (Warr et al., 1979; Wilks & Neto, 2013). Wilks and Neto (2013) postulate that job satisfaction is less of an emotional and spontaneous response than workplace wellbeing when occupants complete job related questionnaires. Unlike earlier research that operationalizes workplace wellbeing as job satisfaction, Wright and Bonett (2007) argue that job satisfaction and workplace wellbeing are independent constructs, and Wilks and Neto (2013) determine that a positive correlation exists between job satisfaction and workplace wellbeing. Therefore, consistent with this line of enquiry, in order to fully understand personal occupant workplace perceptions of wellbeing, it is necessary to examine independently job satisfaction and as a predictor of workplace wellbeing.

Wilks and Neto (2013) studied the relationship between age, gender, workplace wellbeing, and job satisfaction by surveying a sample of 446 full-time working Caucasian adults. Wilks and Neto concluded that job satisfaction and workplace wellbeing assessed different aspects of occupant perception of their jobs and that job satisfaction positively correlated with workplace wellbeing especially for their younger participants (18-49 years old). For older participants (50 years and older) of Wilks and Neto's study, their workplace wellbeing was low while their job satisfaction was high, which indicates the distinction between the job satisfaction and workplace wellbeing constructs.

Wright and Bonett (2007) examined the relationship among workplace wellbeing, job satisfaction, and employee job performance in relation to job turnover with a sample of 112 managers employed in U.S. West Coast organizations. The study determined that when an employee measures low workplace wellbeing and low job satisfaction that the probability for turnover is high (Wright & Bonett, 2007). In this study, job satisfaction and workplace wellbeing was positively correlated with a large effect size (Wright & Bonett, 2007).

CHAPTER 3. METHOD

Research Design

This study applied an ex-post facto design through a combination of field observations of selected LEED-certified and non-LEED-certified buildings at Auburn University (AU) (Phase 1) and a survey with full-time employees that work at these buildings (Phase 2). Prior to initiating the first phase, six AU buildings were selected including three LEED-certified and three non-LEED-certified buildings. In Phase 1 of the study, to operationalize the sustainable indoor environmental quality (IEQ) construct, observations were conducted to objectively assess the selected six buildings' sustainable IEQ according to the LEED BD+C: New Construction version 4 certification standards. In Phase 2, a survey of the building occupants was conducted through a self-administered, web-based questionnaire to determine their satisfaction with IEQ, self-rated health, workplace wellbeing, and job satisfaction.

Building Selection

An important component of the study was the selection of six AU buildings that represented the LEED-certified and non-LEED-certified buildings. In 2014, AU had 25,912 students enrolled in undergraduate, graduate, and professional levels of education in more than 140 degrees ("About Auburn University", 2014) supported by 5,380 employees. The AU Campus Map 2013-14 (see Figure 3.1) establishes 188 buildings in the AU building inventory. The building types across the campus range from student residence halls, athletic buildings, educational buildings, libraries, laboratories, and activity centers to operational buildings including hot water plants, solar houses, and parking decks.

A review of the USGBC's online inventory of LEED-certified buildings revealed 15 AU buildings listed as either certified or as having certification in progress, as noted in Table 3.1

(USGBC, 2013b). Among the 15 buildings, three buildings were business type occupancies with offices, classrooms, laboratories, and conference spaces as presented in Table 3.2 and thus were selected for this study to represent LEED-certified building. The other LEED-certified buildings on campus did not provide occupant offices for AU faculty, administration, and staff.

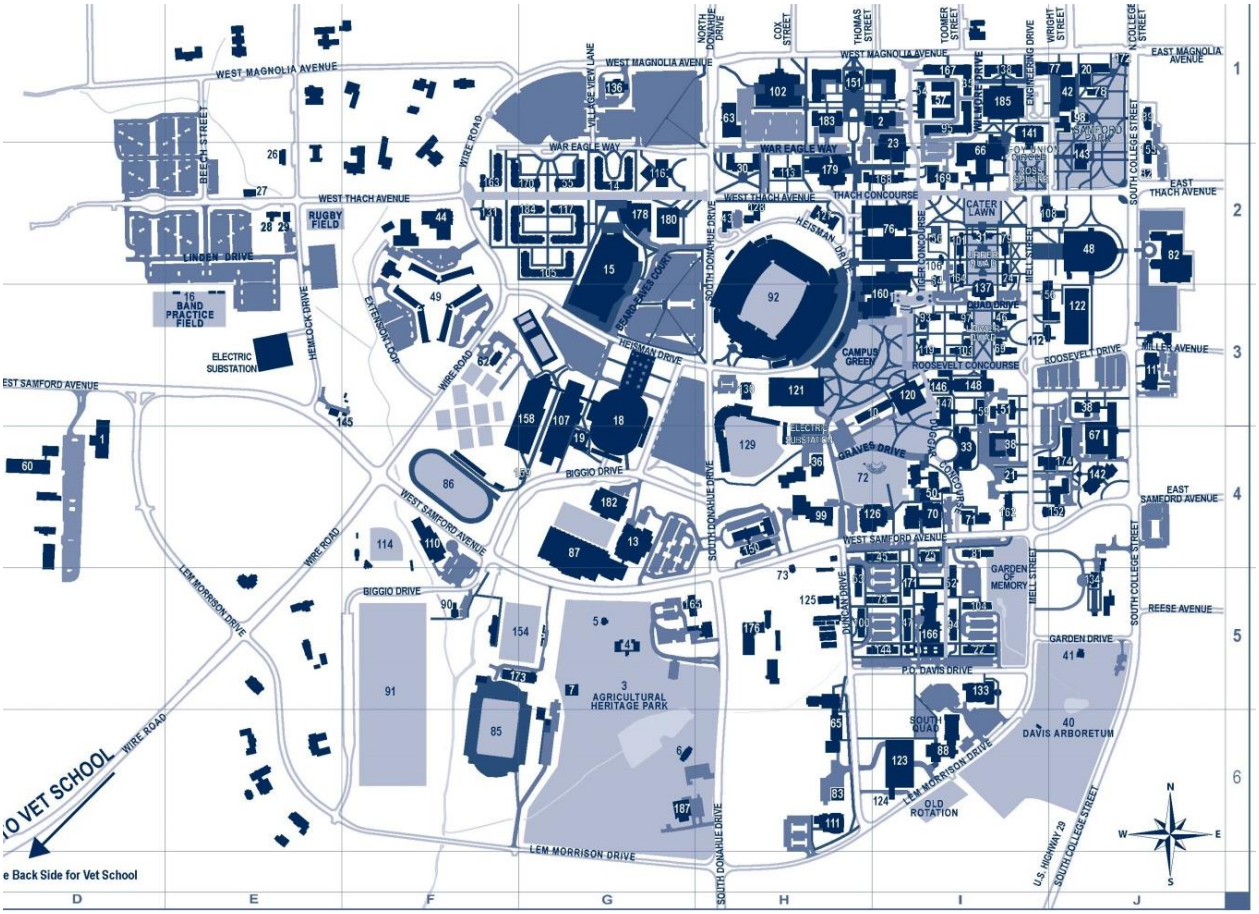


Figure 3.1. Auburn University Campus Map. (Auburn University, 2013)

Table 3.1

LEED Versions and Their Use in Auburn University Buildings

LEED Version	Date Launched	LEED-certified and Registered AU Buildings
LEED V1.0	August 1998	None
LEED V2.0	March 2000	Research Park- Building One [Core & Shell- gold]; GB Andrews Forestry Sciences Lab [Existing Buildings- in progress]
LEED V2.1	2002	Miller Gorrie Center- Building Science [New Construction- gold]
LEED V2.2	2005	Office of Information Technology [New Construction- silver]; Dairy Barn at AG Heritage Park [New Construction- in progress]; Track & Soccer Facility [New Construction- in progress]; Aquatic Resource Management Center [New Construction- silver]; Poultry & Animal Nutrition Center [New Construction- in progress]; Village Student Housing [New Construction- in progress]
LEED V3 (2009)	April 2009	Small Animal Teaching Hospital [New Construction- in progress]; Overton Classroom Addition [New Construction- in progress]; Residence Hall [New Construction- in progress]; Kinesiology [New Construction- in progress]; CASIC Building [New Construction- in progress]; Indoor Practice Facility [New Construction- in progress]
LEED V4	November 2013	None at this time

Note. Adapted from (1) "Foundations of LEED," by USGBC. Copyright 2014 by USGBC and (2) "USGBC Project Directory- Auburn University Search Results," by USGBC. Copyright 2013 by USGBC.

Table 3.2

AU LEED-Certified Buildings Selected for This Study

LEED-certified Auburn University Buildings	Year Built	Project Rating System	Certification Received	Version
Miller-Gorrie Center- Building Science	2006	New Construction	Gold – 39/69	Version 2.1
Office of Information Technology	2011	New Construction	Silver – 33/69	Version 2.2
Kinesiology	2013	New Construction	In progress	Version 2009

Note. Adapted from "USGBC Project Directory- Auburn University Search Results", by USGBC. Copyright 2013 by USGBC.

Of the selected three LEED-certified buildings, the Miller-Gorrie Center- Building Science (see Figure 3.2) achieved LEED Gold certification by satisfying 39 out of the 69 credit points in the New Construction version 2.1 rating system. For the IEQ credit area, the Miller Gorrie Center- Building Science met 13 out of the 15 points. Two credits that were not achieved were Credit 2.0 ventilation effectiveness and Credit 3.2 the construction indoor air quality management plan- after construction, each worth one point.

The Office of Information Technology (OIT) building (see Figure 3.3) received LEED Silver certification by achieving 33 out of the 69 credit points in the New Construction version 2.2 rating system. The OIT building obtained 10 out of the 15 IEQ points. Points were not achieved under Credit 2 increased ventilation, Credit 5 indoor chemical and pollutant source control, Credit 6.2 controllability of systems- thermal comfort, Credit 7.2 thermal comfort verification, and Credit 8.2 daylight and views- views for 90% of spaces.

For the Kinesiology building (see Figure 3.4), the details from the USGBC website were unavailable because LEED Certification was still in progress. The architectural firm who was contracted to design the buildings, Infinity Architecture in Montgomery, Alabama, was contacted to confirm the details of the projected LEED Certification. The Kinesiology Building is in pursuit of LEED Silver certification by submitting 53 out of the 100 points in the New Construction version 2009 (v3) rating system. The Kinesiology building is attempting to receive points for 13 out of the 15 possible IEQ credits. The building will not meet Credit 5, indoor chemical and pollutant source control, and Credit 8.2 daylight and views- views for 90% of spaces.

With the high number of buildings, the AU campus architect, Jim Carroll was consulted to construct the list of non-LEED-certified buildings appropriate to this study. Among the 173

campus buildings that were not LEED-certified, buildings that had similar interior programming as the selected LEED-certified buildings (i.e., interiors with offices, classrooms, laboratories, and conference spaces) were considered for the initial selection. Therefore, buildings used for student residences, athletics, food services, or operations were disqualified.

The next criterion used for selecting the non-LEED-certified building was the architectural characteristics. Ideally, this meant finding buildings with similar characteristics of gross square footage (size), age, company ownership, company culture, occupant activities, architectural style, and geographical location (Newsham et al., 2012) as the selected LEED-certified buildings. Given the available buildings on the AU campus, age could not be made equivalent between the LEED-certified and non-LEED-certified buildings, because all LEED-certified buildings were more recently built. However, the non-LEED-certified buildings have been renovated several times since their initial construction including upgrades to the HVAC mechanical systems, lighting systems, and materiality. Therefore, the older non-LEED-certified buildings were deemed a valid comparison regardless of the building's original year of construction. These characteristics impact the IEQ credits, and thus the researcher attempted to provide the best case comparison. In all characteristics, the aim in the comparison was to match each LEED-certified building with a similar non-LEED-certified building. This approach follows that of Newsham et al. (2012) which aimed to align buildings as closely as possible to ensure confidence that the measured outcome was due to sustainable factors rather than a multiplicity of other building differences. Ensuring similar architectural characteristics between LEED-certified and non-LEED-certified buildings was expected to enable the IEQ to be more equally compared based on sustainable systems and design features. Initially, five non-LEED-certified buildings, including Ramsay Hall (1925), Textile Engineering Building (1930), Thach Hall (1951),

Tichenor Hall (1940), and Miller Hall (1952) were considered comparable to the selected three LEED-certified buildings. This group of buildings were identified because each met the desired criteria of interior programming (offices, classrooms, and laboratories), an east-west geographical orientation, single corridor design to maximize access to daylight (goal of LEED-certified buildings), number of floors, square footage, large windows, tall ceilings, and all with relative building updates to lighting, HVAC, and uses as required by departments. Among the five buildings, access to occupants was granted for this study by administrators from only two buildings, Tichenor Hall and Miller Hall, which did not provide the desirable sample size for Phase 2, occupant survey. Therefore, a second round of building selection resulted in the inclusion of Spidle Hall (1962), as the building met the desired criteria and provided sufficient occupants to meet the desired sample size projections. The building was initially excluded from the selection because it was orientated north to south with all other buildings positioned east to west. However, given that OIT is an "L" shaped building with orientation both east to west and north to south Spidle Hall was deemed comparable. Consequently, the three non-LEED-certified buildings selected for the study were Tichenor Hall (see Figure 3.5), Miller Hall (see Figure 3.6), and Spidle Hall (see Figure 3.7). Table 3.3 (LEED-certified buildings) and Table 3.4 (non-LEED-certified buildings) present building characteristics for the six buildings selected for this study.

Table 3.3

Selected AU Building Characteristics Comparison: LEED-Certified Buildings

Auburn University Buildings	Year Built	Occupants' Academic Units	Use/ Spaces	Building Square Footage	Number of Floors	No. of full-time Occupants
Miller-Gorrie Center-Building Science	2006	Building Science Department	Classrooms, offices, labs, auditorium	42,500	3	24
Office of Information Technology	2011	Office of Information Technology	Offices, meeting rooms, labs, classrooms	62,500	3	115
Kinesiology	2013	School of Kinesiology	Classrooms, offices, labs, auditorium	58,000	3	32

Table 3.4

Selected AU Building Characteristics Comparison: Non-LEED-Certified Buildings

Auburn University Buildings	Year Built	Occupants' Academic Units	Use/ Spaces	Building Square Footage	Number of Floors	No. of full-time Occupants
Tichenor Hall	1940	Department of Communication and Journalism	Classrooms, offices, labs, auditorium	39,250	3	48
Miller Hall	1952	School of Nursing; School of Pharmacy	Classrooms, offices, labs	22,800	3	29
Spidle Hall	1962	College of Human Sciences	Classrooms, offices, labs, auditorium	50,000	3	70

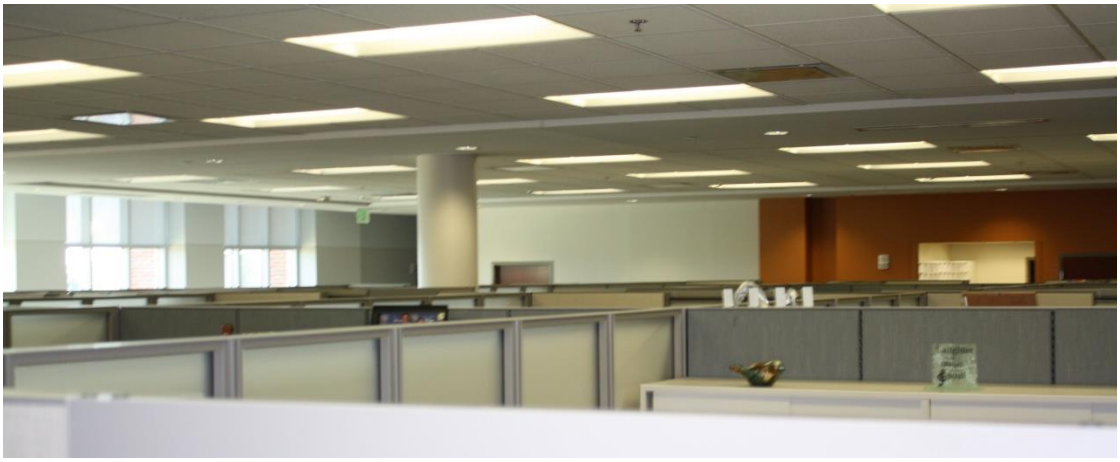
Building Exterior

Typical Office A.

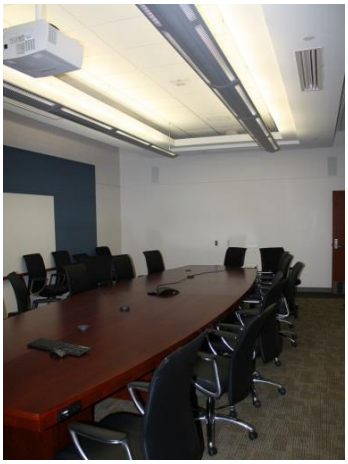
Typical Office B

Figure 3.2. Photographs of Miller-Gorrie Center- Building Science at Auburn University in Auburn, Alabama. © 2014 A. Ortlieb

Building Exterior



Typical Open Office Plan



Conference Room

Typical Carpet

Open Office (Corridor)

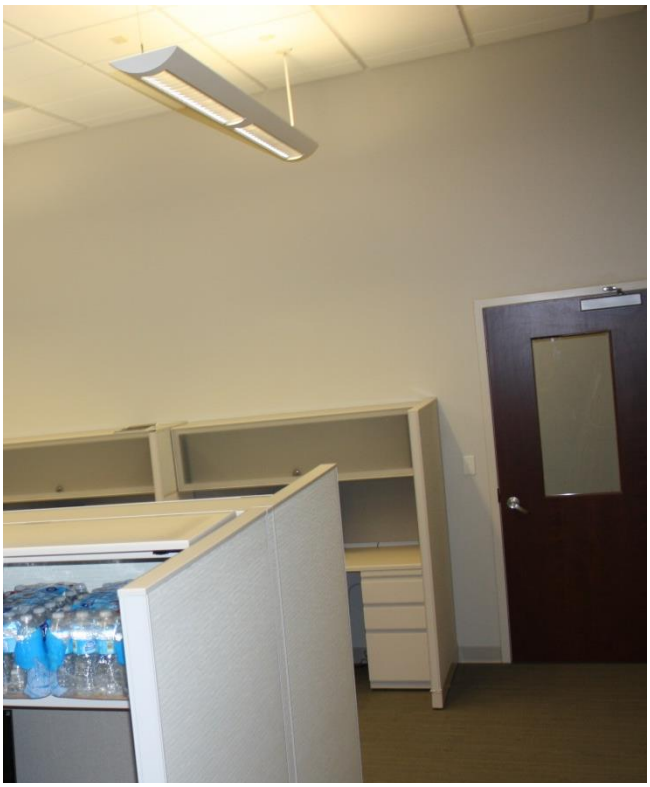
Figure 3.3. Photographs of Office of Information Technology at Auburn University in Auburn, Alabama. © 2014 A.Ortlieb

Building Exterior

Typical Lab

Auditorium

Typical Office



Typical Graduate Office

Figure 3.4. Photographs of the Kinesiology building at Auburn University in Auburn, Alabama. © 2014 A. Ortlieb

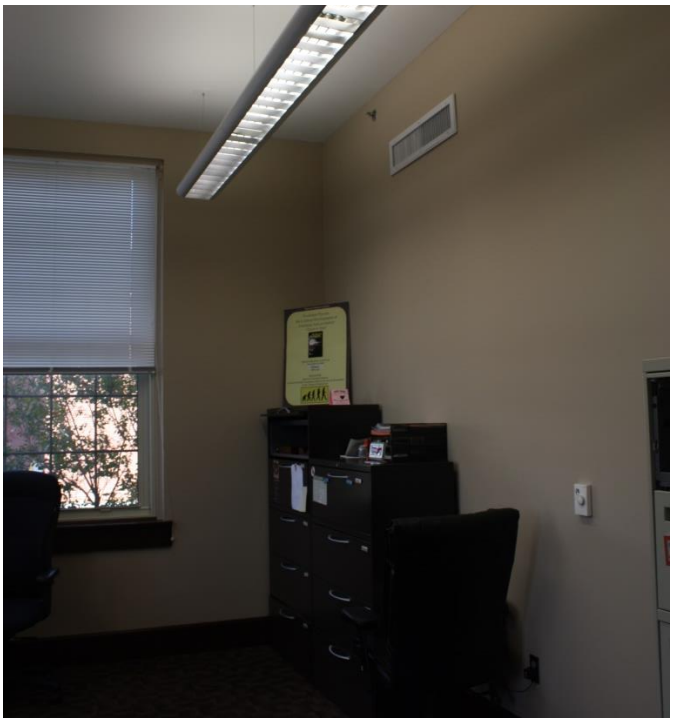
Building Exterior

Typical Classroom

Typical Office

Atypical Office

Conference Room

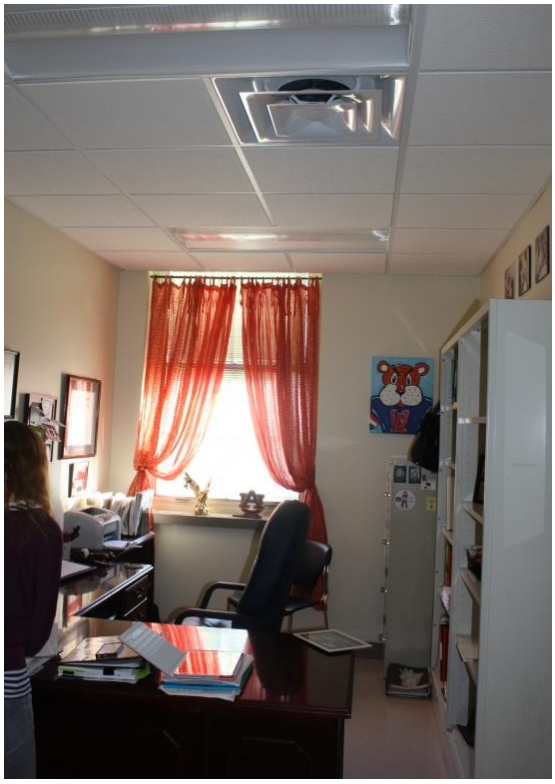


Typical Office

Figure 3.5. Photographs of Tichenor Hall at Auburn University in Auburn, Alabama. © 2014 A. Ortlieb

Building Exterior

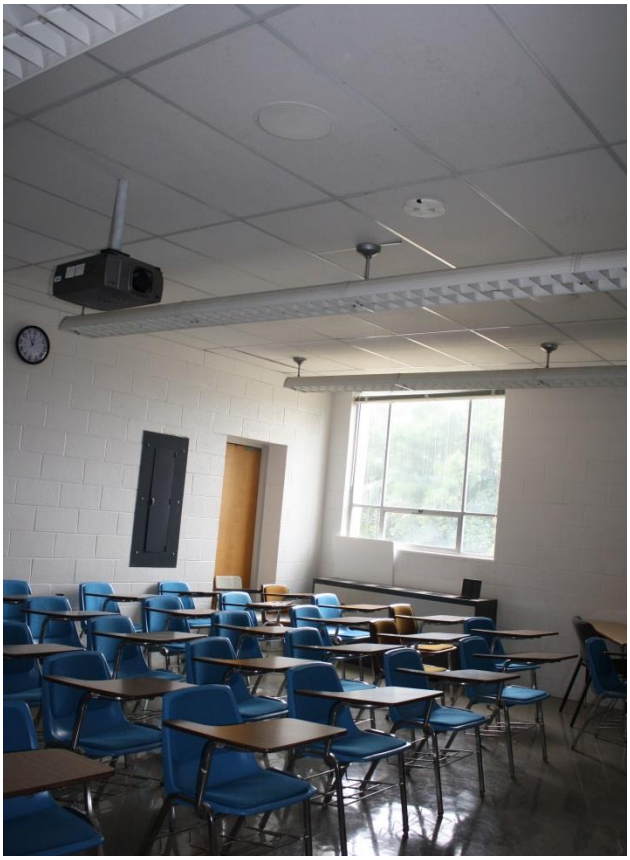
Conference Room



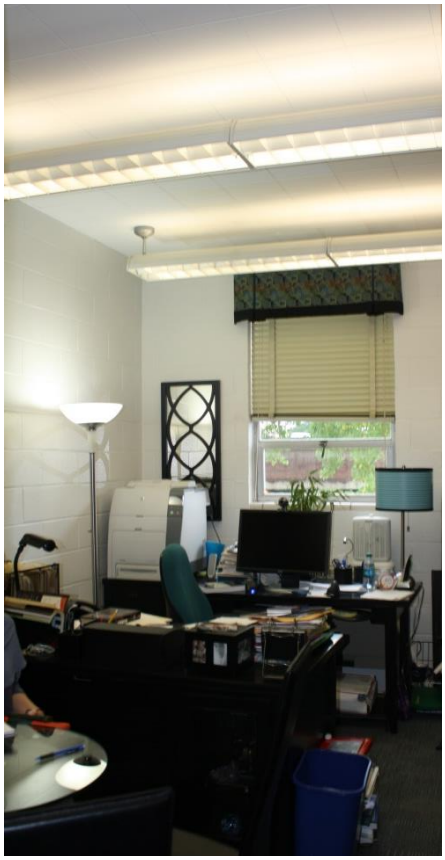
Typical Office

Figure 3.6. Photographs of Miller Hall at Auburn University in Auburn, Alabama. © 2014 A. Ortlieb

Building Exterior



Typical Classroom



Typical Office

Figure 3.7. Photographs of Spidle Hall at Auburn University in Auburn, Alabama. © 2014 A. Ortlieb

Phase 1: Objective Sustainable Indoor Environmental Quality Assessment

In Phase 1, field observations of the selected six buildings were conducted to assess their objective sustainable IEQ according to the LEED BD+C: New Construction version 4 rating system IEQ prerequisites and credits. The observation occurred through two procedures: (1) facility verification and (2) site verification. Facility verification is the researcher's meeting with the facility department about each of the six buildings to assess if the assigned six facility verification credits were met through building construction documents, LEED Certification credit documents, or any other pertinent sources. Two independent coders, both of whom have earned sustainable LEED credentials (LEED Green Associate and LEED Accredited Professional) conducted the site verification. The site verification occurred through entering and walking through each of the six buildings room by room and assessing the five designated credits (5, 6, 7, 8, and 9). The purpose of having two coders instead of one is to ensure observational reliability.

Instrument

The LEED BD+C: New Construction version 4 IEQ credit category requires sustainable buildings to meet two prerequisites and potentially earn up to 16 points in areas of indoor air quality, low-emitting materials, thermal comfort, access to daylight and views, acoustics performance, and interior lighting as described in Table 3.5. The project must meet the two IEQ prerequisites in order to qualify to achieve any of the IEQ credits. Therefore, if a project does not meet the prerequisites, the building will be considered non-LEED-certified. For the purpose of this study, only Prerequisite 1 and 13 of the 15 IEQ credits were used. All buildings met Prerequisite 2 (Environmental tobacco smoke control) because AU is a smoke-free campus policy, and thus no variability exists among the buildings. Further, two IEQ credits including

Credit 3 (Construction IAQ Management Plan) and Credit 4 (IAQ Assessment) were not applicable to this study because the parameters of the credit require specific time frames (during or following construction in the designated LEED certification timeframe) for the actions to be taken that were not within the scope of this study.

Two instruments were created to conduct the objective sustainable IEQ assessment including one for the site verification and the other for the facility verification. The site verification instrument was used to record the building name, date including time, reviewers' initials, and room numbers. Further, the site verification document contained the observation coding sheet which refers to a cross tabulation chart with the room numbers across the top and IEQ Credits 5, 6, 7, 8, and 9 in the left column with blanks throughout. This coding sheet format enabled reviewers to code their observation results room by room in each building either by recording such codes as '1' (yes), '2' (no), and '3' (maybe) for Credits 5, 6, 7, and 8 or by entering the raw on-site measurements scores open-endedly for acoustics (Credit 9) and daylight (Credit 7). Finally, a space below the chart was left blank for comments throughout the observation process (see Appendix A for the site verification document).

The second instrument was designed to be used during the facility verification. The facility verification document included two parts. First, the upper section mimicked the format of the LEED BD+C: New Construction version 4 Scorecard (see Figure 2.1) where IEQ credit numbers, titles, and points were listed with an assessment section to the left. The assessment section to the left includes a column for each of the following: 'x' (no), '?' (maybe), and the number of actual credits (yes). These columns document the IEQ credits the building either complies or does not comply with. The second section, below the adopted Scorecard, is the IEQ credit category descriptions which include the strategies, points, and compliance regulations.

Further, this section includes a "notes" area under each credit category to record the raw information provided by the facility verification method and to record the site verification analysis for each building. Following the documentation of the raw and analyzed information the IEQ Scorecard was used to record the final credit assessment marked 'x' (no), '?' (maybe), and the number of credits (yes) for the building's ability to meet the IEQ credit requirements. The facility verification document is presented in Appendix B.

Procedure

The site and facility verification procedures were conducted between September 2014 and May 2015, employing their corresponding coding instruments described earlier (see Appendices A and B). The two verification procedures merge expertise, building information data, and observation to verify and construct a comprehensive assessment of the LEED IEQ credits for each building in the study. Only the occupied spaces were included in the study, excluding hallways, washrooms, storage rooms, and utility rooms from the analyses, aligning with LEED certification criterion.

First, the facility verification was accomplished through multiple e-mails, several face to face meetings, and three full days reviewing the building construction and material specification documents. The researcher assessed the identified credits (i.e., Prerequisite 1, Credits 1, 2, 5, 6, 7, 8, and 9) that required facilities management data and knowledge of the operations and maintenance of the buildings. The credits necessitating data verification were completed for each building. For the LEED-certified buildings, the validated LEED Scorecard provided the majority of data to verify the building completion of LEED IEQ credits and prerequisites. The facility verification data for LEED-certified buildings that were not addressed by the LEED Scorecard

Table 3.5

Observation Methods for Objective IEQ (Adapted from USGBC, LEED BD+C: New Construction Version 4 Credits[a])

Credit	Description	Sustainable IEQ Factor	Method Required	Method Used: Site Verification	Method Used: Facility Verification
Prereq. 1	Minimum indoor air quality performance	Indoor air quality	Verification with facility management that the buildings' mechanical systems comply with ventilation and monitoring standards of ASHRAE 62.1-2010.	NA	AU Facilities (Eric Moore) confirmed all 6 buildings are mechanically ventilated, and 5 met the prerequisite requirements (Miller Hall did not meet).
Prereq. 2	Environmental tobacco smoke control	Indoor air quality	NA (All AU campus buildings meet the prerequisite as the campus was designated a smoke-free campus.)	NA	NA
Credit 1	Enhanced indoor air quality strategies	Indoor air quality	Verification with facility management that mechanically ventilated spaces comply with interior cross-contaminated prevention, filtration equipped with Minimum Efficiency Reporting Value (MERV) filters of 13 or better and CO_2 monitored. Entryway systems will be observed at each site visit.	During site visit, the researchers confirmed all buildings met the entryway requirement.	AU Facilities (Eric Moore) confirmed the campus policy requires all buildings to have MERV filters of value 13 meeting the filtration standard. Further, facilities identified which buildings had carbon dioxide monitoring systems. AU Facilities could not confirm if the buildings had interior cross-contamination prevention systems.

Credit	Description	Sustainable IEQ Factor	Method Required	Method Used: Site Verification	Method Used: Facility Verification
Credit 2	Low emitting materials	Indoor air quality	Verification with facility management that all materials comply with VOC limits standards.	NA	For the LEED-certified buildings, the scorecard provided by USGBC regarding the original points awarded for the buildings was reviewed. Points were adopted from the previously awarded IEQ low emitting material credits. For the non-LEED-certified buildings, AU Facilities (Anna Ruth Gatlin) was consulted to determine if this credit was met.
Credit 3	Construction indoor air quality management plan	Indoor air quality	NA (This credit requires management during building construction, which is not applicable because this study was conducted post-occupancy.)	NA	NA
Credit 4	Indoor air quality assessment	Indoor air quality	NA (This credit requires flush-out just prior to building occupancy which is not applicable because this study was conducted post-occupancy.)	NA	NA

Credit	Description	Sustainable IEQ Factor	Method Required	Method Used: Site Verification	Method Used: Facility Verification
Credit 5	Thermal comfort	Thermal comfort	Site-verify individual thermal controls for at least 50% of individual occupant spaces. Verification with facility management that HVAC systems meet ASHRAE standard 55-2010.	The researchers site-verified thermal control of the spaces.	AU Facilities (Eric Moore) was unable to confirm if the AU buildings met ASHRAE Standard 55-2010.
Credit 6	Interior lighting	Lighting quality and control	Site-verify individual lighting controls with at least three lighting levels or scenes for 90% of building occupants. Review building documents for light sources that 75% have a rated life of at least 24,000 hrs or more, all fixtures have a CRI of 80 or higher, less than 25% have direct-only fixtures, and 90% meet threshold levels for average surface reflectance.	The researchers site-verified lighting controls, photographed the walls, floor and ceiling to determine CRI, and recorded detailed information such as luminaire type and lamp type.	The researcher accessed building specification documents for detailed information on lamp types, lighting fixtures and lighting placement. The lamp specifications were confirmed on the manufacturers' websites.
Credit 7	Daylight	Daylight and views	Site-verify spaces achieve illuminance levels between 300 lux and 3,000 lux (28 footcandles and 279 footcandles)	The researchers' measured each space for illuminance levels with three separate measurement tools.	For LEED-certified buildings, the researcher accessed the building's LEED scorecard to adopt the points received for the daylight credit during the certification process.

Credit	Description	Sustainable IEQ Factor	Method Required	Method Used: Site Verification	Method Used: Facility Verification
Credit 8	Quality views	Daylight and views	Site-verify 75% of all regularly occupied spaces achieve a direct, unobscured line of sight to the outdoors.	The researchers observed the view from each window to confirm a direct unobscured line of sight to the outdoors.	For LEED-certified buildings, the researcher accessed the building's LEED scorecard to adopt the points received for the quality views credit during the certification process.
Credit 9	Acoustic performance	Acoustics	Verification with facility management that building design comply with HVAC background noise levels per 2011 ASHRAE Handbook, sound isolation class ratings, reverberation time requirements, and masking systems.	The researchers measured (using three different tools) the sound level (dBA) in each space.	AU Facilities (Eric Moore) was unable to confirm if the AU buildings met the acoustic performance requirements.

Note. NA = not applicable

[a] Adapted from "*LEED for BD+C: New Construction IEQ Credits",* by USGBC. Copyright 2013 by USGBC.

and all facility verification data for the non-LEED-certified buildings were collected through consultations of the building construction drawing set and the building systems information, and the expertise provided by the AU Campus Architect, Jim Carroll, and AU Facility Department Mechanical Engineer, Ken Martin.

Site verification was performed for the credits requiring site verification (i.e., Credits 5, 6, 7, 8, and 9), through on-site building coding by the researcher and another coder using methods detailed in Table 3.5. Prior to accessing the building, the researcher identified and contacted each of the buildings' on-site coordinators to confirm availability and to set-up a time to assess the building. In several cases, the two coders who conducted the site verification visited each building several times as some rooms were occupied and unavailable during the first visit. The building site visit days and times are noted in Table 3.6.

For each site verification, the two coders went room by room together often escorted by the building coordinator. Each coder independently observed the indoor environments of the six buildings using the IEQ observation coding sheet to code the five credits. For each room, the coders observed the space for evidence of individual temperature control (Credit 5), individual lighting control enabling occupants to adjust the lighting with at least three lighting levels or scenes (on, off, midlevel) (Credit 6), window glare control device (credit 7), and window views to affirm a direct line of sight to the outdoors (Credit 8). The two coders used '1' (yes), '2' (no), and '3' (maybe), depending on whether they determined that the room met the credit standards or not. Further, the coders recorded the on-site measurements for acoustics (dBA) (Credit 9) and daylight (in lux) (Credit 7). Acoustics were measured with three devices using three separate apps: Iphone 4 with app "dB VolumeMeter," Ipad with app "SPLnFFT," and Ipad with app "SoundMeter+." The acoustical readings recorded the minimum, maximum, and average dB(A)

on the observation form. The use of three devices enabled the researcher to confirm reliability of the devices and measurements.

Table 3.6

AU Building Site Visit Details

Auburn University Buildings	Visit 1	Visit 2	Visit 3
Miller-Gorrie Center-Building Science	September 22, 2014 2:00 – 3:40pm	October 3, 2014 9:00 am – 10:15pm	not required
Office of Information Technology	September 22, 2014 3:45pm – 6:00pm	September 29, 2014 3:30pm – 4:30pm	not required
Kinesiology	September 26, 2014 7:00am – 9:50am	October 3, 2014 7:00am – 8:40am	not required
Tichenor Hall	October 9, 2014 12:50pm – 5:10pm	October 10, 2014 3:20pm – 3:45pm	not required
Miller Hall	October 6, 2014 1:00pm – 4:00pm	not required	not required
Spidle Hall	September 19, 2014 7:00am – 1:10pm	September 26, 2014 12:00– 1:00pm	October 3, 2014 10:15am – 1:00pm

Daylight was measured by recording the illuminance of daylight in the rooms. This required the coders to turn off all artificial light sources and open all window glare control devices to measure the illuminance in lux at appropriate work plane height (approximately 30") on the required square grid as described by Credit 7. Again, the measurement was obtained by three separate devices: light meter Extech HD 400, Iphone 4 with app "LuxMeter," and Ipad with app "LuxMeter." Multiple measurements were obtained for each room. The individual coders documented each of the readings and analyzed if the readings met the illuminance levels

between 300 and 3000 lux to determine if the room met the requirement. Again, the two coders used '1' (yes), '2' (no), and '3' (maybe), depending on whether they determined that the room met the illuminance standard or not.

Phase 2: Occupant Survey

Sampling and Data Collection Procedures

In Phase 2, a survey was conducted through a self-administered web-based questionnaire with a target population of the AU employees who worked in the selected six buildings. A list of AU employees was obtained through the 2014 salary data to identify the employees in the six buildings. This AU employee list provided the name, department, and title for all AU employees whose salaries were budged in for fiscal year 2014. Employees in the selected buildings were identified through the following procedure: 1) visit each of the six buildings to photograph the directory boards, 2) transcribe the departments and employee names for each building, 3) cross reference the building directory transcription to department websites and the AU employee list, and 4) submit the semi-final building list to the appointed building coordinator for review, revision, and finalization. A total of 318 employees were identified in the finalized list, of which 171 were LEED-certified building employees, whereas 147 were non-LEED-certified building employees (see Tables 3.3 and 3.4 for the number of employees from each of the six buildings). As the employee list does not provide the AU e-mail of the employees, the finalized list was cross referenced with the online public access individual name directory on AU website to identify the email addresses of the employees.

After receiving permission from the Institutional Review Board (IRB) at Auburn University, the employees in the finalized list were contacted through an introduction letter delivered to each employee's workplace mailbox by the building coordinator and/or the

researcher depending on the involvement of the building coordinator. The pre-notice letter (see Appendix E) included the purpose of the study, the nature of the participant's involvement, timeline of the survey, and a small monetary token of appreciation of one dollar. A week after the delivery of the pre-notice letter, an e-mail was sent to the employees' AU account with the web-based questionnaire instructions and the URL to access the survey website. The participant was encouraged to complete the web-based questionnaire in the two weeks, September 25 – October 14, 2014, following the initial e-mail. A reminder e-mail was sent one week after the initial e-mail and again a week later to individuals who had not yet participated in the survey. At the end of the third week, the web-based questionnaire was closed. Qualtrics was used to create and host the survey. Each participant was assigned an individual web link through the Qualtrics online system, which was provided to the participants in the initial invitation e-mail and each subsequent e-mail reminder.

Participants who accessed the questionnaire website through the URL provided in the invitation or reminder email first saw the IRB-approved information letter (see Appendix C), which explained the identity of the researcher, the importance of the study, and the confidentiality of the study and sought participant consent by clicking on the 'Continue to Survey' button, which led to the initial screen of the online questionnaire.

Instrument

The survey was conducted using a self-administered web-based questionnaire. The online questionnaire was created using the Qualtrics online research suite accessed through the AU licensing certificate. The questionnaire included sections on satisfaction with IEQ, health, workplace wellbeing, job satisfaction, personal workspace demographics, employment

demographics, and personal demographics. The specific section measures used in the questionnaire are explained in detail below.

Satisfaction with IEQ. The satisfaction with IEQ was measured by the items for satisfaction with sustainable IEQ factors (16-items) and those for satisfaction with non-sustainability related IEQ factors (22 items), and one measuring overall satisfaction (unused in this study), for a total of 39 items. The items were framed for the occupant to assess the conditions of their personal workspace on the AU campus by using the participant directions and item wordings presented in Table 3.7 (sustainable IEQ) and Table 3.8 (non-sustainability related IEQ). Veitch, Charles, Farley, and Newsham's (2007) COPE: Environmental Satisfaction in Open-Plan Environments scale provided the foundation of the 16-item satisfaction with sustainable IEQ factors of thermal comfort and control, lighting control, indoor air quality, acoustics, and access to daylight and views. Satisfaction with non-sustainability related IEQ factors (aesthetics, privacy, control, cleanliness, safety, and comfort with workspace furnishings of their work area) was measured by 22 items including 10 items adopted from the COPE study questionnaire (Veitch et al., 2007), 4 additional items developed by the researcher, an item adopted from Carlopio (1996), 2 items adapted from Brennan et al. (2002), and 5 items adapted from Lee and Brand (2005), as denoted in Table 3.8. Brennan et al. (2002) items initially read "I feel personally safe coming to and going from work" and "I have enough storage space at my workspace" and were adapted to unify the instructions to "For your office workspace, please indicate your level of satisfaction with each of the following:" with a slight change in pronoun placement in the items "your safety coming to and going from work" and "the storage space at your office workspace." The five items from Lee and Brand (2005) were adapted to include the IEQ satisfaction instruction "For your office workspace, please indicate your level of

satisfaction with each of the following:" and included pronoun modification. For example, the initial item was "I like the style/quality of my furniture" rated using a scale ranging from "yes, very much so" (7) to "no, not at all" (1), and was revised to read "the style of your office furniture." A second example demonstrates a similar pronoun adjustment "I determine the organization/appearance of my work area" and was revised to "your opportunity to personalization of your office." All items for satisfaction with IEQ factors were rated on a 7-point Likert-type scale where 1 is "very dissatisfied," 2 "dissatisfied," 3 "somewhat dissatisfied," 4 "neutral," 5 "somewhat satisfied," 6 "satisfied," and 7 "very satisfied."

Table 3.7

Measures of Satisfaction with Sustainable IEQ

Dimension	**Items**	**Source**
The following set of statements relates to your satisfaction in your Auburn University assigned office workspace over the last 4 weeks. Your workspace is the place (desk, cubicle, office, etc.) where you do the majority of your office work on the AU campus. For your office workspace, please indicate your level of satisfaction with each of the following:		
Lighting	1. the amount of lighting on the desktop (desk surface)	Veitch et al. (2007)
	2. the amount of light for computer work	Veitch et al. (2007)
	3. amount of reflected light or glare on the computer screen	Veitch et al. (2007)
	4. the quality of lighting	Veitch et al. (2007)
Lighting Control	5. the ability to control the lights by turning them off and on	Developed by researcher
	6. the flexibility to adjust the levels of lighting for your activities	Developed by researcher

Dimension	Items	Source
Lighting Control	7. your ability to adjust the amount of light from the exterior windows (i.e. blinds, curtains)	Developed by researcher
Daylight & Views	8. the amount of natural light	Developed by researcher
	9. your access to a view of outside from where you sit	Developed by researcher
	10. the view outside your exterior window	Veitch et al., (2007)
Indoor Air Quality	11. the air quality	Veitch et al., (2007)
	12. the smells	Developed by researcher
	13. the humidity	Developed by researcher
Thermal comfort	14. the air movement	Veitch et al., (2007)
	15. the temperature	Veitch et al., (2007)
Thermal Control	16. your ability to control the temperature	Developed by researcher
Acoustics	17. the amount of noise from other people's conversations while you are at your office workspace	Veitch et al., (2007)
	18. the amount of background noise (i.e. not speech) you hear at your office workspace	Veitch et al., (2007)
	19. your ability to concentrate on your work while in your office workspace	Lee & Brand, (2005)
Acoustic Control	20. your ability to control the noise in your office workspace	Developed by researcher

Table 3.8

Measures of Satisfaction with Non-Sustainability Related IEQ

Dimension	Items	Source
The following set of statements relates to your satisfaction in your Auburn University assigned office workspace over the last 4 weeks. Your workspace is the place (desk, cubicle, office, etc.) where you do the majority of your office work on the AU campus. Please indicate your level of satisfaction with each of the following:		
Privacy	21. the frequency of distractions from other people while in your office workspace	Veitch et al., (2007)
	22. the degree of enclosure of your office workspace by walls, screens or furniture	Veitch et al., (2007)
	23. the level of visual privacy within your office workspace	Veitch et al., (2007)
	24. the distance between you and other people you work with	Veitch et al., (2007)
	25. the level of privacy for conversations in your office workspace	Veitch et al., (2007)
Control	26. your opportunity to personalization of your office	Lee & Brand, (2005)
	27. your ability to organize and change the appearance of your office	Lee & Brand, (2005)
	28. your office to adapt for accommodation of your various activities (i.e. impromptu meetings)	Lee & Brand, (2005)
Comfort-Workstation	29. the size of your office workspace to accommodate your work, materials, and visitors	Veitch et al., (2007)
	30. your options to adjust your office workspace to increase your physical comfort	Veitch et al., (2007)
	31. the storage space at your office workspace	Brennan et al., (2002)
Aesthetic	32. the aesthetic appearance	Veitch et al., (2007)
	33. the style of your office furniture	Lee & Brand, (2005)
	34. the color in your office	Developed by researcher

Dimension	Items	Source
Comfort-Chair	35. the comfort of your office chair	Developed by researcher
	36. the adjustability of your office chair	Developed by researcher
Cleanliness	37. the cleanliness of the facilities at work	Carlopio, (1996)
Safety	38. your safety coming to and going from work	Brennan et al., (2002)

Health. Twelve items from the SF-12 Short-Form Health Survey were adapted to assess occupants' self-reported overall, physical, and psychological health (Ware et al., 1996). Ware et al. (1996) based the SF-12 on the Medical Outcomes Study 36-Item Short-From Health Survey (SF-36) to adapt the physical and mental component summaries (Ware et al., 1996). The goal of the SF-12 is to provide a form that could maintain the SF-36 reliability and comparability, yet be taken in less than two minutes (Ware et al., 1996).

The physical health component included five items addressing physical functioning, role-physical, bodily pain, and general health. The psychological health component includes five items measuring the occupant's vitality, social functioning, role-emotional, and mental health. Lastly, two items measured the overall health of the occupant. The original items used a mixture of 2- to 6-point scale items and the item wordings tended to be long and sometimes unclear. Therefore, to enhance the clarity and consistency of the scale items, the original item wordings was modified in a more straightforward way, and the scale response formats were adjusted to have all items rated on a 5-point scale. For example, two items from each of physical and psychological health were originally rated on a 2-point scale of "yes" or "no." The four items' scales were changed in this study to a 5-point scale where 1 is "Not limited at all", 2 "Limited a little bit", 3 "Moderately limited", 4 "Limited quite a bit", and 5 "Extremely limited." The modified scale items and response formats are presented in Table 3.9.

Table 3.9

Measurement for Health: Adapted from Ware et al.'s (1996) SF-12 Survey

Dimension	Items[a]	Response format
Overall health	The following set of statements relates to your health. 1. In general, would you say your health is:	5-point response format: excellent, very good, good, fair, poor
	Based on the past four (4) weeks, how often have you experienced the following: 2. physical health or emotional problems interfered with your work activities (R)	5-point response format: "all of the time"; "most of the time"; "some of the time"; "a little of the time"; "none of the time"
Physical Health	Given your current health, please indicate your level of limitation with each of the following: 3. performing moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf 4. climbing several flights of stairs	5-point response format: 1 = "Not limited at all", 2 = "Limited a little bit", 3 = "Moderately limited", 4 = "Limited quite a bit", 5 = "Extremely limited"
	The following set of statements relates to your health. Based on the past four (4) weeks, please indicate your agreement with the following: 5. I have accomplished less than I would like due to my physical health. (R) 6. I was limited in the kind of work or other activities due to my physical health. (R)	5-point response format (1 = Strongly Disagree, 5 = Strongly Agree)
	7. During the past 4 weeks, how much did pain interfere with your normal work (including work in and out of the office)? (R)	5-point response format: "not at all"; "a little bit"; "moderately"; "quite a bit"; "extremely"
Psychological Health	The following set of statements relates to your health. Based on the past four (4) weeks, how often have you experienced the following: 8. feeling calm and peaceful 9. having a lot of energy 10. feeling downhearted and blue (R)	5-point response format: 5 = "all of the time"; 4 = "most of the time"; 3 = "some of the time"; 2 = "a little of the time"; 1 = "none of the time"

Dimension	Items[a]	Response format
	The following set of statements relates to your health. Based on the past four (4) weeks, please indicate your agreement with the following: 11. I have accomplished less than I would like due to my emotional problems. (R) 12. I was limited in the kind of work or other activities due to my emotional problems. (R)	5-point response format (1 – Strongly Disagree, 5 = Strongly Agree)

[a] (R) at the end of the item wording indicates a reverse-coded item

Workplace Wellbeing. The measurement of workplace wellbeing was adapted from Roysamb et al.'s (2003) subjective wellbeing index with modifications to reflect the workplace context. The original workplace wellbeing index measures overall work life and general outlook tendencies through four items with a mixture of 6-, 5-, and 4-point scales (Roysamb et al., 2003). The item wordings and response scales for workplace wellbeing were again modified for this study in order to enhance the clarity of their meanings and consistency of the response formats (see Table 3.10). For example, the original question was phrased "When you think about your life at present, would you say you are mostly satisfied with your life, or mostly dissatisfied" and was adapted to "How satisfied are you with your work life at present?" (Roysamb et al., 2003). Further, the two items "Are you usually happy or dejected" and "Are you usually tired and worn out or strong and fit" were revised the instruction to read "How do you usually feel at work?" rated on a 5-point semantic differential scale, where the first item used 1 for "dejected" and 5 for "happy," and for the second item, 1 for "tired and worn out" and 5 for "very strong and fit" (Roysamb et al.,2003).

Table 3.10

Workplace Wellbeing Measurement: Adapted from Roysamb et al. (2003)

Items[a]	Response Format
The following set of statements relates to your level of satisfaction with work. 1. How satisfied are you with your work life at present?	5 point response format: 1 = "Very dissatisfied"; 2 = "Dissatisfied"; 3 = "Neutral"; 4 = "Satisfied"; 5 = "Very satisfied"
How do you usually feel at work? 2. dejected: happy	5 point response categories, ranging from 1= dejected to 5 =happy
3. tired and worn out: strong and fit	5 point response format: 1 = tired and worn out to 5 = very strong and fit
4. 'Over the last 4 weeks, how often have you suffered from nervousness at work (felt irritable, anxious, tense or restless)? (R)	5 point response format: 5 = "All of the time"; 4 = "Most of the time"; 3 = "Some of the time"; 2 = "A little of the time"; 1 = "None of the time"

[a] (R) at the end of the item wording indicates a reverse-coded item

Job Satisfaction. Occupants' job satisfaction was measured as a control variable so that its effect could be controlled for when testing relationships with workplace wellbeing as the dependent variable. The job satisfaction measure (five items), adapted from Danielsson and Bodin (2008), addressed the occupant's attitude toward work and the social work environment. The original items were rated by a mixture of 4- and 5-point scales. To enhance the clarity the questions, the instructions and question wording were modified. Three items started with "Please indicate how often you experience the following" followed by the three items "Having too much to do at work," "My relationship with your closest supervisor working out positively," and "The goals at your work challenging and realistic at the same time," whereas the remaining two items were asked in question formats ("How do you perceive the cooperation with your own work group?" and "How satisfied or dissatisfied are you with your work?"). To improve the consistency of the response format, all five items were rated on 5-point scales (see Table 3.11).

Table 3.11

Job Satisfaction Measurement: Adopted from Danielsson and Bodin, (2008)

Items [a]	**Response Format**
The following set of statements relates to your level of satisfaction with work. Please indicate how often you experience the following:	
1. Having too much to do at work (R) 2. My relationship with your closest supervisor working out positively 3. The goals at your work challenging and realistic at the same time	5 point response format: 1 = "Very rarely"; 2 = "Rarely"; 3 = "Sometimes"; 4 = "Fairly often"; 5 = "Very often"
4. How do you perceive the cooperation with your own work group?	5 point response format: 1 = "Very bad"; 2 = "Fairly bad"; 3 = "Neutral"; 4 = "Fairly good"; 5 = "Very good"
5. How satisfied or dissatisfied are you with your work?	5 point response format: 1 = "Very dissatisfied"; 2 = "Dissatisfied"; 3 = "Neutral"; 4 = "Satisfied"; 5 = "Very satisfied"

[a] (R) at the end of the item wording indicates a reverse-coded item

Personal Information. The personal information items were divided into three separate subsections for clarity of measurement, including 1) employment, 2) personal workspace, and 3) demographic information, adopting the measures used by Bluyssen (2014) and Zagreus et al. (2004). Employment information included four items measuring the type of position, work hours over a week, and time spent in the building and in the assigned workspace, presented in Table 3.12 (Bluyssen, 2014; Zagreus et al., 2004). Ten items addressing the occupant's personal workspace demographics provided data on the occupant's building, floor, years in the space, office type, number of exterior windows, operability of the windows, control of lights, use of secondary lighting, and access to a working thermostat (see Table 3.13; Bluyssen, 2014; Zagreus

et al., 2004). Lastly, the demographic information was assessed using five items addressing age, gender, income, education, and ethnicity, as shown in Table 3.14 (Bluyssen, 2014; Zagreus et al., 2004).

Table 3.12

Employment Information Items: Adopted from Bluyssen (2014)

Variable	**Items**
This next question asks about your Auburn University work description.	
Type of Employment Position	1. How would you describe the type of work you do? ☐ Administrative support ☐ Technical Staff ☐ Instructor ☐ Professor ☐ Research Professor ☐ Adjunct Professor ☐ Managerial/supervisory ☐ Other: _____
Work hours over a week	2. How many hours do you work in a normal work week? Please choose only one of the following: Less than 1hr, 1-5 hours, 6-10 hours, 11-15 hours, 16-20 hours, 21-25 hours, 26-30 hours, 31-35 hours, 36-40 hours, 41-45 hours, 46-50 hours, 51-55 hours, More than 55 hours
Work hours spent in the building	3. On average, how many hours per week do you work in this building? Please choose only one of the following: Less than 1hr, 1-5 hours, 6-10 hours, 11-15 hours, 16-20 hours, 21-25 hours, 26-30 hours, 31-35 hours, 36-40 hours, 41-45 hours, 46-50 hours, 51-55 hours, More than 55 hours
Time spent in assigned workspace	4. On average, how many hours per week do you spend in your workspace? Your Auburn University workspace is the place (desk, cubicle, office, etc.) where you do the majority of your work on campus. Please choose only one of the following: Less than 1hr, 1-5 hours, 6-10 hours, 11-15 hours, 16-20 hours, 21-25 hours, 26-30 hours, 31-35 hours, 36-40 hours, 41-45 hours, 46-50 hours, 51-55 hours, More than 55 hours

Table 3.13

Measures of Personal Workspace Information

Dimension	Items	Sources
This next set of questions asks about your personal Auburn University workspace location.		
Building	1. In which building is your AU primary office workspace? ☐ Information Technology Building ☐ Kinesiology Building ☐ Tichenor Hall ☐ M. Miller Gorrie Center ☐ Thach Hall ☐ Miller Hall ☐ Spidle Hall ☐ Other: _____	Developed by researcher
Floor	2. Which floor is your office workspace located? Basement, 1st floor, 2nd floor, 3rd floor, 4th floor	Adapted from Bluyssen, 2014
Years in Space	3. How many years have you been working in your current office workspace? enter the number of years (open-ended), enter the number of months (open-ended)	Adapted from Bluyssen, 2014
Office Type	4. Which best describes the space in which your work area is located? single person private office, shared private office, open space with partitions, open space without partitions, other: _____	Adopted from Bluyssen, 2014
Access to Daylight	5. How many exterior windows are located in your office workspace? none, 1 to 3, more than 3	Adopted from Bluyssen, 2014
Access to Fresh Air	6. Can you open any of the exterior windows in your office workspace? Yes, no	Adopted from Bluyssen, 2014
Light switch	7. Does your work area have a functioning light switch? Yes, no 8. Does your workspace have multiple lighting switches for you to adjust the amount of light in the space? Yes, no 9. Does your office workspace offer a secondary light source (such as a desk light)? Yes, no	Developed by researcher
Thermostat	10. Does your office workspace have a working thermostat? Yes, no	Developed by researcher

Table 3.14

Demographics

Variable	Items	Source
Age	1. What is your age (in number of years)? _____	Adopted from Bluyssen, 2014
Gender	2. What is your gender? Male, Female	Adopted from Bluyssen, 2014
Ethnicity	3. How would you describe the ethnicity? ☐ White, Non-Hispanic ☐ Hispanic ☐ Black, Non-Hispanic ☐ American Indian/ Alaskan Native ☐ Asian/ Pacific Islander ☐ Other (please specify) _____	Developed by the researcher
Education	4. What is the highest level of education you have completed? ☐ 8th Grade or Less ☐ Some High School ☐ High School Diploma ☐ Some College or Technical School ☐ Bachelor's Degree ☐ Some Graduate School ☐ Graduate Degree (Master's, Doctorate, etc.)	Adapted from Bluyssen, 2014
Income	5. From all the sources of household income you have, what was your total household income in 2013? ☐ Less than $10,000 ☐ $10,000 - 29,999 ☐ $30,000 - 49,999 ☐ $50,000 - 69,999 ☐ $70,000 - 89,999 ☐ $90,000 - 109,999 ☐ $110,000 - 129,999 ☐ $130,000 - 149,999 ☐ $150,000 - 169,999 ☐ $170,000 - 199,999 ☐ ☐ More than $200,000	Developed by the researcher

Pilot Study

Following the completion of the self-administered web-based questionnaire, the researcher solicited review and feedback from graduate faculty and graduate students. A total of ten respondents accessed the web-based pilot questionnaire from August 25 through September 19, 2014. The respondents provided feedback on question sets and minor changes were made accordingly to the survey instrument. Based on feedback from the pilot study, the instrument adjustments increased the readability and clarification of the items.

Data Cleaning Procedure

Before beginning analysis of the survey data, the researcher cleaned the data set by removing ten participants from the accepting sample of 209. Five participants were removed due to substantial incomplete as they left more than 60% of the questions unanswered. An additional four participants were removed as 10% of the questions were left incomplete. One additional participant was removed because they answered that they did not work in one of the six building selected for this study. Therefore, the final web-based questionnaire produced a final sample of 199 participants, resulting in a usable response rate of 62.6%.

Next, the researcher reviewed open-ended responses to the "other" response category items "Which Auburn University building do you work in?", and "Which best describes the space in which your workstation is located?" and recoded the responses as five replied with comments already listed in the question options. Finally, nine items that required reverse coding were recoded accordingly.

CHAPTER 4: RESULTS

This chapter discusses descriptive statistics of sample characteristics, preliminary analysis results related to the occupant survey instrument validity and reliability, preliminary descriptive results from the building observation coding, and results related to research questions.

Survey Sample Characteristics

The sample consisted of occupants from three LEED-certified buildings and three non-LEED-certified buildings. A total of 199 respondents participated in the survey, including 109 respondents from the LEED-certified buildings − Office of Information Technology (78), Kinesiology (19), and Miller Gorrie Science Center (12) − and 90 from the non-LEED-certified buildings − Tichenor Hall (24), Miller Hall (20), and Spidle Hall (46).

The demographic data from the survey respondents revealed that just over half the sample was female (54.3%). The mean age of the respondents was 47.0 years old (*SD* = 11.43). A majority of the respondents were highly educated (84.4% with a bachelor's degree or above, 52.3% with graduate degrees), Caucasian (79.9%), and relatively affluent (80.4% with an annual income of $50,000 or more). The respondents were primarily employed as professors (28.1%), technical staff (26.1%), or administrator support staff (20.6%) and worked 36 or more hours a week (95.5%). The comprehensive demographic profile illustrating frequencies for the sample is shown in Table 4.1.

Between the LEED versus non-LEED-certified building occupants, significant differences were noted in gender (61.5% male in LEED and 77.8% female in non-LEED-certified buildings), position at the university with the highest response rate (46.8% as technical support in LEED and 45.6% as professors in non-LEED-certified buildings), and highest level of education (36.7% with a graduate degree in LEED and 71.1% in non-LEED-certified buildings)

as evidenced in Table 4.1. Age (LEED: *M* = 47.4, *SD* = 10.14; non-LEED: *M* = 46.5, *SD* = 12.85), ethnicity, hours worked in a week, and annual household income were relatively similar for the two groups (see Table 4.1).

Table 4.1

Survey Sample Demographic Characteristics

	Total Sample *(n = 199)*		LEED-certified (*n* = 109)		Non-LEED-certified (*n* = 90)	
Characteristic	*f*	%	*f*	%	*f*	%
Age						
21 - 29 years old	14	7.0%	4	3.6%	10	11.1%
30 - 39 years old	39	20%	20	18.4%	19	21.0%
40 - 49 years old	49	25%	29	26.7%	17	18.7%
50 - 59 years old	60	30%	36	33.1%	24	26.5%
60 - 69 years old	23	12%	9	8.1%	14	15.5%
70 years and up	4	2.0%	2	1.8%	2	2.2%
Missing	10	5.0%	1	0.9%	0	0.0%
Gender						
Male	86	43.2%	67	61.5%	19	21.1%
Female	108	54.3%	38	34.9%	70	77.8%
Missing	5	2.5%	4	3.7%	0	1.1%
Highest grade of school						
High school diploma	2	1.0%	1	0.9%	1	1.1%
Some college or technical school	25	12.6%	13	11.9%	12	13.3%
Bachelor's degree	53	26.6%	44	40.4%	9	10.0%
Some graduate school	11	5.5%	8	7.3%	3	3.3%
Graduate degree (Master's, Doctorate)	104	52.3%	40	36.7%	64	71.1%
Missing	4	2.0%	3	2.8%	1	1.1%
Ethnicity						
American Indian/Alaskan Native	1	0.5%	1	0.9%	0	0.0%
Asian/Pacific Islander	8	4.0%	7	6.4%	1	1.1%
Hispanic	3	1.5%	1	0.9%	2	2.2%
Black, Non-Hispanic	17	8.5%	8	7.3%	9	10.0%
White, Non-Hispanic	159	79.9%	87	79.8%	72	80.0%
Other	3	1.5%	1	0.9%	2	2.2%
Missing	8	4.0%	4	3.7%	4	4.4%

	Total Sample *(n = 199)*		LEED-certified (*n* = 109)		Non-LEED-certified (*n* = 90)	
Characteristic	*f*	%	*f*	%	*f*	%
Annual household income						
$10,000 to $29,999	3	1.5%	1	0.9%	2	2.2%
$30,000 to $49,999	13	6.5%	7	6.4%	6	6.7%
$50,000 to $69,999	33	16.6%	23	21.1%	10	11.1%
$70,000 to $89,999	32	16.1%	13	11.9%	19	21.1%
$90,000 to $109,999	24	12.1%	15	13.8%	9	10.0%
$110,000 to $129,999	31	15.6%	17	15.6%	14	15.6%
$130,000 to $149,999	10	5.0%	5	4.6%	5	5.6%
$150,000 to $169,999	11	5.5%	3	2.8%	8	8.9%
$170,000 to $200,000	3	1.5%	2	1.8%	1	1.1%
$200,000 and above	16	8.0%	8	7.3%	8	8.9%
Missing	23	11.6%	15	13.8%	8	8.9%
Position at University						
Administrator Support	41	20.6%	16	14.7%	25	27.8%
Technical Staff	53	26.6%	51	46.8%	2	2.2%
Instructor	4	2.0%	0	0.0%	4	4.4%
Professor	56	28.1%	15	13.8%	41	45.6%
Research Professor	4	2.0%	3	2.8%	1	1.1%
Managerial/Supervisor	26	11.6%	16	14.7%	7	7.8%
Academic Advisor	4	2.0%	0	0.0%	6	6.7%
IT Support	2	1.0%	2	1.8%	4	4.4%
Missing	1	0.5%	1	0.9%	0	0.0%
Hours spent working in a week						
6 – 10 hours	1	0.5%	1	0.9%	0	0.0%
16 – 20 hours	5	2.5%	2	1.8%	3	3.3%
21 – 25 hours	2	1.0%	1	0.9%	1	1.1%
36 – 40 hours	71	35.7%	47	43.1%	24	26.5%
41 – 45 hours	50	25.1%	33	30.3%	17	18.7%
46 – 50 hours	38	19.1%	11	10.1%	27	30.0%
51 – 55 hours	10	5.0%	5	4.6%	5	5.6%
56 hours or more	21	10.6%	8	7.3%	13	14.4%
Missing	1	0.5%	1	0.9%	0	0.0%

In terms of participants' work environment characteristics (see Table 4.2), the majority of occupants worked in their assigned building for less than three years (60.4%) and worked in single person private offices (59.8%). Further, most respondents worked in their assigned

university building (79.8%) and office (59.3%) an average of 36 or more hours per week. Notable differences between the occupants of the LEED versus non-LEED-certified buildings exist in the numbers of years they had been worked in the building as the LEED-certified buildings are newer construction. A greater number of respondents from the LEED-certified buildings have been worked in their building less than three years (76.1%), as compared to 42.1% of the non-LEED-certified building sample. The sample from the non-LEED-certified buildings reported a higher percentage of occupants having private offices (78.9%), whereas the LEED-certified buildings had equal number in private offices (44.0%) and open space with partitions (41.3%). Another notable difference is in the number of respondents who reported working between 36-40 hours in the building (non-LEED-certified = 35.6% and LEED-certified = 56.9%). The number of hours worked in the assigned office between 36- 40 hours a week was different between the two groups (non-LEED-certified = 35.6% and LEED-certified = 43.1%). These incremental differences are to be expected given the differences in their employment position and departments housed in the different buildings at the University.

The occupant survey data also revealed the physical topographies of the buildings. The average office workspace had one to three windows (59.3%) with just over half being inoperable (54.3%). The occupants reported that their office space had a functioning light switch (76.4%) with the majority having a single level control by a basic on/off application (72.9%) instead of one with at least three lighting levels or scenes (on, off, midlevel). More than half of the respondents reported having a secondary light source such as a task light on their desk (63.3%). Lastly, when asked about temperature control, half of the sample reported having a lack of control over the personal temperature at/in their office workspace (50.8%), as shown in Table 4.3.

Table 4.2

Survey Sample Work Environment Characteristics

	Total Sample *(n = 199)*		LEED-certified (*n* = 109)		Non-LEED-certified (*n* = 90)	
Characteristic	*f*	%	*f*	%	*f*	%
Floor						
Basement	3	1.5%	1	0.9%	2	2.2%
First floor	51	25.6%	26	23.9%	25	27.8%
Second floor	73	36.7%	35	32.1%	38	42.2%
Third floor	71	35.7%	46	42.2%	25	27.8%
Missing	1	0.5%	1	0.9%	0	0.0%
Years worked in their current office workspace						
0 – 1 years	51	25.7%	27	24.7%	24	26.6%
2 – 3 years	69	34.7%	56	51.4%	14	15.5%
4 – 5 years	33	16.5%	13	12.0%	20	22.2%
6 – 7 years	18	9.0%	5	4.6%	13	14.4%
8 – 9 years	14	7.0%	5	4.6%	9	10.0%
10 – 11 years	3	1.5%	0	0.0%	3	3.3%
12 years and up	7	3.5%	1	0.9%	6	6.6%
Missing	1	0.5%	2	1.8%	1	1.1%
Office workspace type						
Single person private office	119	59.8%	48	44.0%	71	78.9%
Shared private office	17	8.5%	8	7.3%	9	10.0%
Open space with partitions	51	25.6%	45	41.3%	6	6.7%
Open space without partitions	11	5.5%	7	6.4%	4	4.4%
Other	1	0.5%	1	0.9%	0	0.0%
Hours spent working in the building						
1 – 5 hours	2	1.0%	1	0.9%	1	1.1%
11 – 15 hours	1	0.5%	1	0.9%	0	0.0%
16 – 20 hours	8	4.0%	3	2.8%	5	5.6%
21 – 25 hours	4	2.0%	2	1.8%	2	2.2%
26 – 30 hours	13	6.5%	3	2.8%	10	11.1%
31 – 35 hours	12	6.0%	4	3.7%	8	8.9%
36 – 40 hours	94	47.2%	62	56.9%	32	35.6%
41 – 45 hours	40	20.1%	23	21.1%	17	18.9%
46 – 50 hours	16	8.0%	6	5.5%	10	11.1%
51 – 55 hours	1	0.5%	4	3.7%	1	1.1%
56 hours or more	8	4.0%	0	0.0%	4	4.4%
Hours spent working in the assigned office						
1 – 5 hours	2	1.0%	1	0.9%	1	1.1%
6 – 10 hours	5	2.5%	5	4.6%	0	0.0%

Characteristic	Total Sample *(n = 199)*		LEED-certified (*n* = 109)		Non-LEED-certified (*n* = 90)	
	f	%	*f*	%	*f*	%
11 – 15 hours	5	2.5%	2	1.8%	3	3.3%
16 – 20 hours	13	6.5%	3	2.8%	10	11.1%
21 – 25 hours	13	6.5%	5	4.6%	8	8.9%
26 – 30 hours	20	10.1%	12	11.0%	8	8.9%
31 – 35 hours	21	10.6%	15	13.8%	6	6.7%
36 – 40 hours	79	39.7%	47	43.1%	32	35.6%
41 – 45 hours	31	15.6%	16	14.7%	15	16.7%
46 – 50 hours	6	3.0%	2	1.8%	4	4.4%
51 – 55 hours	1	0.5%	0	0.0%	1	1.1%
56 hours or more	1	0.5%	0	0.0%	1	1.1%
Missing	2	1.0%	1	0.9%	1	1.1%

Differences among physical properties of the offices occurred between the LEED and non-LEED-certified building occupants (see Table 4.3). For the number of exterior windows, the non-LEED-certified occupants reported having a higher percentage of offices with one or more windows (76.6% non-LEED and 56.9% LEED-certified). Further, the non-LEED-certified windows were reported as operable (73.3%) considerately more than the LEED-certified windows (17.4%). Noteworthy is the difference between the percentages of non-LEED-certified occupants who reported being unable to adjust the lighting level (94.4%) through control in switching with at least three lighting levels or scenes (on, off, midlevel). Just under half of the LEED-certified occupants reported lighting levels were adjustable (44.0%) with more having no adjustability (55.0%). The differences between respondents from the two groups reporting having a secondary light source and personal temperature control were marginal.

Table 4.3

Survey Sample Workspace Topographic Characteristics

	Total Sample *(n = 199)*		LEED-certified (*n* = 109)		Non-LEED-certified (*n* = 90)	
Characteristic	*f*	%	*f*	%	*f*	%
Number of exterior windows						
None	68	34.2%	47	43.1%	21	23.3%
1 to 3	118	59.3%	52	47.7%	66	73.3%
More than 3	13	6.5%	10	9.2%	3	3.3%
Window operability						
Yes	85	42.7%	19	17.4%	66	73.3%
No	108	54.3%	86	78.9%	22	24.4%
Missing	6	3.0%	4	3.7%	2	2.2%
Functioning light switch						
Yes	152	76.4%	76	69.7%	76	84.4%
No	47	23.6%	33	30.3%	14	15.6%
Multiple light switches to adjust the amount of light						
Yes	53	26.6%	48	44.0%	5	5.6%
No	145	72.9%	60	55.0%	85	94.4%
Missing	1	0.5%	1	0.9%	0	0.0%
Provision of secondary light source						
Yes	126	63.3%	78	71.6%	48	53.3%
No	73	36.7%	31	28.4%	42	46.7%
Working thermostat						
Yes	97	48.7%	60	55.0%	37	41.1%
No	101	50.8%	49	45.0%	52	57.8%
Missing	1	0.5%	0	0.0%	1	1.1%

Preliminary Analysis Results

Survey Instrument Factor Analysis and Reliability

A series of exploratory factor analysis (EFA) was conducted with the occupant survey data to verify the dimensionality of the multiple-item measurements (sustainable IEQ satisfaction, non-sustainability IEQ satisfaction, health, workplace wellbeing, and job satisfaction). Prior to the EFA, Pearson bivariate correlation analyses were run to assess the degree of linearity among items from each of the following groups of measures (1) all 39 IEQ satisfaction items, (2) 12

items of physical, psychological and overall health, and (3) the combined nine items of job satisfaction and workplace wellbeing. The correlation tests enable the early prediction of unique interactions between measures and the identification of outliers, if any, prior to proceeding with the factor analysis (Green & Salkind, 2011). Results from the correlation analyses revealed no obvious problems (i.e. no too high or too low correlations between items from the same measurement), so all items were subject to EFA.

EFA was conducted using the principal component analysis procedure with varimax rotation with SPSS Version 22. The varimax rotation method was chosen because it maximizes the variance of factor loading (Tabachnick & Fidell, 2007). Three criteria were used to determine the number of factors: the number of factors with an eigenvalue over 1.0, the scree plots, and the interpretability of the factor solution (Green & Salkind, 2011).

First, for the 20 items of sustainable IEQ satisfaction, the rotated component matrix resulting from the principal components analysis indicated four factors, (1) indoor air quality and comfort, (2) quality and control of lighting, (3) acoustics, and (4) daylight and views, as shown in Table 4.4.

Next, with regard to EFA of the covariate IEQ satisfaction items, two of the original 18 items were exempt from the EFA because each of them represented a single IEQ dimension conceptually. The two items addressed (1) satisfaction with safety ("how satisfied with your safety coming to and going from work?") and (2) satisfaction with cleanliness ("how satisfied are you with the cleanliness of the facilities at work?"). Based on the EFA of the 16 items, one item "How satisfied are you with the accommodation of your work area to adapt for your various activities (i.e. impromptu meetings)?" was removed because it cross-loaded onto two factors.

Another EFA was run with the remaining 15 items, four factors were extracted including (1) privacy (2) appearance, (3) desk comfort, and (4) chair comfort as presented in Table 4.5.

Table 4.4

Factor Analysis Results: Sustainable IEQ Satisfaction Items

	Factor[a]			
Items	Indoor air quality & control	Lighting quality & control	Acoustics	Daylight & views
The following set of statements relates to your satisfaction in your Auburn University assigned office workspace over the last 4 weeks. Your workspace is the place (desk, cubicle, office, etc.) where you do the majority of your office work on the AU campus. For your office workspace, please indicate your level of satisfaction with each of the following:				
the humidity	.858			
the air movement	.854			
the air quality	.843			
the temperature	.796			
the smells	.788			
your ability to control the temperature	.613			
the amount of light for computer work	.309	.842		
the quality of lighting	.320	.840		
the amount of lighting on the desktop (desk surface)		.806		
the flexibility to adjust the levels of lighting for your activities		.796		
the ability to control the lighting by turning them off and on		.741		
amount of reflected light or glare in the computer screen		.728		
your ability to control the noise in your office workspace			.899	

Items	Factor[a]			
	Indoor air quality & control	Lighting quality & control	Acoustics	Daylight & views
the amount of noise from other people's conversations while you are at your office workspace			.875	
your ability to concentrate on your work while in your office workspace			.857	
the amount of background noise (i.e. not speech) you hear at your office workspace			.853	
your access to a view of outside from where you sit				.923
the amount of natural light				.891
the view outside your exterior window				.862
your ability to adjust the amount of light from the exterior windows (i.e. blinds, curtains)	.322			.537
Eigen value	8.69	2.50	2.23	1.90
% Variance explained	22.65	21.34	17.32	15.26
Cronbach's α	.92	.92	.94	.88

[a] Numbers under factor names by each item indicate factor loading values from the rotated component matrix. Loadings below .30 are omitted from the table.

Table 4.5

Factor Analysis Results: Control Variables (Non-Sustainability Related) IEQ Satisfaction Items

Items	Factor[a]			
	Privacy	Appearance	Desk comfort	Chair comfort
The following set of statements relates to your satisfaction in your Auburn University assigned office workspace over the last 4 weeks. Your workspace is the place (desk, cubicle, office, etc.) where you do the majority of your office work on the AU campus. Please indicate your level of satisfaction with each of the following:				
the degree of enclosure of your office workspace	.865			

Items	Factor[a]			
	Privacy	Appearance	Desk comfort	Chair comfort
by walls, screens or furniture				
the level of visual privacy within your office workspace	.852			
the level of privacy for conversations in your office workspace	.832			
the distance between you and other people you work with	.774		.431	
the frequency of distractions from other people while in your office workspace	.756			
your ability to organize and change the appearance of your office		.796		
the style of your office furniture		.774		.351
your opportunity to personalization your office		.762		
the color in your office		.760		
the aesthetic appearance		.754		
the storage space at your office workspace			.788	
the size of your office workspace to accommodate your work, materials, and visitors	.351		.775	
your options to adjust your office workspace to increase your physical comfort		.441	.663	
the adjustability of your office chair				.938
the comfort of your office chair				.909
Eigen value	6.85	2.53	1.20	0.93
% Variance explained	25.33	23.48	14.17	13.78
[b]Cronbach's α	.91	.88	.82	.88[b]

[a] Numbers under factor names by each item indicate factor loading values from the rotated component matrix. Loadings below .30 are omitted from the table

[b] The Chair Comfort factor had only two items. So, a correlation was calculated in lieu of Cronbach's α.

The EFA of the 10 physical and psychological health items resulted in two factors (1) physical health and (2) psychological health, as expected (see Table 4.6). The two overall health items "in general, would you say your health is" and "during the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your work activities?" were excluded from the EFA, because they did not belong to either factor conceptually, nor were they included in the original research questions and conceptual model of this study.

The EFA of the nine workplace wellbeing and job satisfaction items initially identified three items ("how satisfied are you with your work life at present?", "are you usually happy or dejected at work?", and "how often do you have too much to do?") with cross-loading or low-loading problems. After eliminating these items, two factors were obtained from the second EFA, including job satisfaction (four items) and workplace wellbeing (two items) (see Table 4.7).

Following the EFAs, Cronbach α was calculated to assess the internal consistency reliability of items from each of the factors that contained three or more items. All of the factors resulted in Cronbach's α of 0.7 or higher (see Tables 4.4 through 4.7), and thus were considered reliable (DeVillis, 2003; Kline, 2005). For the factors with only two items, Pearson correlations were calculated, all of which were found significant (see Tables 4.5 and 4.7).

Objective IEQ Building Observation Coding

The objective sustainable indoor environmental quality (IEQ) was measured through the two procedures: (1) facility verification and (2) site verification which evaluated the buildings' sustainable IEQ using a method modified from the LEED version 4 New Construction IEQ credits. The specific verification method for each credit required by LEED and that used for this study were summarized in Table 3.5. The descriptive results from the site and facility verifications are as follows.

Table 4.6

Factor Analysis Results: Health (Physical and Psychological) Items

Items	Factor[a]	
	Physical health	Psychological health
Given your current health, please indicate your level of limitation with each of the following: performing moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	.871	
Given your current health, please indicate your level of limitation with each of the following: climbing several flights of stairs	.836	
Based on the past four (4) weeks, please indicate your agreement with the following: I was limited in the kind of work or other activities due to my physical health.	.788	.370
Based on the past four (4) weeks, please indicate your agreement with the following: I have accomplished less than I would like due to my physical health.	.767	.340
During the past 4 weeks, how much did pain interfere with your normal work (including both work in and out of the office)?	.712	
Based on the past four (4) weeks, please indicate your agreement with the following: I have accomplished less than I would like due to my emotional problems.		.841
Based on the past four (4) weeks, please indicate your agreement with the following: I was limited in the kind of work or other activities due to my emotional problems.		.834
Based on the past four (4) weeks, how often have you experienced the following: feeling downhearted and blue?		.812
Based on the past four (4) weeks, how often have you experienced the following: feeling calm and peaceful?		.589
Based on the past four (4) weeks, how often have you experienced the following: having a lot of energy?	.315	.504
Eigen value	4.42	1.93
% Variance explained	33.75	29.75
Cronbach's α	.86	.81

[a] Numbers under factor names by each item indicate factor loading values from the rotated component matrix. Loadings below .30 are omitted from the table

Table 4.7

Factor Analysis Results: Job Satisfaction and Workplace Wellbeing Items

Items	Factor[a]	
	Job Satisfaction	Workplace wellbeing
How often do you experience the following: My relationship with your closest supervisor working out positively?	.788	
How often do you experience the following: The goals at your work are challenging and realistic at the same time?	.730	
How satisfied or / dissatisfied are you with your work?-	.707	.448
How do you perceive the cooperation with your own work group?	.591	.396
How do you usually feel at work: strong and fit, or tired and worn out at work?		.834
Over the last 4 weeks, how often have you suffered from nervousness at work (felt irritable, anxious, tense or restless)?		.759
Eigen value	2.67	1.11
% Variance explained	33.95	28.94
[b]Cronbach's α	.73	.45[b]

[a] Numbers under factor names by each item indicate factor loading values from the rotated component matrix. Loadings below .30 are omitted from the table

[b] The Workplace Wellbeing factor had only two items. So, a correlation was calculated in lieu of Cronbach's α.

Site Verification. Complying with the LEED IEQ credit, both coders used '1' (yes), '2' (no), and '3' (maybe) to record their observation results for each room regarding Credits 5 *Thermal Comfort*, 6 *Interior Lighting* (control only), 7 *Daylight*, and 8 *Quality Views*. The coding results of the two coders were compared room by room and then building by building. A total of 428 rooms were coded from the six building, with an average of the four credit inter-coder reliability rate of 93.2% (see Tables 4.8 and 4.9). For the disagreed upon codes, only buildings that were borderline to either meeting or not meeting the IEQ credit requirement were

rechecked. Spidle Hall had 10 rooms that were rechecked by the two coders. All other buildings either met the IEQ credit sufficiently or were already so low that the difference of the disagreed rooms would have made no difference in the building receiving the points. The areas in Tables 4.8 through 4.11 identified as not applicable (NA) refer to the buildings that already were awarded a LEED certification. For these buildings, the points were given based on those awarded during the LEED certification process, which were confirmed through the facility verification process, and thus no additional site verification was performed. The room-level site verification data were transcribed into an Excel spreadsheet for the calculation of percentages to the codes 'yes,' 'no,' and 'maybe' for each of Credits 5, 6, 7, and 8. The percentage results are presented in Tables 4.10 and Table 4.11. This process was needed because many of the LEED IEQ credits required a percentage of the occupied space to be complaint to the credit.

Table 4.8

Inter-Coder Reliability for Site Verification of Objective IEQ Credits 5 and 6

Buildings	N	IEQc5		IEQc6	
		# Disagreed	% Agreed	# Disagreed	% Agreed
Spidle Hall	102	1	99.0%	8	92.1%
Miller Hall	49	1	98.0%	4	91.9%
Tichenor Hall	69	3	95.7%	5	92.8%
Miller Gorrie Center- Building Science	43	4	90.7%	2	95.3%
Office of Information Technology	78	NA	NA	7	91.0%
Kinesiology	87	4	95.4%	10	88.5%
[a]Total Inter-coder reliability			96.3%		91.6%

Note. NA = not applicable
N = Total number of rooms observed
[a] Calculated by dividing the total agreed by the total number rooms assessed and multiplying by 100 to determine the percentage.

Table 4.9

Inter-Coder Reliability for Site Verification of Objective IEQ Credits 7 and 8

Buildings	N	IEQc7		IEQc8	
		# Disagreed	% Agreed	# Disagreed	% Agreed
Spidle Hall	102	9	91.2%	10	90.2%
Miller Hall	49	13	67.3%	0	100.0%
Tichenor Hall	69	4	94.3%	0	100.0%
Miller Gorrie Center- Building Science	43	NA	NA	NA	NA
Office of Information Technology	78	NA	NA	0	100.0%
Kinesiology	87	NA	NA	3	96.6%
[a]Total Inter-coder reliability			96.3%		91.6%

Note. NA = not applicable
N = Total number of rooms observed
[a] Calculated by dividing the total agreed by the total number rooms assessed and multiplying by 100 to determine the percentage.

Table 4.10

Site Verification Results for the LEED IEQ Credits 5 and 6 (Version 4)

Buildings	*N*	IEQc5 (%)			IEQc6 (%)		
		yes	No	maybe	yes	no	maybe
Spidle Hall	102	46%	45%	9%	14%	76%	11%
Miller Hall	49	33%	65%	2%	6%	86%	8%
Tichenor Hall	69	59%	36%	4%	6%	87%	7%
Miller Gorrie Center- Building Science	43	58%	28%	14%	19%	74%	7%
Office of Information Technology	78	NA	NA	NA	39%	51%	10%
Kinesiology	87	71%	24%	5%	36%	52%	11%

Note. NA = not applicable
N = Total number of rooms observed

Table 4.11

Site Verification Results for the LEED IEQ Credits 7 and 8 (Version 4)

Buildings	*N*	IEQc7 (%)			IEQc8 (%)		
		yes	No	maybe	yes	no	maybe
Spidle Hall	102	27%	62%	12%	47%	40%	13%
Miller Hall	49	18%	55%	27%	82%	18%	0.0%
Tichenor Hall	69	26%	68%	6%	80%	19%	1.0%
Miller Gorrie Center- Building Science	43	NA	NA	NA	NA	NA	NA
Office of Information Technology	78	NA	NA	NA	51%	44%	5%
Kinesiology	87	NA	NA	NA	68%	28%	3%

Note. NA = not applicable
N = Total number of rooms observed

Based on the room coding percentage results (see Tables 10 and 11) from the site verification as well as the facility verification results (i.e., points awarded during the LEED-certification process, if any, the credit points for each building were finalized for Credits 5 through 8 and presented in Tables 4.15 and 4.16 for the LEED-certified and non-LEED-certified buildings, respectively.

Facility Verification. Following the site verification, the researcher contacted the Facility Management Department of Auburn University gaining access to the building construction and specification documents. For Prerequisite 1, *Minimum Indoor Air Quality Performance*, the Facility Management Department was able to confirm that all buildings met the requirements except Miller Hall.

Unfortunately, information was unavailable to verify full compliance with Credit 1 as only two of the three credit requirements could be verified. All of the six buildings met (1) entryway systems as verified on-site and through construction documents and (3) filtration as the campus has a HVAC systems standard to use minimum efficiency reporting value (MERV) of 13

filters in all buildings. As for requirement (2), interior cross-contamination, this portion of the credit could not be verified due to a lack of resources. Credit 1 has an additional enhanced IAQ strategy option where the facility department was able to verify which buildings met the carbon dioxide monitoring and any additional source control. All buildings complied with the enhanced IAQ strategy except for Miller Hall, which did not meet the LEED Credit standard for carbon dioxide monitoring. For both the prerequisite and Credit 1, the whole building system was required to be compliant.

For Credit 2, the construction and specification documents were analyzed for the material and finish specifications. The three non-LEED buildings have had several renovations since their construction. However, the materials installed within the spaces did not meet the low VOC emissions, and therefore, were insufficient to meet the credit. This was confirmed by facility management. In the case of the LEED-certified buildings, the building's original points earned toward certification were reviewed and adopted for Credit 2.

The construction documents provided information on Credit 6 *Lighting* (quality) to verify and complete the lighting fixtures and lamp types for each room. During the site verification the type of lamps installed were recorded in as many rooms as the researcher could access. The researcher conducted an online search in order to determine the light sources' compliance with: (1) a minimum of 75% of the lamps having a rated life of 24,000 hours or more, (2) all lamps having a CRI of 80 or higher, and (3) less than 25% of the luminaires being direct-only fixtures type such as a recessed light. The last strategy of Credit 6 required 90% of the regularly occupied spaces to meet minimum light reflectance levels for the following surfaces: 85% for ceilings, 60% for walls, and 25% for floors. This analysis was accomplished by comparing the documented photographs and record of finishes to the construction documents provided by the Facility

Management Department. Once the comparison was made, the finishes of the rooms were equated to light reflectance charts. Finally with the specification details for each lamp source and light reflectance levels, the researcher calculated the percentages for each of the Credit 6 requirements by dividing the number of rooms that met the condition by the total number of rooms for each building.

Lastly for Credit 7 and Credit 8, the non-LEED-certified buildings were verified during the site verification. For the LEED-certified buildings, the scorecard provided by USGBC regarding the original points awarded for the building was reviewed online. Points were adopted from those awarded during the LEED certification process. The Green Business Certification Inc. reviews the project's LEED application and verifies the achieved credits by employing technical experts to ensure projects (buildings) "meet the highest levels of quality and integrity" (USGBC, 2015, para. 24). Therefore, the adoption of the points received during the certification process was deemed valid and reliable.

Final Building Scores. Based on the EFA of the satisfaction with sustainable IEQ factors, the seven objective IEQ LEED credits were grouped into four factors (1) indoor air quality and thermal comfort, (2) lighting quality and control, (3) acoustics, and (4) daylight and views presented in Table 4.13. For prerequisite 2, Credit 1, part 2 of Credit 5, and Credit 9, all buildings received the exact same score. This was due either to an existing campus policy or a lack of information to complete the credit. For example, Credit 9 *Acoustic Performance* was unable to be completed due to the lack of information regarding the acoustical rating of all materials and construction used in the space. Therefore, there was no observable difference between the buildings and no numerical score was assigned. The remaining prerequisite and credits were assessed based on the site and facility verified data for each building.

The final building scores were organized congruently with the satisfaction with sustainable IEQ factors finalized from the factor analysis of the occupant survey data. In other words, the site- and facility-verification results for each credit were no longer assessed individually. Instead, they were grouped into the IEQ factors corresponding to those finalized through the factor analysis of the satisfaction with sustainable IEQ data from the occupant survey. The objective sustainable IEQ score for each building was calculated for each factor by summing the total scores received for all credits addressing the factor.

Specifically, for the indoor air quality and thermal comfort factor, the credit score total was a summation of the buildings' design to meet the following criteria: (a) minimum IAQ performance, (b) if the building had carbon dioxide monitoring, (c) low emitting materials based on either the original LEED certification or facility verification and (d) thermal comfort control for 50% of individual occupant spaces from Tables 4.10 and 4.11.

For the lighting control and quality factor, the total credit score was based on (a) 90% of occupants having lighting control at three levels as assessed by the percentage of Credit 6 in Tables 4.10 and 4.11, and (b) meeting for of the lighting quality requirements. The lighting quality data was collected as a yes or no for each of the four criterions. The two requirement sets were then tabulated together for a final factor score as noted in Table 4.13.

Factor 3, acoustics, could not be conducted to meet the LEED BD+C: New Construction and Major Renovation version 4 IEQ Credit 9 requirements. However, decibel readings were recorded for each room using the average dB(A) measurement from three separate devices. Each room then received an average score of the three measures. All of the averages were then further averaged so that each buildings had an overall average acoustical reading dB(A) as noted in Table 4.12. The building results indicate the average acoustical readings are between 46.4 to 47.9

dB(A) with one outlier, the Kinesiology building (53.8 dB(A)). During the Kinesiology building's measurements, it was difficult to obtain accurate readings due to continuous conversations at the time of building access. Acoustics did not produce observable differences between the LEED and non- LEED-certified buildings, therefore, the objective acoustical factor will not be considered in RQ3 and RQ4.

Table 4.12

Objective On-Site Measured Acoustical Averages for Buildings

		FINAL [dB(A)]			
	Building	***n***	**Max**	**Average**	**Min**
LEED-certified Buildings	Office of Information Technology	77	55.4	46.9	43.1
	Miller-Gorrie Center-Building Science	42	58.6	46.9	43.5
	Kinesiology	78	61.3	53.8	41.3
Non-LEED-certified Buildings	Tichenor Hall	68	62.0	46.6	40.5
	Miller Hall	48	58.8	46.4	39.6
	Spidle Hall	51	64.7	47.9	44.0

Note: all averaged acoustical readings are based on the average of each column's readings whereas the (*) noted number is based on the room average score creating the overall building score.

Lastly for the daylight and views factor, the score is based on two requirements from Credit 7, *Daylight,* (1) occupant spaces provide manual or automatic glare control devices based on site verification, and (2) provide daylight for 75% (2 points) or 90% (3 points) of occupant spaces as reviewed in Tables 4.10 and 4.11. One requirement from Credit 8, *Views,* completes this credit score by requiring compliance of 75% of occupants having a quality view as

determined by the percentage of the site verification (see Tables 4.10 and 4.11). The three requirements construct the factor score as found in Table 4.13.

Two credit scoring schemes were used to numerically represent the observable data after evaluation of the building's rooms according to the LEED version 4 IEQ credits. The first scheme maintained the U.S. Green Building Council (USGBC) LEED version 4 credit values, while the second converted each credit requirement, which often awarded multiple points as a single (1) point. LEED Certification requires credits to be either 1) fully met or 2) to meet the requirements as prescribed. If a building does not meet all the requirements described by the credit, no points would be awarded. However, for the study, the points were not used as an all or nothing, rather each portion of the requirement received proportionate points. For example, Credit 6 requires part 1, lighting control and part 2, lighting quality to be fully met to receive the two points. This study evaluated Credit 6 as two separate parts, so that a building would receive credit for one or the other or both parts. Further the four sub-categories of lighting quality were assigned proportionate points such that a building meeting a sub-category received a quarter points for each of the sub-categories. The modified scheme assigns a single point to each requirement regardless if it is a sub-category of a credit or a single requirement.

The purpose of the two score schemes is to explore any statistical differences the modified score may produce from the LEED score. For example, for the lighting quality and control factor, total points that may be awarded with the LEED score is 2. A single point may be earned for both meeting occupant control by 90%, and for complying with all four of the quality sub-credits. On the other hand, in the modified score a single point may be earned for the occupant control of the lights, and for each of the four sub-categories as presented in Table 4.13. A building can receive a total LEED IEQ credit score between 0 to 10.5 and a modified score

between 0 to 12 points. The credit totals, point breakdown for each scheme, and compliance for the LEED-certified buildings are reflected in Table 4.14 and the non-LEED-certified buildings in Table 4.15. Each building's final objective sustainable IEQ scores for the three IEQ factors−(1) indoor air quality and thermal comfort, (2) lighting quality and control, and (3) daylight and views− based on the LEED and modified scoring schemes are presented in Table 4.16, and Figure 4.1 presents a holistic view of the building scores based on the LEED scoring scheme relating to each IEQ factor.

Table 4.13

Objective Sustainable IEQ Scoring Schemes

	Possible Score Total	
Factor and Credit Description	LEED	Modified
Indoor air quality and thermal comfort	4.5	4
Prerequisite 1: minimum indoor air quality performance *		
Prerequisite 2: environmental tobacco smoke control *		
Credit 1: enhanced indoor air quality strategies		
1. Entryway systems *		
2. Interior cross-contamination prevention *		
3. Filtration *		
4. Carbon dioxide monitoring		
Credit 2: low emitting materials		
Credit 5: thermal comfort		
1. Control of thermal comfort		
2. Thermal comfort design *		
3.		
Lighting quality and control	2	5
Credit 6:		
1. lighting control by 90% of occupants		
2. lighting quality		
a. Use light sources with a CRI of 80 or higher in the whole building		
b. Use light sources rated 24,000 hours of 75% of the space		
c. Use direct lighting for less than 25% of the whole space		

Factor and Credit Description	Possible Score Total LEED	Modified
d. For 90% of the space, the surface reflectance should be 85% for ceilings, 60% for walls and 25% for floors		
Acoustics *	n/a	n/a
Credit 9: acoustic performance for the whole space		
Background noise, sound transmission and reverberation time		
Daylight and views	4	3
Credit 7: Daylight		
1. Provide manual or automatic glare control devices		
2. Provide daylight for 75% or 90% of occupants		
Credit 8: quality views provided for 75% of occupants		

Note: credits marked with an (*) indicate credits where no measureable difference was noted and therefore, no numerical value was assigned.

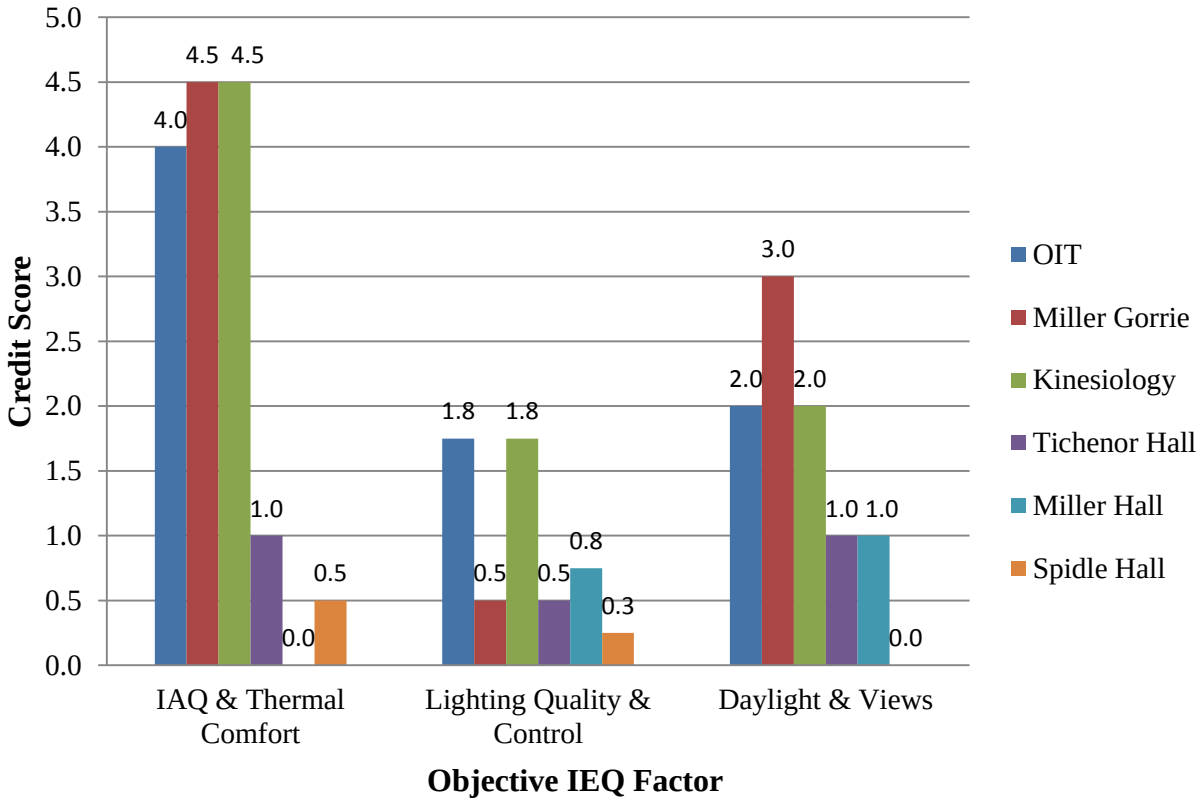


Figure 4.1. Objective Sustainable IEQ Scores Calculated Based on the LEED Scoring Scheme

Table 4.14

LEED BD+C: New Construction (Version 4) IEQ Credit Scores for LEED-certified Buildings

LEED BD+C: New Construction Version 4 IEQ Credit Criterion	Score Scheme Possible Totals		Office of Information Technology			Miller Gorrie Center-Building Sciences			Kinesiology Building		
	LEED	MOD	LEED	MOD	Comply	LEED	MOD	Comply	LEED	MOD	Comply
Prerequisite 1: Minimum Indoor Air Quality Performance		0-1		1	yes		1	yes		1	yes
Prerequisite 2: Environmental Tobacco Smoke Control		x			yes			yes			yes
Credit 1: Enhanced Indoor Air Quality Strategies (2) (ALL 1-3)		x			unknown			unknown			unknown
1. entryway systems		x			yes			yes			yes
2. interior cross-contamination prevention		x			unknown			unknown			unknown
3. filtration		x			yes			yes			yes
7. carbon dioxide monitoring (Additional: 1 point)	0-1	0-1	1	1	yes	1	1	yes	1	1	yes
Credit 2: Low Emitting Materials (1-3)	0-3	0-1	3	1	yes	3	1	yes	3	1	yes
Credit 5: Thermal Comfort (1) BOTH		x			no			unknown			unknown
1. Thermal Comfort Control	0-.5	0-1	0	0	no	0.5	1	yes	0.5	1	yes
2. Thermal comfort design		x			unknown			unknown			unknown
Credit 6: Interior Lighting (1-2) (one or both)		x									
1. Lighting Control 90% (1)	0-1	0-1	1	1	yes	0	0	no	1	1	yes
2. Lighting quality (1) (Need 4)		x									
b. use light sources with a CRI of 80	0-.25	0-1	0.25	1	yes	0.25	1	yes	0.25	1	yes

LEED BD+C: New Construction Version 4 IEQ Credit Criterion	Score Scheme Possible Totals		Office of Information Technology			Miller Gorrie Center-Building Sciences			Kinesiology Building		
	LEED	MOD	LEED	MOD	Comply	LEED	MOD	Comply	LEED	MOD	Comply
or higher (whole building)											
c. use light sources rated 24,000 hours (75% of space)	0-.25	0-1	0.25	1	yes	0.25	1	yes	0.25	1	yes
d. use direct-only for less than 25% of space	0-.25	0-1	0.25	1	yes	0	0	no	0.25	1	yes
e. FOR 90% of space, 85% for ceilings, 60% for walls, and 25% for floors	0-.25	0-1	0	0	no	0	0	no	0	0	no
Credit 7: Daylight (2-3) (BOTH)		x									
1. Provide manual or automatic glare control devices		0-1		1	yes		1	yes		1	yes
2. Measurement (75%=2 points, 90%=3 points)	0-3	0-1	2	1	yes	2	1	yes	2	1	yes
Credit 8: Quality Views (1): Provide views for 75%	0-1	0-1	0	0	no	1	1	yes	0	0	no
Credit 9: Acoustic Performance (1) All 3 for all occupied spaces		x			no			no			no
1. Background Noise		x	x		no	x		no	x		no
2. Sound Transmission (Isolation)		x	?		unknown	?		unknown	?		unknown
3. Reverberation Time		x	?		unknown	?		unknown	?		unknown
Totals	10.5	12	7.75	9		8	9		8.25	10	

Note. MOD = modified
Adapted from "*LEED for BD+C: New Construction IEQ Credits",* by USGBC. Copyright 2013 by USGBC.

Table 4.15

LEED BD+C: New Construction (Version 4) IEQ Credit Scores for Non-LEED-certified Buildings

LEED BD+C: New Construction Version 4 IEQ Credit Criterion	Score Scheme Possible Totals		Spidle Hall			Miller Hall			Tichenor Hall		
	LEED	MOD	LEED	MOD	Comply	LEED	MOD	Comply	LEED	MOD	Comply
Prerequisite 1: Minimum Indoor Air Quality Performance		0-1		1	yes		0	no		1	yes
Prerequisite 2: Environmental Tobacco Smoke Control		x			yes			yes			yes
Credit 1: Enhanced Indoor Air Quality Strategies (2) (ALL 1-3)		x			unknown			unknown			unknown
1. entryway systems		x			yes			yes			yes
2. interior cross-contamination prevention		x			unknown			unknown			unknown
3. filtration		x			yes			yes			yes
7. carbon dioxide monitoring (Additional: 1 point)	0-1	0-1	0	0	no	0	0	no	1	1	yes
Credit 2: Low Emitting Materials (1-3)	0-3	0-1	0	0	no	0	0	no	0	0	no
Credit 5: Thermal Comfort (1) BOTH											
1. Thermal Comfort Control	0-.5	0-1	0.5	1	yes	0	0	no	0	0	no
2. Thermal comfort design		x			unknown			unknown			unknown
Credit 6: Interior Lighting (1-2) (one or both)											
1. Lighting Control 90% (1)	0-1	0-1	0	0	no	0	0	no	0	0	no
2. Lighting quality (1) (Need 4)		x									

LEED BD+C: New Construction Version 4 IEQ Credit Criterion	Score Scheme Possible Totals		Spidle Hall			Miller Hall			Tichenor Hall		
	LEED	MOD	LEED	MOD	Comply	LEED	MOD	Comply	LEED	MOD	Comply
b. use light sources with a CRI of 80 or higher (whole building)	0-.25	0-1	0	0	no	0.25	1	yes	0.25	1	yes
c. use light sources rated 24,000 hours (75% of space)	0-.25	0-1	0.25	1	yes	0.25	1	yes	0.25	1	yes
d. use direct-only for less than 25% of space	0-.25	0-1	0	0	no	0.25	1	yes	0	0	no
e. FOR 90% of space, 85% for ceilings, 60% for walls, and 25% for floors	0-.25	0-1	0	0	no	0	0	no	0	0	no
Credit 7: Daylight (2-3) (BOTH)											
1. Provide manual or automatic glare control devices		0-1		1	yes		1	yes		1	yes
2. Measurement (75%=2 points, 90%=3 points)	0-3	0-1	0	0	no	0	0	no	0	0	no
Credit 8: Quality Views (1): Provide views for 75%	0-1	0-1	0	0	no	1	1	yes	1	1	yes
Credit 9: Acoustic Performance (1) All 3 for all occupied spaces											
1. Background Noise		x	x		no	x		no	x		no
2. Sound Transmission (Isolation)		x	?		unknown	?		unknown	?		unknown
3. Reverberation Time		x	?		unknown	?		unknown	?		unknown
Totals	10.5	12	0.75	4		1.75	5		2.5	6	

Note. MOD = modified

Adapted from "*LEED for BD+C: New Construction IEQ Credits",* by USGBC. Copyright 2013 by USGBC.

Table 4.16

Objective On-Site Measured Building Results for LEED BD+C: New Construction (Version 4) IEQ Credits

	Buildings	Credit Score Scheme	Total	Indoor Air Quality and Thermal Comfort	Lighting Quality and Control	Daylight and Views
LEED-certified Buildings	Office of Information Technology	LEED	7.75	4	1.75	2
		Modified	9	3	4	2
	Miller Gorrie Center-Building Science	LEED	8	4.5	0.5	3
		Modified	9	4	2	3
	Kinesiology	LEED	8.25	4.5	1.75	2
		Modified	10	4	4	2
Non-LEED-certified Buildings	Tichenor Hall	LEED	2.5	1	0.5	1
		Modified	6	2	2	2
	Miller Hall	LEED	1.75	0	0.75	1
		Modified	5	0	3	2
	Spidle Hall	LEED	0.75	0.5	0.25	0
		Modified	4	2	1	1

Results Related to Research Questions

Research Question 1: Is the Objective Sustainable Indoor Environmental Quality Higher in a LEED-certified Building than in a Non-LEED-certified Building?

In order to answer RQ1, the final credit score schemes were analyzed by reviewing the observed sustainable IEQ factors (1) indoor air quality and comfort, (2) quality and control of lighting, (3) acoustics, and (4) daylight and views for LEED and non-LEED-certified buildings. In both scoring schemes, LEED and researcher modified, the three LEED-certified buildings resulted in higher total scores than the three non-LEED-certified buildings (see Table 4.16 and

Figure 4.1). In particular, the LEED score scheme resulted in the LEED-certified buildings achieving a total score ranging from 7.75 to 8.25, whereas scores of the non-LEED-certified buildings ranged between 0.75 and 2.5. Using the researcher modified scheme, the LEED-certified buildings achieved scores ranging from 9 to 10, and the non-LEED-certified buildings achieved scores ranging from 4 to 6.

For indoor air quality and thermal comfort, the highest possible LEED IEQ score total was 4.5. The highest possible IEQ score was 4 with the researcher modified scheme (see Table 4.13). The LEED-certified buildings received a LEED IEQ score of 4-4.5 and a researcher modified score of 3-4; whereas the non-LEED-certified buildings resulted in a LEED IEQ score of 0-1 points and a researcher modified score of 0-2. Overall, the LEED-certified buildings had little variance between the scores as shown in Table 4.16. However, with the non-LEED-certified buildings, Miller Hall did not receive any points with either scheme. This is a result of the building not meeting prerequisite 1, minimum IAQ performance (one point), having no carbon dioxide monitoring (one point), and a limited portion (33%) of occupants having thermal control (one point). Similarly to the other non-LEED-certified buildings, Miller Hall did not meet credit 2 low emitting material requirements. For indoor air quality and thermal comfort, LEED-certified buildings had a higher objective IEQ score than non-LEED-certified buildings. This is due to the LEED-certified buildings having met minimum indoor air quality strategies, carbon dioxide monitors, designed with low-emitting materials, and thermal control of individual workspaces.

For lighting control and quality, the highest possible LEED IEQ credit score was 2. The highest possible IEQ score was 5 with the researcher modified scheme. The modified scheme was 3 points higher due to the part 2 sub-categories of Credit 6. Two of the LEED-certified

buildings, Office of Information Technology and Kinesiology received 1.75 points on the LEED IEQ credit score and 4 points with the researcher modified scheme. Miller Gorrie Center- Building Science building (LEED-certified) received a 0.5 on the LEED IEQ credit score and a 2 with the modified scheme as the building provided lighting control for only 19% of occupants and met only two out of the four lighting quality part 2 sub-categories as demonstrated in Table 4.14. For the non-LEED-certified buildings, some variance occurred between the three buildings factor 2 credit score schemes: Tichenor Hall (0.5 LEED, 2 modified), Miller Hall (0.75 LEED, 3 modified), and Spidle Hall (0.25 LEED, 1 modified). The three non-LEED-certified buildings consistently did not meet Credit 6 part 1, lighting control, and Credit 6 part 2 sub-category 4, surface reflectance. The buildings did, however, each receive points for Credit 6 part 2 sub-category 2, 75% of all light source with a 24,000 hours lamp life due to campus facility maintenance strategies (see Table 4.15). Therefore, due to the LEED BD+C: New Construction IEQ sustainable lighting strategies, LEED-certified buildings have higher quality and control of lighting than non-LEED-certified buildings.

The acoustics factor could not be conducted to meet the LEED version 4 New Construction IEQ credit nine requirements. As shown in Table 4.12, the six buildings have little dB(A) variance. Therefore, there is insufficient variance in the data to say LEED or non-LEED-certified buildings excel in acoustics.

Lastly, for daylight and views, the total possible LEED IEQ credit score is 4 with the modified scheme being 3 points. Two of the LEED-certified buildings, Office of Information Technology and Kinesiology received a 2 on the LEED IEQ credit score and the modified scheme. Miller Gorrie Center- Building Science building (LEED-certified) received 3 points on the LEED IEQ credit score and the modified scheme as the building provide access to views for

75% of occupants as demonstrated in Table 4.14. Office of Information Technology provided access to view to 51% of occupants and Kinesiology to only 68%, therefore not meeting the requirement. The non-LEED-certified buildings received a 1 or below for the LEED IEQ credit score and a 2 or below for the modified scheme. Not one of the non-LEED-certified buildings received a point for Credit 7, *Daylight* as the buildings did not meet the requirement that 75% of the occupied spaces have daylight illuminance levels between 300 lux and 3,000 lux. Miller Hall and Tichenor Hall received a point for Credit 8, *Views*, however, Spidle Hall did not meet the 75% requirement having only 47% of occupied spaces with a quality view shown in Table 4.15. Therefore, the LEED-certified buildings provided more daylight and access to views than the non-LEED-certified buildings.

Overall, LEED-certified buildings have a higher score with the objective sustainable IEQ factors: (1) indoor air quality and comfort, (2) quality and control of lighting, and (3) daylight and views than non-LEED-certified buildings. Subsequently, the overall sustainable IEQ is higher in LEED-certified buildings than non-LEED-certified buildings. This means that by designing a building that complies with the LEED BD+C: New Construction rating system, IEQ buildings should have a higher quality indoor environment for occupants.

Research Question 2: Is Occupants' Satisfaction with the Sustainable Indoor Environmental Quality Higher in a LEED-certified Building than in a Non-LEED-certified Building?

To address RQ2, a one-way multivariate analysis of variance (MANOVA) was conducted to determine the difference between occupants of LEED versus non-LEED-certified buildings in their satisfaction with the sustainable IEQ factors (1) indoor air quality and comfort, (2) quality and control of lighting, (3) acoustics, and (4) daylight and views. MANOVA results revealed

significant differences between the LEED versus non-LEED-certified buildings on the dependent measures, Wilk's $\lambda = 0.853$, $F(4,193) = 8.33$, $p < .001$, partial $\eta^2 = .147$), warranting follow-up univariate analysis for each dependent variable (i.e., satisfaction with each sustainable IEQ factor). Univariate analyses of variances (ANOVAs) revealed a significant difference between the LEED and non-LEED-certified buildings in terms of the indoor air quality and thermal comfort factor, $F(1, 196) = 23.41$, $p < .001$, partial $\eta^2 = .107$ and the lighting quality and control factor, $F(1, 196) = 16.53$, $p < .001$, partial $\eta^2 = .078$. Both factors' mean scores were greater among occupants of the LEED buildings than among those of the non-LEED buildings (see Table 4.17 and Figure 4.2). On the other hand, no significant difference was detected between the LEED and non-LEED buildings in the occupants' satisfaction with acoustics $F(1, 196) = 1.020$, $p = .314$, partial $\eta^2 = .005$, and daylight and views $F(1, 196) = 0.593$, $p = .442$, partial $\eta^2 = .003$. Given these results, RQ2 is answered in that occupants' satisfaction with the sustainable indoor environmental quality is higher in a LEED-certified building than in a non-LEED-certified building, and this is particularly true for indoor air quality and thermal comfort and lighting quality and control.

To delve into the above results, a second MANOVA was conducted to determine differences among the six buildings. Following the significant MANOVA results (Wilk's $\lambda = 0.595$, $F(20,628) = 85.32$, $p < .001$, partial $\eta^2 = .122$), univariate ANOVAs showed the occupant satisfaction for indoor air quality and thermal comfort factor, $F(5, 192) = 11.48$, $p < .001$, partial $\eta^2 = .23$, the lighting quality and control factor, $F(5,192) = 7.097$, $p < .001$, partial $\eta^2 = .156$, and daylight and views, $F(5,192) = 10.275$, $p < .001$, partial $\eta^2 = .211$, were significantly different between the occupants from different buildings, while acoustics was not significantly different,

$F(5,192) = 1.92$, $p = .092$, partial $\eta^2 = .048$,. Table 4.18 and Figure 4.3 present the mean scores of each dependent variable for the six buildings.

Table 4.17

Sustainable IEQ Satisfaction Mean Scores by Building Type

Factor	Building Group	*M*	*SD*	*n*
Indoor air quality and thermal comfort	LEED-certified Building	5.50	1.096	109
	Non-LEED-certified Building	4.62	1.476	89
Lighting quality and control	LEED-certified Building	5.58	1.106	109
	Non-LEED-certified Building	4.81	1.557	89
Acoustics	LEED-certified Building	4.62	1.624	109
	Non-LEED-certified Building	4.38	1.699	89
Daylight and views	LEED-certified Building	5.06	1.957	109
	Non-LEED-certified Building	4.84	2.026	89

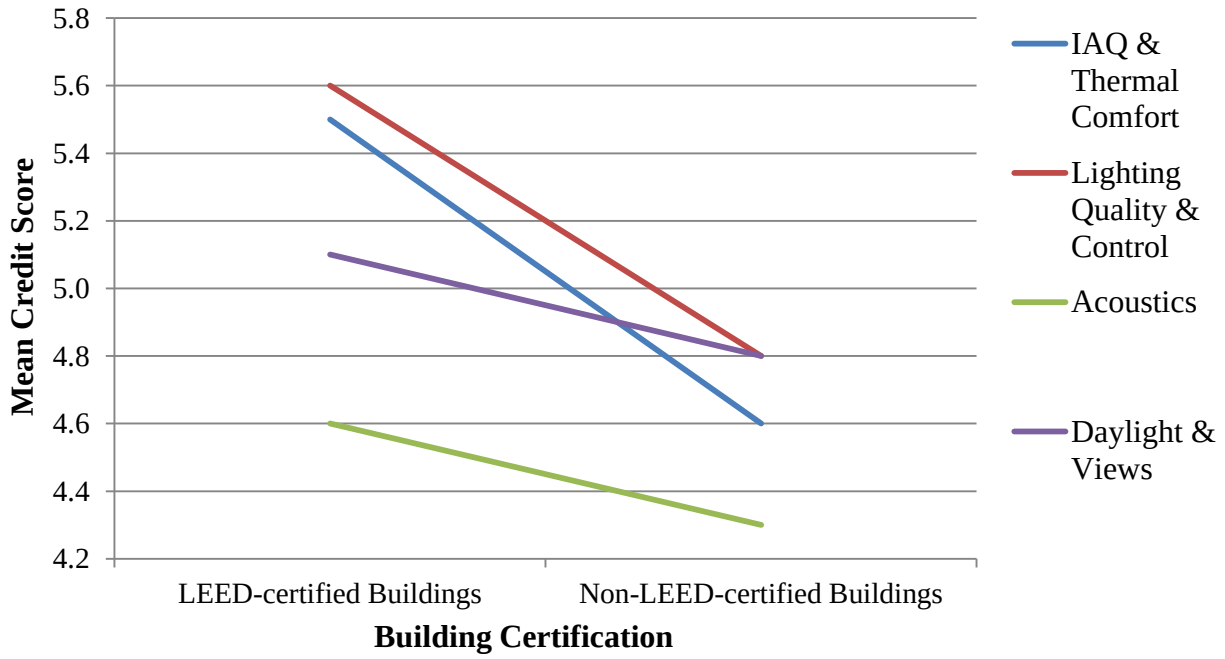


Figure 4.2. Mean Scores of Occupant Satisfaction with the Sustainable IEQ.

Tukey post-hoc tests showed that occupants from Spidle Hall had a significantly lower satisfaction with indoor air quality and thermal comfort than occupants from all five other buildings: Office of Information Technology ($p < .001$), Kinesiology ($p < .001$), Miller Gorrie Science Center ($p < .001$), Tichenor Hall ($p < .001$), and Miller Hall ($p < .05$). Occupants from Spidle Hall had statistically significantly lower satisfaction with lighting comfort and control than occupants from three other buildings: Office of Information Technology ($p < .001$), Kinesiology ($p < .001$), and Miller Hall ($p < .001$). Satisfaction with daylight and views was higher among occupants from Kinesiology ($p < .001$) and Tichenor Hall ($p < .001$) than those from the Office of Information Technology, while occupants from Spidle Hall had significantly lower satisfaction with daylight and views than occupants from Kinesiology ($p < .001$), Tichenor Hall ($p < .001$), Miller Gorrie Science Center ($p < .001$), and Miller Hall ($p = .011$).The Tukey post-hoc tests for acoustic satisfaction indicated no statistical difference between any of the six buildings.

These building analysis results indicate that unique characteristics of the buildings compromised the homogeneity within each group of buildings in that not all LEED buildings had a significantly higher satisfaction than all non-LEED buildings. However, in spite of the building differences, the results do substantiate that overall occupants of LEED-certified buildings are more satisfied with the sustainable IEQ factors than those in non-LEED-certified buildings.

Table 4.18

Descriptive Statistics of Sustainable IEQ Satisfaction by Building

Sustainable IEQ Factor	Building Group	Building	*M*	*SD*
Indoor Air Quality and thermal comfort	LEED-certified	Office of Information Tech.	5.375	.136
		Kinesiology	6.026	.276
		Miller Gorrie Science Center	5.486	.347
	Non-LEED-certified	Tichenor Hall	5.444	.245
		Miller Hall	5.038	.269
		Spidle Hall	3.985	.179
Lighting comfort and control	LEED-certified	Office of Information Tech.	5.563	.145
		Kinesiology	5.798	.294
		Miller Gorrie Science Center	5.361	.370
	Non-LEED-certified	Tichenor Hall	4.972	.262
		Miller Hall	5.717	.287
		Spidle Hall	4.322	.191
Acoustics	LEED-certified	Office of Information Tech.	4.403	.186
		Kinesiology	5.145	.376
		Miller Gorrie Science Center	5.188	.473
	Non-LEED-certified	Tichenor Hall	4.750	.335
		Miller Hall	4.688	.367
		Spidle Hall	4.044	.244
Daylight and views	LEED-certified	Office of Information Tech.	4.537	.202
		Kinesiology	6.632	.410
		Miller Gorrie Science Center	5.965	.516
	Non-LEED-certified	Tichenor Hall	6.035	.365
		Miller Hall	5.529	.400
		Spidle Hall	3.898	.266

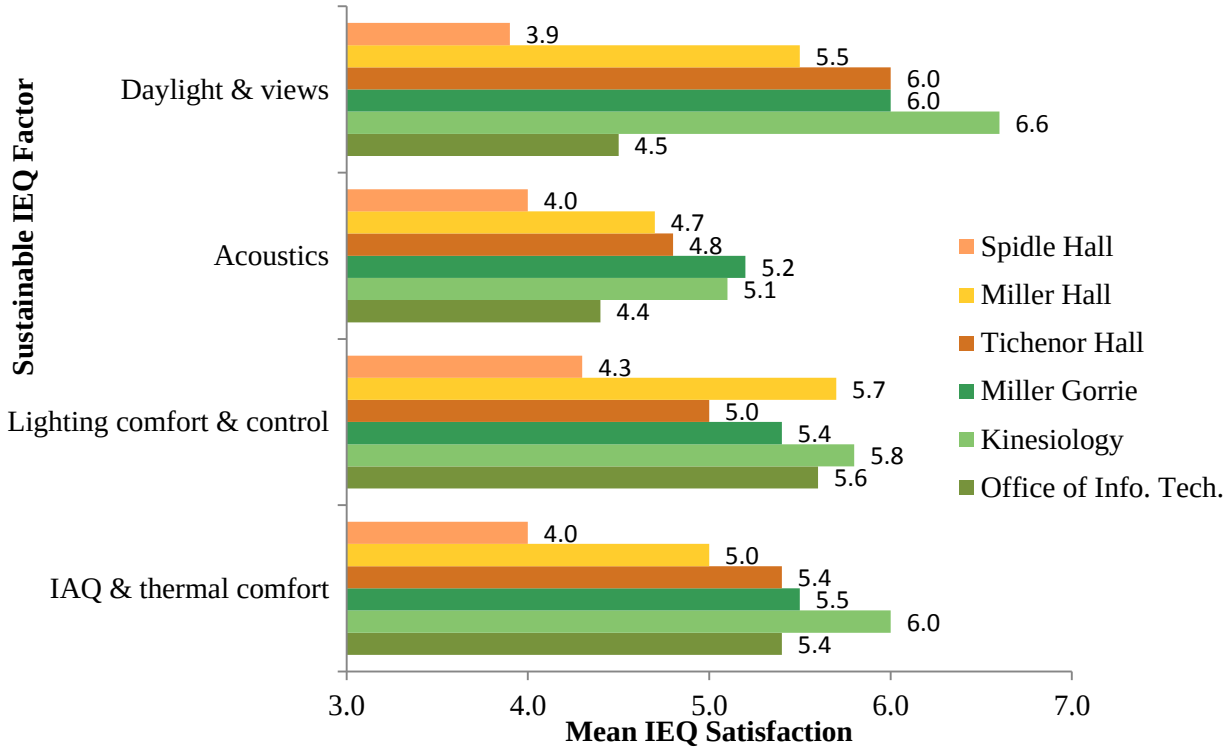


Figure 4.3. Occupant Satisfaction of the Sustainable IEQs.

Research Question 3: Is There a Relationship between a Building's Objective Sustainable IEQ and Occupants' Satisfaction with Sustainable IEQ of the Building?

To address RQ3, a series of simple linear regression analyses were conducted for the relationship between the objective IEQ score and the satisfaction with IEQ in each of the sustainable IEQ factors, except for the acoustics factor for which no significant difference between buildings was found in both the objective and satisfaction scores. The results revealed significant positive relationships in all three IEQ factors. Table 4.19 presents the regression results when the objective sustainable IEQ scores calculated based on the LEED scoring scheme were used for the analysis. The significance test results remained consistent when the objective IEQ scores based on the researcher-modified scoring scheme were used for the analysis, and the β estimates also remained very similar. In fact, this was the case for all regression results for all

the remaining research questions as well. Hence, only results from the analysis using the LEED-based objective IEQ scores are reported here for all research questions.

Table 4.19

Regression Results for the Relationship between Objective IEQ and Satisfaction with IEQ

	Factor		
	Indoor Air Quality & Thermal Comfort	Quality & Control of Lighting	Daylight & Views
Std. β	.34	.31	.20
p	< .001	< .001	<.01
adj. R²	.085	.094	.035

Research Question 4: Does Workplace Buildings' Objective Sustainable IEQ Positively Predict the Building Occupants' (a) Physical Health and (b) Psychological Health?

To address RQ4, a series of stepwise multiple regression analyses were conducted. The first stepwise multiple regression analysis was run to predict (a) physical health and (b) psychological health from the three objective sustainable IEQ factor scores: (a) indoor air quality and thermal comfort, (b) lighting control and comfort, and (c) access to daylight and views. For this analysis, the scores calculated by the LEED method were used for the objective sustainable IEQ factor scores since results from both LEED and researcher-modified scoring schemes were very similar.

The regression analyses were done both with and without control variables. The control variables were satisfaction with non-sustainability related IEQ factors such as (1) appearance, (2) privacy, (3) desk comfort, (4) chair comfort, (5) cleanliness, and (5) safety. Results from both the analyses with and without the control variables revealed that no objective sustainable IEQ factors

significantly predicted either physical or psychological health of occupants. On the other hand, one of the control variables, satisfaction with privacy significantly predicted psychological health, *std.* β =.378, p <.001, adj. R^2 =.139.

Although overall health is not a part of the research question, Kendell (2001) reviews the distinction between mental and physical illness in psychiatry literature and criticizes the studies that refer to the two health parameters as distinct and isolated measures of one's health. Kendell's view aligns with interior design research of overall self-rated health and supports the variable of overall health (Blyussen, 2014). Therefore, further analysis was done to see whether the same results would be obtained for overall health. Again, the regression analysis was conducted with and without control variables. Results from a stepwise multiple regression with overall health as the dependent variable revealed that none of the three objective sustainable IEQ factors significantly predicted overall health (p > .05), whereas the control variable of satisfaction with privacy significantly predicted overall health, *std.* β =.303, p <.001, adj. R^2 =.087. Thus, it can be concluded that objective sustainable IEQ factors are not significant predictors of health directly.

Research Question 5: Does Occupants' Satisfaction with Sustainable IEQ Positively Predict Their a) Physical Health and b) Psychological Health?

To address RQ5, several stepwise multiple regressions were conducted after confirming that the data met the assumptions of linearity, independence of errors, homoscedasticity, unusual points and normality of residuals. Again, the regression analyses were conducted both with and without the control variables.

Regressions without Control Variables

First, a stepwise multiple regression was run to predict physical health from the occupants' satisfaction with the four sustainable IEQ factors (a) indoor air quality and thermal comfort, (b) lighting control and quality, (c) acoustics, and (d) access to daylight and views. The second stepwise multiple regression with stepwise procedure was conducted for psychological health as the dependent variable with satisfaction with the IEQ factors as the independent variables. In both cases, the only predictor that significantly entered the regression models was the indoor air quality and thermal comfort factor. All others failed to enter the model due to the lack of significance. Indoor air quality and thermal comfort positively predicted physical health, *std.* β = .216, p <.01, adj. R^2 =.042, and psychological health, *std.* β = .318,, p <.001, adj. R^2 =.096. The adjusted R^2 indicates that 4.2% of the variance of the occupants' physical health and 9.6% for psychological health were explained by the variance in their satisfaction with indoor air quality and thermal comfort of their office workspace.

Although not part of the original research question, a multiple regression was conducted to predict overall health from the occupants' satisfaction with the four sustainable IEQ factors. In addition to the indoor air quality and thermal comfort factor (*std.* β = .224, p < .01), the acoustics factor (*std.* β = .152, p < .05) also significantly predicted overall health, $F(2,195)$= 10.99, p <.001, adj. R^2 =.092.

Regressions with Control Variables

From the priori conceptual model (see Figure 1.2), satisfaction with (1) appearance, (2) privacy, (3) desk comfort, (4) chair comfort, (5) cleanliness, and (5) safety were considered as possible control variables in predicting health. Therefore, stepwise multiple regressions explained in the previous section were repeated this time with the inclusion of these control

variables as additional predictors. Results again revealed indoor air quality and thermal comfort as the only significant predictor of physical health. All control variables failed to enter the model. The indoor air quality and thermal comfort variable statistically predicts physical health significantly, *std.* β = .22, p < .01, adj. R^2 =.042.

For psychological health, in addition to the indoor air quality and thermal comfort factor (*std.* β = .21, p < .01), which was also significant in the analysis without the control variables, a control variable, satisfaction with privacy (*std.* β = .302, p < .001) also was found to significantly predict psychological health, $F(2,193) = 21.39$, $p < .001$ adj. $R^2 = .17$. All other control variables failed to enter the model.

To predict overall health, while indoor air quality and thermal comfort (*std.* β = .197, p < .01) remained significant in the model with the control variables, the acoustics factor, which was significant in the model without the control variables, became non-significant. Instead, the control variable, satisfaction with privacy (*std.* β = .232, p < .01) again was found to be a significant positive predictor of overall health, $F(2,193) = 13.83$, p <.001, adj. R^2 =.116. All the other independent variables were also not significant.

Research Question 6: Does Occupants' Satisfaction with Sustainable IEQ Positively Predict the Occupants' Workplace Wellbeing through its Influence on the Occupants' Physical and Psychological Health?

To address RQ6, a series of stepwise multiple regression analyses were conducted to test the mediation effect of physical and psychological health for the relationship between satisfaction with sustainable IEQ and workplace wellbeing. According to Baron and Kenney (1986), for a mediation to exist, three conditions must be met: (1) the independent variable (i.e., satisfaction with sustainable IEQ) should significantly predict the mediator (i.e., physical and

psychological health); (2) the mediator should significantly predict the outcome variable (i.e., workplace wellbeing); and (3) the relationship between the independent variable and the outcome variable should be non-significant when the relationship between the mediator and the outcome variable is controlled for (i.e., when both the mediator and the independent variables are modeled as predictors).

RQ5 related results presented in the previous section show that the first condition of mediation was partially met because occupants' satisfaction with indoor air quality and thermal comfort (independent variable) significantly predicted both physical and psychological health (mediator).

To test whether the data met the second condition of mediation, a stepwise multiple regression was run to predict occupant workplace wellbeing (dependent variable) from physical health and psychological health (mediator). In addition, to control for the potential confounding effect of job satisfaction on workplace wellbeing, which is strongly suggested by the literature (Wilks & Neto, 2013; Wright & Bonett, 2007), job satisfaction was also added to the regression model as a control variable. The results of the stepwise regression revealed that physical health (*std.* β = .205, $p < .001$), psychological health (*std.* β = .465, $p < .001$), and job satisfaction (*std.* β = .193, $p < .001$) were all significant factors that positively influenced occupant workplace wellbeing, $F(3,194) = 55.71$, $p < .001$, adj. $R^2 = .454$. This result indicates that the second condition of mediation was met.

To address the third condition of mediation, another stepwise multiple regression was run to predict occupant workplace wellbeing (dependent variable) from both the mediators (physical and psychological health) and the independent variables (satisfaction with the four sustainable IEQ factors). In addition, job satisfaction was again included as the control variable in this model.

Results revealed that significant influences of the two mediators-- physical health (*std.* β = .204, $p < .001$) and psychological health (*std.* β = .441, $p < .001$)—as well as the control variable, job satisfaction (*std.* β = .173, $p < .01$) on workplace wellbeing. Further, the influence of satisfaction with indoor air quality and thermal comfort, which was the only significant independent variable for physical and psychological health (mediators), was non-significant ($p < .05$); whereas satisfaction with acoustics, which was not a significant predictor of physical and psychological health, turned out to be a significant direct predictor of workplace wellbeing (*std.* β = .129, $p < .05$), $F(4,192) = 44.289$, $p < .001$, adj. $R^2 = .469$. These results demonstrate that the influence of satisfaction with indoor air quality and thermal comfort on workplace wellbeing occurs through its role in enhancing physical health and psychological health as the mediators. This mediation effect of health did not occur for the relationship between satisfaction with the other three sustainable IEQ factors and workplace wellbeing because of the absence of their relationship to physical or psychological health. However, it is interesting to note that satisfaction with acoustics was found to have a direct influence on workplace wellbeing despite that it did not affect physical or psychological health.

CHAPTER 5: DISCUSSION

The purpose of this study is to examine how workplace wellbeing is influenced by the sustainable quality of the workplace indoor environment, specifically by working in a Leadership in Energy and Environmental Design (LEED)-certified building (vs. a non-LEED-certified building), through enhanced physical and psychological health. This chapter summarizes and discusses significant findings from the occupant survey and the field observations of the six Auburn University (AU) buildings. This will be followed by a discussion of the theoretical and practical implications of the findings, limitations of the study, and recommendations for future research.

Summary and Discussion of Findings

This ex-post facto research study was a blend of field observations of six LEED-certified and non-LEED-certified buildings on the AU campus (Phase 1) and a web-based survey with a sample of the occupants of the six buildings who are AU employees (Phase 2). In Phase 1, the on-site measurements and observations employed the LEED Building Design and Construction (BD+C): New Construction and Major Renovation version 4 indoor environmental quality (IEQ) prerequisites and credits as the determinant for objective sustainable IEQ. In Phase 2, occupants of the six buildings participated in a web-based survey addressing satisfaction with sustainable and non-sustainability related IEQ factors, self-rated physical and psychological health, workplace wellbeing, and job satisfaction. Findings for each research question are discussed in terms of their significance to the literature as follows.

Research Question 1: Objective Sustainable IEQ in LEED-certified versus non-LEED-certified Buildings

RQ1 addresses whether the objective sustainable IEQ is higher in LEED-certified buildings than in non-LEED-certified buildings through analyses of the observed sustainable IEQ factors--(1) indoor air quality and comfort, (2) quality and control of lighting, and (3) daylight and views-- as prescribed by the LEED BD+C: New Construction version 4 IEQ credits. Scores for objective sustainable IEQ factors were generally higher in the LEED-certified buildings than in the non-LEED-certified buildings, with only one exception (the lighting quality and control score of Miller-Gorrie Center-Building Science, which is LEED-certified, was equal to or smaller than the scores of two non-LEED-certified buildings). Therefore, the finding of the higher objective IEQ sustainability score in LEED-certified buildings supports the argument made by Ghodrati et al. (2012) that buildings with sustainable IEQ features based on the LEED IEQ credits have better IEQ than non-LEED-certified buildings. By using sustainable strategies in building design that are required to meet LEED certification criteria, buildings may achieve a higher sustainable indoor environmental quality than does a conventionally designed building that does not consciously implement such sustainable strategies.

To the researcher's knowledge, this study represents the most explicit comparison of the objective sustainable IEQ between LEED-certified buildings and non-LEED-certified buildings, especially using the LEED BD+C: New Construction version 4 IEQ credits as the benchmark for sustainability. In fact, the researcher did not find a single study categorically utilizing one of the six versions (e.g. versions 1.0, 2.0, 2.1, 2.2, 2009, 4.0) of the LEED certification IEQ credits as the measure of sustainability in a post-occupancy objective assessment. Moreover, post-occupancy objective assessments that evaluate sustainable IEQ performance comparatively

between LEED-certified buildings and non-LEED-certified buildings are scarce. Newsham et al. (2012) compared the objective IEQ between sustainable buildings, which were mostly LEED-certified, and conventional buildings, but failed to demonstrate significant differences in the IEQ between the sustainable and conventional buildings. But, Newsham et al.'s study did not use LEED certification IEQ credits to assess the buildings' IEQ; instead, they used various professional standards (e.g. ASTM standard for sound, ANSI 2004 for lighting illuminance, ASHRAE 55.2004 for indoor air quality, etc.). LEED BD+C: New Construction version 4 uses many of the same professional standards, specifically ASHRAE 2010 for sound and indoor air quality, but not the ANSI 2004 for lighting illuminance. The variations in the version of the standard may account for the variance in findings.

Research Question 2: Occupant Satisfaction with Sustainable IEQ in LEED-certified versus non-LEED-certified Buildings

RQ2 addressed the sustainable IEQ in LEED-certified buildings and non-LEED-certified buildings through the evaluation of the occupants' satisfaction as determined by the web-based survey data. In this study, occupants of LEED-certified buildings were equally satisfied to or more satisfied than those of non-LEED-certified buildings. Specifically, occupants' satisfaction was higher in LEED-certified buildings in the indoor air quality and thermal comfort factor and the lighting quality and control factor. The findings suggest that the sustainable design of the IEQ of the building can result in higher occupant satisfaction with sustainable IEQ factors. This direct relationship substantiates with the user-centered theory that the environment impacts user perception such that a higher quality environment, designed with sustainable strategies, results in a higher perception of the space through occupant satisfaction (Vischer, 2008). Furthermore, the user-centered theory ascertains a component of building performance assessment is through the

perception of its occupants (Vischer, 2008). This connection between the quality of the indoor environment and occupant perception is critical for those who engage both in the ownership, design, and maintenance of buildings.

On the other hand, the occupants of LEED- and non-LEED-certified buildings were equally satisfied with acoustics and daylight and views. This result may be contributed by the building's exterior and interior design features. For example, five of the six buildings (except the Office of Information Technology building) had the majority of employees assigned to work in private offices along the perimeter of the building, which would result in access to daylight and views, and control over acoustics explaining the lack of occupant satisfaction difference by employees in a LEED-certified buildings and non-LEED-certified buildings. The Office of Information Technology building was designed with open offices using high panel systems with doors to help provide acoustical control and privacy for the occupants. However, the high panels resulted in a lack of daylight and access to views for many occupants.

The findings of this study are comparable to the one CBE study that determined occupants of LEED-certified buildings had a higher satisfaction with thermal comfort and air quality than non-LEED-certified buildings (Abbaszadeh et al., 2006). However, the study (Abbaszadeh et al., 2006) did not find lighting quality and control to have any measurable difference between the two building types (LEED-certified and non-LEED-certified buildings). In contrast, the Altomonte and Schiavon (2013) study established that occupants of LEED-certified buildings had lower satisfaction with the amount of light, privacy, and temperature than non-LEED-certified buildings. Nevertheless, it is important to recognize that these differences in findings may be due to the locations of the buildings assessed, building age, occupancy type, and building design. Conversely, the present study controlled for the occupancy type by selecting

buildings with offices, classrooms, laboratories, and conference spaces from a single ownership (e.g. Auburn University). By selecting buildings from one organization, several confounding factors such as company culture, employee activities, maintenance and operations, and overall master facility plans are minimized. Further, the building characteristics (common gross square footage (size), architectural style, and geographical location) were considered during the building selection. By controlling for the building characteristics, the confounding variables are reduced enabling the researcher to specifically address satisfaction with the sustainable IEQ.

Research Question 3: Objective Sustainable IEQ and Satisfaction with Sustainable IEQ

RQ3 addressed the relationship between the objectively and subjectively measured sustainable IEQ. In all three sustainable IEQ factors considered in this study, (1) indoor air quality and comfort, (2) lighting quality and control, and (3) daylight and views, a positive relationship was found between the buildings' objectively assessed sustainable IEQ scores and the occupants' subjectively felt satisfaction. In other words, a higher quality sustainable indoor environment results in higher occupant satisfaction.

Newsham et al. (2012) assessed the physical objective IEQ and conducted occupant surveys (n = 2545) from 24 buildings (12 LEED-certified, 12 non-LEED-certified) and found higher quality physical conditions of lighting, access to daylight, and indoor air quality resulted in higher occupant satisfaction. Hedge et al. (2014) indicated in their study of two LEED-certified buildings and one non-LEED-certified building that occupants were more satisfied by the better daylight and indoor air quality in the LEED-certified buildings. Both Newsham et al.'s and Hedge et al.'s studies affirm the findings of this study indicating that the design of higher quality built environments, specifically the sustainable indoor environments, result in higher satisfaction in the building occupants.

Moreover, by showing that the objective sustainable IEQ, as measured post-occupancy using the LEED B+D: New Construction IEQ credits, is significantly related to occupant satisfaction, this study demonstrates that the way the U.S. Green Building Council (USGBC) has distributed and designed the strategies of the LEED IEQ credits has some level of validity, in terms of its connection to the way occupants perceive the IEQ. However, the magnitude of the relationship between objective IEQ and satisfaction with IEQ was moderate, with standardized βs ranging .20 and .34, indicating the LEED B+D: New Construction IEQ credits and scoring system are still away from perfectly capturing what make occupants satisfied.

Research Questions 4 and 5: Sustainable IEQ and Physical and Psychological Health

RQ4 and RQ5 addressed whether the building occupants' physical and psychological health are linked to the buildings' objective sustainable IEQ and occupants' satisfaction with sustainable IEQ, respectively. Results from this study reveal no significant direct connection between objective sustainable IEQ of the buildings and their occupants' physical or psychological health. However, occupants' satisfaction with sustainable IEQ, specifically satisfaction with indoor air quality and thermal comfort, does have a significant direct influence on physical and psychological health. This result corroborates Steemers and Manchanda's (2010) finding from a study of 12 office buildings where they found that satisfaction with indoor air quality and thermal comfort and overall occupant satisfaction were significantly related to self-reported health as well as the finding from Newsham et al. (2012) which correlated the quality of indoor air to employee absences due to illness (i.e., poor health). Steemers and Manchanda (2010) concluded that occupants who were satisfied with their work environment were more productive and comfortable and reported better health. The Newsham et al.'s (2012) study correlated the quality of indoor air to employee absences due to illness (i.e., poor health).

This study fails to produce evidence for a direct relationship between objective sustainable IEQ and occupant health. However, given the RQ3 related finding that a high objective sustainable IEQ positively influence occupants' satisfaction with the sustainable IEQ, it is feasible that objective sustainable IEQ of the building may indirectly impact occupant physical and psychological health by its influence on occupant satisfaction. Further, objective sustainable IEQ and occupants' satisfaction with the sustainable IEQ is better in LEED-certified buildings versus non-LEED-certified buildings. As a result, one may infer working in a LEED-certified building results in better occupant health supporting the argument made by the USGBC regarding the LEED sustainable building program (Green Building Education Services [GBES], 2011). This argument agrees with the findings of Hedge et al. (2014) who reported that occupants of LEED-certified buildings reported a higher sense of IEQ satisfaction and better self-reported health than those of the non-LEED-certified building and is further substantiated by Newsham et al. (2012) that reported LEED-certified building occupants recording better subjective physical health than non-LEED-certified occupants.

Research Question 6: Satisfaction with Sustainable IEQ, Health, and Workplace Wellbeing

RQ6 addressed whether occupants' satisfaction with sustainable IEQ anticipated the occupants' workplace wellbeing through its influence on the occupants' physical and psychological health. This study reveals that occupants' satisfaction with indoor air quality and thermal comfort positively indirectly influence the occupants' workplace wellbeing by enhancing their physical and psychological health, whereas, occupants' satisfaction with acoustics of their building directly influences the occupants' workplace wellbeing. Hedge et al. (2014) reported a strong correlation between occupant concerns regarding indoor air quality, thermal comfort and acoustics, as it related to their health and work productivity. Previous literature sporadically

addressed the relationship between satisfaction with IEQ and health (e.g., Ghodrati et al., 2012; Hedge et al., 2014; Newsham et al., 2012; Singh et al., 2010; Steemers & Manchanda, 2010) and that between health and wellbeing (e.g., Heerwagen, 1998; Steemers & Manchanda, 2010), but little empirically tested the effect of satisfaction with IEQ on wellbeing that is mediated by health in a single study. Therefore, this study addresses this gap.

Significance of the Study

Theoretical Implications

This study design and findings have several implications for the interior design literature. Broadly speaking, through the examination of the macro phenomenon of working in a sustainable building, evaluation of the objective and subjective sustainable IEQ, occupant health (physical and psychological) and overall workplace wellbeing, this study identifies the relationships among these variables as an integral part of the indoor environment experience, with the user's satisfaction of the environment at the center of the phenomenon (Vischer, 2008). In doing so, this study contributes to the IEQ research by establishing the connection between sustainable IEQ satisfaction and workplace wellbeing mediated by health (physical and psychological).

More specifically, first, the findings that LEED-certified buildings showed superior objective IEQ performance as well as produced higher occupant satisfaction with the IEQ than did non-LEED-certified buildings provide verification that by embracing LEED certification in construction of buildings, the IEQ, in both objective and subjective terms, is enhanced by the sustainable strategies predicated by the LEED credit category requirements. Recently, there has been negative attention toward the LEED certification rating system (e.g. banning of public funds towards the construction of buildings with the intent to pursue LEED certification)

(Melton, 2012). Therefore, these findings support proponents of the LEED certification program through empirical evidence that LEED-certified buildings provide an enhanced objective and subjective indoor environment, which has been lacking in the existing literature.

Next, IEQ research has been lacking in quantitative measures that employ both an objective and subjective measure to assess IEQ, specifically in relation to the LEED IEQ credits (Steemers & Manchanda, 2010). Therefore, the fact that objective IEQ, as measured using LEED IEQ credits, is significantly related to occupant satisfaction is an important contribution. The outcome that a positive linear relationship exists between objective and subjective IEQ may cause one to ask if the subjective measure is sufficient single-handedly to assess the quality of the sustainable indoor environment. Without the objective assessment, one may interpret the findings of RQ2 (acoustics, daylight and views equal in LEED-certified and non-LEED-certified buildings) as LEED-certified buildings having the same objective IEQ as non-LEED-certified buildings. However, the objective assessment indicates that LEED-certified buildings rate higher than non-LEED-certified buildings for daylight and views. Therefore, the engagement of objective and subjective measurement of IEQ is critical to provide a comprehensive view of a building's performance.

Fourth, to the researcher's knowledge, no previous research has been undertaken within the sustainable built environment where the relationships of IEQ with health and workplace wellbeing are considered separately. Several studies of satisfaction with IEQ infer the outcomes of wellbeing without empirically supporting the postulation (Leaman & Bordass, 2007; Schell et al., 2012; Steemers & Manchanda, 2010; Veitch et al., 2003). Moreover, a number of studies describe wellbeing as psychological health (Heerwagen, 1998; Smith & Pitt, 2009; Steemers & Manchanda, 2010); however, literature provides evidence that psychological health is a separate

dimensions of workplace wellbeing (Blyussen, 2014; Canadian Mental Health Association, n.d.; Danko et al., 1990; World Health Organization, 1948). In the same way, other IEQ satisfaction studies operationalize the measure of workplace wellbeing as job satisfaction (Newsham et al., 2012) or productivity (Heerwagen, 1998; Singh, Syal, Grady, & Korkmaz, 2010; Steemers & Manchanda, 2010). Yet, Wilks and Neto (2013) and Wright and Bonett (2007) determine that job satisfaction is distinct from workplace wellbeing, as it tends to be less of an emotional and spontaneous response. For example, Newsham et al. used a single workplace job satisfaction item to determine workplace wellbeing (2012). Therefore, this study is the first to identify health and workplace wellbeing, as separate dimensions, influenced by IEQ satisfaction. Further, this study statistically controlled for the effect of job satisfaction on workplace wellbeing in the analysis of the relationship between satisfaction with IEQ and workplace wellbeing. In doing so, this study captured the concept of workplace wellbeing (beyond just job satisfaction) that may be influenced by the indoor environmental factors of the workplace.

Practical Implications

This study also has implications with practical significance. First, from a business strategy perspective, findings of this study provide insight related to endeavors to increase employee job satisfaction, productivity, and decreased absenteeism through the identified indoor environmental factor (acoustics and indoor air quality and thermal comfort) that indirectly influenced employees' workplace wellbeing. The components that should be considered to provide enhanced indoor air and thermal comfort include low number of airborne particles including allergens, high quality air filters, naturally ventilated HVAC system, low emitting materials, and provide occupant adjustable humidity, temperature, and air movement (USGBC,

2013). This aligns with the commissioning and goal identification required by LEED certification as part of the integrated project delivery (USGBC, 2013c).

Further, this study determined that occupants' satisfaction with acoustics of their building directly influenced the occupants' physical and psychological health. The indirect and direct costs of poor wellbeing and health to payroll can total 25% to 35% due to employee insurance, absenteeism, disability, presenteeism, and illness resulting in medical and pharmaceutical care (Chenoweth, 2011). However, according to the research from The Healthways Center of Health Research published whitepaper, the positive effects of improved wellbeing result in lower healthcare costs and increased productivity by 5% (Healthways, 2011). Further, their research suggests a decrease in unscheduled absences (5%), lower presenteeism (24%), lower medical costs (60%), and lower prescription costs (66%) (Healthways, 2011). These findings substantiate the importance of employee health and workplace wellbeing and the subsequent importance of an occupant's satisfaction with acoustics. Acoustics is especially important to businesses who intend to provide open plan offices for their employees. Kim and de Dear (2013) identified that private offices outperformed open plan workspaces in satisfaction with IEQ, particularly in acoustics, privacy and proxemics. Those in open plan workspaces identified visual privacy and noise level as the highest priority for improvement contradicting the assumption that open plan environments improved communication and IEQ satisfaction (Kim & de Dear, 2013). Therefore, the planning and design of open plan offices need to provide a level of acoustics and privacy in order to prevent decreased satisfaction with IEQ and subsequent workplace wellbeing and health impacts.

In regards to interior design education and professional practice, the findings confirm the importance of sustainability and building system as integral components of indoor environments.

A shocking reality is that among the 88, 767 LEED Credentials, Accredited Professionals (AP) and Green Associates throughout the United States and Canada, less than 5,000 identify themselves as practicing in the area of interior design, which is only 5.37% (USGBC, 2013e). This data excludes the 106, 640 LEED credentials prior to 2009 where individuals did not specialize in a particular LEED Rating System such as BD+C. Previous studies have been conducted to determine the interior designer's role with sustainable energy and daylighting (Theodorson, 2014), and building information modeling (Lee, 2012). Interior designers play two critical roles in sustainable design of the built environment (1) actively engagement in the integrate design process to ensure their defined responsibilities interconnects in support of the sustainable goals, and (2) conditioning of the building occupants to change their behavior in support of sustainable operations (Sorrento, 2012). The significant leadership role of the interior designer is to be an advocate for end users and exemplars of collaboration (Theodorson, 2014). The relationship between the lack of LEED credentialed interior designers and the significance of an interior designer's sustainable practice needs to be rectified. For this reason, the interior design practitioners need to become more engaged with LEED certification through becoming credentialed. Once credentialed, access to the dissemination of relevant and current sustainability information is critical to the success of high quality indoor environments. This means emerging professionals require sustainable education integrated throughout their interior design curriculums to prepare for collaborating on sustainable integrated design teams. The emphasis of sustainability should focus on the IEQ factors specifically in the area of occupant satisfaction with indoor air quality, acoustics, and privacy. For interior design practitioners, continuing education courses and post-occupancy evaluations will provide the means to gain critical insights into occupant satisfaction. By focusing on these areas, higher quality indoor environments are

developed enhancing occupant health and wellbeing. This approach aligns with the interior designer's fundamental responsibility to support the health, safety and wellbeing of occupants through enhancing their quality of life in the interior environment (Guerin & Kwon, 2010). Essentially, the heart of interior design practice is human sustainability (Guerin & Kwon, 2010).

Lastly, although the LEED BD+C: New Construction (version 4) IEQ credits and scoring system had some validity, it is not designed for post-occupancy assessment. To date, an official LEED IEQ post-occupancy evaluation does not exist; therefore, the development of a LEED IEQ post-occupancy evaluation (objective and subjective) for LEED-certified buildings would address potential concerns with performance and would integrate into revisions/additions to the future versions of the LEED certification system. This study shows that continuous efforts need to be made by certification bodies such as LEED to continuously update their credits and standards to reflect what really matters to occupants (given the only moderate relationship between objective and subjective IEQ found in this study).

Limitations and Recommendations

Findings of this study must be interpreted with caution in light of several methodological and conceptual limitations. First, the selection of the buildings and sample was restricted to the Auburn University (AU) campus suggesting a limitation in the external validity of this study. The variety and options the AU building database provided for LEED-certified and non-LEED-certified buildings were limited by the campus architectural style, regional influence, history, geographical influences, and sustainable values. Therefore, the generalizability of the findings to other LEED-certified and non-LEED-certified buildings is limited. Further, this restriction to AU buildings meant all campus buildings met regulated standards for construction, maintenance, and operations resulting in little variance in a couple of the objective measures (i.e. all buildings met

prerequisite 2 smoking area distances from buildings). Future comparative research studies, between LEED-certified and non-LEED-certified buildings, require a larger sample of buildings, specifically LEED-certified buildings. Equally important is that the future comparative studies to included non-LEED-certified buildings constructed since 1998, preferably the same year as the comparative LEED-certified building sample. Alternatively, to a traditional comparative study, future research should assemble a non-LEED-certified IEQ performance database to establish performance benchmarks. The database would provide the benchmarks of non-LEED-certified building performance to subsequently evaluate LEED-certified buildings. The database would allow a researcher to conduct objective IEQ assessment of LEED-certified buildings with the subsequent analysis against a national database of non-LEED-certified buildings. In addition, the non-LEED-certified IEQ performance database would establish conventional benchmarks to determine the excellence in building construction through sustainable IEQ strategies achieved by LEED-certified buildings. The potential geographical scale and size of a database may identify if LEED IEQ credits sufficiently excel above the conventional models of modern construction.

Second, the selection of the buildings and sample also implies potential issues with internal validity. Despite the effort to choose buildings with similar structure, usage, and history, variances inevitably existed among the selected buildings in terms of square footage, age, number of renovations, operational standards at time of build/renovation, department needs and uses, which might have introduced confounding effects in the comparison of LEED-certified and non-LEED-certified buildings. For example, the inferiority of Spidle Hall within the non-LEED-certified building group and the differential building use/design of the Office of Information Technology building within the LEED-certified building group might have introduced more unexplained errors in the comparison analysis for LEED- versus non-LEED-

certified buildings. As long as these types of studies are conducted post-occupancy, building characters will continue to impact direct comparisons of sustainable versus conventional (or LEED-certified vs. non-LEED-certified) buildings. Future research in building selection should endeavor to development protocols for the selection of comparative buildings. Whether, within the umbrella of a comparative building protocol or without, future research into the characteristics that make a building unique, yet homogeneous within a group is needed. In short, the exploration of building characteristics that matters to comparative IEQ assessments (e.g. when is a pairing too homogeneous) needs to be explored for researchers to make future building selections.

Next, the fact that this study was conducted at a single point in time which affixed the user and the built environment as permanent non-changing rather than a dynamic adjusting inter-relationship as defined in the user-centered theory could be considered a limitation (Stokols, 1992; Vischer 2008). In particular, LEED IEQ credit 7 *Daylight* required the daylight readings be obtained during two different times of year and between the hours of 9 a.m. and 3 p.m. (USGBC, 2013). Unfortunately, the timing of this study did not provide the opportunity to complete both readings, and was limited by the availability of the buildings' on-site coordinators often taking readings before or after the prescribed times (see Table 3.6 for breakdown of visits). In conjunction with the time of day of the readings was the influence of varying weather. Some days had clear skies and others were overcast potentially impacting the LEED IEQ credit 7 *Daylight* readings. Further to the affixed single point of time limitation of site verifications, the occupant survey was also conducted only once over the course of the study. Satisfaction, health, and workplace wellbeing can change over time, and thus assessing these measures repeatedly at varying yearly intervals and ranges can provide more insight on whether the occupants'

relationship to the indoor environment changes as weather, work intensity, changes in health, and or any other unforeseen aspects that may impact the overall assessment of the sustainable IEQ and occupant health and wellbeing in the dynamic adjusting inter-relationship, as proposed by the user-centered theory (Vischer, 2008). Therefore, future research should consider a longitudinal approach to capture the changing objective indoor environmental quality as well as occupant perceptions. A longitudinal approach may increase the conceptuality and the sample size, enhance external and internal validity, and address methodological limitations of this study that did not allow the researcher to draw a clear causality of the relationships. For example, an occupant with poor health may be more sensitive to their environment's imperfections, subsequently reporting lower satisfaction with the sustainable IEQ, rather than the environment causing the occupant's health to degrade. Therefore, a longitudinal study would enable a broader understanding of satisfaction, health and workplace wellbeing as it changes over time with university calendars (e.g. start of a semester more stressful) and with the seasons providing differences of IEQ through thermal comfort and quality of daylight.

Fourth, the student users of the AU buildings are classified by USGBC as transient occupants and therefore are not identified as full-time equivalent occupants (GBES, 2011). For this reason, the student user was not part of the sample of this study. Stokols (1992) explained through the social ecological perspective that wellbeing of occupants is multifaceted including "both the physical environment (e.g., geography, architecture, and technology) and the social environment (e.g., culture, economics, and politics)" (p. 7). Therefore, it should be recognized that the student user group is a component of the social environment and may impact workplace wellbeing of the participants of the university campus, which is not captured in this study. Extension of this study to include the student occupant would capture a broader spectrum of

satisfaction with the IEQ. To magnify this concept further, the measure of workplace wellbeing should be adapted to better capture the social environment of the AU campus employees which includes students. Further, the inclusion of students may provide different views on the IEQ, especially taking into account the different type of student interactions within a university building. For example, student interaction may be limited to a couple hours a week in a classroom to spending 40 to 50 hours a week in a building engaged in lab or studio activities. The student occupant provides a unique opportunity in future research to explore the differences in IEQ satisfaction between student interaction groups and between full-time employees and students.

Fifth, findings of this study were also limited by the choice of survey instruments used to assess the variables of interest such as satisfaction with IEQ, health, and workplace wellbeing. For example, the workplace wellbeing measure and the measure for the control variable, job satisfaction were worded very similarly, making it challenging to establish their discriminant validity. As a result, the final workplace wellbeing items were reduced from four to two items, after deleting two items conceptually similar to job satisfaction. The workplace wellbeing measure requires review, replacement, or additional items to enhance the validity in future research. Further, this is the first study to use the SF-12 Short-Form Health Survey in conjunction with satisfaction with IEQ. Therefore, it is unknown if the SF-12 Short-Form Health Survey fully captured a complete perspective regarding the impacts of occupant satisfaction with IEQ on their health. In addition, it is unknown if the measurement of self-reported subjective health or objective external assessment would better disentangle and provide increased insight into the relationship between occupant satisfaction with IEQ and health. Future research should include analysis of the two types of health measurements (objective and subjective) in relation to

IEQ satisfaction and explore if an alternative self-reported health measure would provide a different outcome. The objective measure of health may be independent, dependent, or may be one measure of health as it relates to the built environment. Further, the causality of the relationship between satisfaction with the sustainable IEQ and health should be explored in future research.

Lastly, although the IEQ satisfaction measure was adapted from Veitch et al. (2007), it is unknown if the satisfaction measure captured all potentially important sustainable IEQ features, specifically from the occupant's perspective. Therefore, future research should explore the sustainable IEQ features and evaluate the relevance to occupants. In fact, occupant awareness of their satisfaction on a sub-conscious level (e.g. IEQ dimensions outside an occupant's perception) should be further explored to better capture a more complete understanding of the impacts of the indoor environment on health and wellbeing. For all survey measures, future research would benefit from interviews or focus groups to gain valuable insights regarding all dimensions, specifically with satisfaction with IEQ, self-reported health, and workplace wellbeing.

Finally, the use of the LEED BD+C: New Construction version 4 IEQ prerequisites and credits as a measure of the objective sustainable IEQ could be seen as a limitation. The sustainable certification is intended for new buildings and not designed for post-occupancy measurements. As such, a number of the credits could not be assessed (credit 3 and 4), and several were difficult as availability of the building specifications was limited. This complicated the interpretation, measurement, and full completion as some items could not be assessed such as acoustics. The assessment of the objective sustainable IEQ was limited by the tools to measure the acoustics and daylight, as calibration and accuracy may have been compromised. Future resources should

be devoted to developing cost-effective measurement tools that are easy to calibrate across multiple devices and provide accurate results. Further, as indicated by the relatively low, although statistically significant, relationship between objective sustainable IEQ and satisfaction with sustainable IEQ, the LEED credit based IEQ measure may not capture all potentially important sustainable IEQ features that matter to occupants. More future research is needed to solidify the important sustainable IEQ features with subsequent evaluation of the LEED IEQ credit base to determine if the use of the construction credits as a post-occupancy sustainable measure is valid. This evaluation may have implications for further versions of LEED certification, LEED pilot credits, or other sustainable building standard developments. Another approach to understanding the relationship between a sustainably constructed environment and occupant health and wellbeing is to duplicating the study with the LEED Buildings Operations and Management (O+M): Existing Buildings rating system to determine if that better captures post-occupancy evaluation of the indoor environment. Additionally, the study could be duplicated using an alternative sustainable rating system such as the Living Building Challenge or the WELL Standard. By exploring alternative sustainable rating systems, commonalities and differences will be determined from the ease of objective measurement to identifying the best tools to assess occupant satisfaction and the impacts on their health and wellbeing.

REFERENCES

Abbaszadeh, S., Zagreus, L., Lehrer, D., & Huizenga, C. (2006). Occupant satisfaction with indoor environmental quality in green buildings. *Proceedings of Healthy Buildings, Lisbon, Portugal, 3*, 365-370. Retrieved from http://www.cbe.berkeley.edu/research /briefs-LEED.htm

Altman, I. (1975). *The environment and social behavior: privacy, personal space, territory, crowding.* Monterey, CA: Brooks/Cole.

Altomonte, S., & Schiavon, S. (2013). Occupant satisfaction in LEED and non-LEED certified buildings. *Building and Environment, 68*, 66-76. doi: 10.1016/j.buildenv.2013.06.008

ASHRAE. (2004). *Thermal environmental conditions for human occupancy: ASHRAE Standard 55-2004*. Retrieved from http://www.almasesepahan.com/fh/download/ASHRAE_ Thermal_Comfort_Standard.pdf

Auburn University (2013). *Auburn University Campus Map 2013-14*. Retrieved from https://cws.auburn.edu/map/Content/files/pdf/CampusMapPrint.pdf

Auburn University, (2014). *About Auburn University.* Retrieved from http://www.auburn.edu/ main/welcome/.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, 51, 1173-1182.

Baylon, D., & Storm, P. (2008). Comparison of commercial LEED buildings and non-LEED buildings within the 2002-2004 Pacific Northwest commercial building stock. *2008 ACEEE Summer Study on Energy Efficiency in Buildings*, 4-1– 4-12. Retrieved April 20, 2014 from http://www.aceee.org/files/proceedings/2008/data/papers/4_57.pdf

Bluyssen, P. M. (2014). *The healthy indoor environment: How to assess occupants' wellbeing in buildings*. New York, NY: Routledge.

Brennan, A., Chugh, J. S., & Kline, T. (2002). Traditional versus open office design: A longitudinal field study. *Environment and Behavior, 34*(3), 279-299. doi: 10.1177/0011391650203400 3001

Brooker, G., & Stone, S. (2010). *What is interior design.* Mies, Switzerland: Rotovision.

Canadian Mental Health Association (n.d.). In *Connection between mental and physical health*. Retrieved April 23, 2014 from http://ontario.cmha.ca/mental-health/connection-between-mental-and-physical-health/

Carlopio, J. R. (1996). Construct validity of a physical work environment satisfaction questionnaire. *Journal of Occupational Health Psychology, 1*(3), 330-344. doi: 1076-8998/96/53.00

Chenoweth, (2011). *Promoting employee well-being: Wellness strategies to improve health, performance, and the bottom line*. Retrieved from http://www.shrm.org/about/foundation/products/documents/6-11%20promoting%20well%20being%20epg-%20final.pdf

Danielsson, C. B., & Bodin, L. (2008). Office type in relation to health, wellbeing, and job satisfaction among employees. *Environment and Behavior, 40*(5), 636-668. doi: 10.1177/0013916507307459

Danko, S., Eshelman, P., & Hedge, A. (1990). A taxonomy of health, safety, and welfare implications of interior design decisions. *Journal of Interior Design, 16*(2), 19-30.

DeVellis, R. F. (2003). *Scale development: Theory and applications* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Ding, S. (2008). Users' privacy preferences in open plan offices. *Facilities, 26*(9/10), 401-417. doi: 10.11080263277081088575 1

Edwards, C. (2011). *Interior design: A critical introduction.* New York, NY: Berg.

Evans, G. W., & McCoy, J. M. (1998). When buildings don't work: The role of architecture in human health. *Journal of Environmental Psychology, 18*, 85-94. doi:10.1006/jevp.1998.0089

Fisk, W.J., &. Rosenfeld A. H. (1997). Estimates of improved productivity and health from better indoor environments. *Indoor Air, 7*, 158-172. doi: 10.1111/j.1600-0668.1997.t01-1-00002

Frontczak, M., Schiavon, S., Goins, J., Arens, E., Zhang, H., & Wargocki, P. (2012). Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design. *Indoor Air, 22*, 119-131. doi: 10.1111/j.1600-0668.2011.00745.x

Frontczak, M., & Wargocki, P. (2011). Literature survey on how different factors influence human comfort in indoor environments. *Building and Environment, 46*, 922-937. doi: 10.1016/j.buildenv.2010.10.021

Ghodrati, N., Samari, M., & Shafiei, M. W. M. (2012). Green buildings impacts on occupants` health and productivity. *Journal of Applied Sciences Research, 8*(8), 4235-4241. Retrieved from http://www.aensiweb.com/jasr/jasr/2012/4235-4241.pdf

Green-Buildings (n.d.). In *Indoor air quality test: Do LEED green buildings meet their own standards?* Retrieved April 20, 2014 from http://www.greenbuildings.com/content /78457- indoor-air- quality-test-do-leed-green-buildings-meet-their-own-standards

Green Building Education Services (2011). *LEED: Green associate study guide*. Lewisville, TX: Green Building Education Services, LLC.

Green, S., B. & Salkind, N., J. (2011). *Using SPSS for windows and Macintosh: Analyzing and understanding data*. Upper Saddle River, NJ: Prentice Hall.

Guerin, D. A., & Kwon, J. (2010). Welfare: Can you talk about your specialized knowledge? In C. S. Martin & D. A. Guerin (Eds.), *The state of the interior design profession* (pp. 110-118). New York: NY: Fairchild.

Health. (n.d.) In *Merriam-Webster's online dictionary* (11th ed.). Retrieved March 29, 2014, from http://www.merriam-webster.com/dictionary/health

Healthways, (2011). *The Science of Well-Being* [White paper]. Retrieved from http://www.healthways.com/blog/2011/12/the-science-of-well-being.

Hedge, A., Miller, I., & Dorsey, J. A. (2014). Occupant comfort and health in green and conventional university buildings. *Work Journal Impact Factor & Information, 49*(3), 363-372. doi: 10.3233/WOR-141870

Heerwagen, J. (1998). Design, productivity and well Being: What are the Links?. *The American Institute of Architects Conference on Highly Effective Facilities*, Cincinnati, OH: Mar. 12-14.

Heerwagen, J. (2000). Green buildings, organizational success and occupant productivity. *Building Research and Information, 28*(5), 353-367. doi: 10.1080/096132100418500

Heerwagen, J. (2010). *Investing in people: The social benefits of sustainable design* [White paper]. Retrieved from http://www.paragonbusinessfurniture.com/documents /InvestingInPeople.pdf

Heinzerling, D., Shiavon, S., Webster, T., & Arens, E. (2013). Indoor environmental quality assessment models: A literature review and a proposed weighting and classification scheme. *Building and Environment, 70,* 210-222. doi: 10.1016/j.buildenv.2013.08.027

International WELL Building Institute (2015). *WELL building standard*. Retrieved July 5, 2015 from http://www.wellcertified.com/well.

Jones, L. (Eds.) (2008). *Environmentally responsible design: Green and sustainable design for interior designers.* Hoboken, NJ: John Wiley & Sons.

Katz, A. (2012, July). About LEED. *U. S. Green Building Council*. Retrieved October 15, 2013, from http://www.usgbc.org/articles/about-leed.

Kellert, S. R. (2005). *Building for life: Designing and understanding human-nature connections*. Washington, DC: Island Press.

Kendell, R. E. (2001). The distinction between mental and physical illness. *The British Journal of Psychiatry, 178,* 490-493. doi: 10.1192/bjp.178.6.490

Kim, J., & de Dear, R. (2013). Workspace satisfaction: The privacy-communication trade-off in open-plan offices. *Journal of Environmental Psychology, 36,* 18-26.

Kim, J., de Dear, R., Candido, C., Zhang, H., & Arens, E. (2013). Gender differences in office occupant perception of indoor environmental quality (IEQ). *Building and Environment, 70,* 245-256. doi: 10.1016/j.buildenv.2013.08.022

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (2nd ed.). New York: Guildford.

Kopec, D. (2006). *Environmental psychology for design*. New York, NY: Fairchild.

Kopec, D. (2009). *Health, sustainability, and the built environment*. New York, NY: Fairchild.

Kroemer, K. H. E., & Grandjean, E. (1997). *Fitting the task to the human: A Textbook of occupational ergonomics* (5th ed.). New York: Taylor & Francis.

Lasser, W. M., Manolis, C., & Winsor, R. D. (2000). Service quality perspectives and satisfaction in private banking. *Journal of Services Marketing, 14*(3), 244-271.

Leaman, A., & Bordass, B. (2007). Are users more tolerant of 'green' buildings? *Building Research & Information, 35*(6), 662-673. doi: 10.1080/0961321070152951.8

Lee, Y. S. (2010). Office layout affecting privacy, interaction, and acoustic quality in LEED-certified buildings. *Building and Environment, 46*, 1594- 1600. doi: 10.1016/j.buildenv.2010.01.007

Lee, Y. (2012). Using building information modeling for green interior simulations and analyses. *Journal of Interior Design, 37*(1), 35-50.

Lee, Y. S., & Brand, J. (2005). Effects of control over office workspace on perceptions of the work environment and work outcomes. *Journal of Environmental Psychology, 25*, 323-333. doi: 10.1016/j.jenvp.2005.08.001

Lee, Y. S., & Guerin, D. A. (2009). Indoor environmental quality related to occupant satisfaction and performance in LEED-certified buildings. *Indoor Built Environment, 18*(4), 293-300. doi: 10.1177/1420326X09105455

Lynn, R. S., & Loehr, D. (2010). Our design responsibility for people and planet. In C. S. Martin & D. A. Guerin (Eds.), *The state of the interior design profession* (pp. 49-58). New York, NY: Fairchild.

Melton, P. (2012). Georgia Outlaws LEED in Latest "Wood Wars" Battle. *Building Green.* Retrieved August 7, 2015, from https://www2.buildinggreen.com/article/georgia-outlaws-leed-latest-wood-wars-battle.

Moloney, C. (2014). *LEED v4 Changes: New Credit Categories?*. Retrieved January 15, 2015, from http://www.poplarnetwork.com/news/leed-v4-changes-new-credit-categories

Morton, S. (2002, November). Business Case for Green Design, *Building Operating Management.* Retrieved March 30, 2014 from http://www.facilitiesnet.com/design construction/article/Business-Case-for-Green-Design--1481

Mülunpalo, S., Vuori, I., Oja, P., Pasanen, M., & Urponen, H. (1997). Self-rated health status as a health measure: The predictive value of self-reported health status on the use of physician services and on mortality in the working-age population. *Journal of Clinical Epidemiology, 50*(5), 517-528. doi:10.1016/S0895-4356(97)00045-0

Muruvi, W. (2012). The Canadian index of wellbeing: A presentation to the research, learning and evaluation action group of the Guelph Wellington taskforce for poverty elimination. *The Research Shop, University of Guelph.* Retrieved November 3, 2013, from http://www.theresearchshop.ca/sites/default/files/CIW%20Presentation_Wanzi%20Muruvi.pdf

Newsham, G., Birt, B., Arsenault, C., Thompson, L., Veitch, J., Mancini, S., Gover, B., Macdonald, I., & Burns, G. (2012). Do green buildings outperform conventional buildings? Indoor environment and energy performance in North American Offices, (RR-329), *National Research Council Canada, Institute for Research in Construction,* Ottawa, ON. Retrieved April 4, 2014 from http://www.mcclungfoundation.org/Documents /GreenBuildings-ConventionalBuildings.pdf

Oliver, R. L. (1981). Measurement and evaluation of satisfaction processes in retail settings. *Journal of Retailing, 57*(3), 25-48.

Page, K. (2005). Subjective wellbeing in the workplace. Unpublished Honors thesis, Deakin University, Melbourne, Australia. Accessed via https://www.deakin.edu.au/research/acqol/publications/resources/thesis-page-k.pdf

Reeder, L. (2010). *Guide to green building rating systems.* Hoboken, NJ: John Wiley & Sons.

Roper, K. O., & Beard, J. L. (2006). Justifying sustainable buildings- Championing green operations. *Journal of Corporate Real Estate, 8*(2), 91-103. doi: 10.1108/14630010610679899

Roysamb, E., Tambs, K., Reichborn-Kiennerud, T., Neale, M. C., & Harris, J. R. (2003). Happiness and health: Environmental and genetic contributions to the relationship between subjective wellbeing, perceived health, and somatic illness. *Journal of Personality and Social Psychology,* 85(6), 1136-1146. doi: 10.1037/0022-3514.85.6.1136

Schell, E., Theorell, T., & Saraste, H. (2012). Workplace aesthetics: Impact of environments upon employee health as compared to ergonomics. *Work: A Journal of Prevention, Assessment and Rehabilitation,* 41(1), 1430-40. doi: 10.3233/WOR-2012-0334-1430

Singh, A., Syal, M., Grady, S.C., & Korkmaz, S. (2010). Effects of green buildings on employee health and productivity. *American Journal of Public Health, 100*(9), 1665-1668.

Smith. A., & Pitt, M. (2009). Sustainable workplaces: Improving staff health and wellbeing using plants. *Journal of Corporate Real Estate, 11*(1), 52-63. doi: 10.1108/14630010910940552

Sorrento, L. (2012). A natural balance: Interior design, humans, and sustainability. *Journal of Interior Design, 37*(2), 9-23. doi: 10.1111/j.1939-1668.2012.01075

Steelcase (2007). *The designer's role in sustainability* [White paper]. Retrieved November 2, 2013 from http://360.steelcase.com/white-papers/the-designers-role-in-sustainability/

Steelcase (2014). *Wellbeing: A bottom line issue*- Issue 67 [White paper]. Retrieved March 7, 2014 from http://360.steelcase.com/issues/wellbeing-a-bottom-line-issue/

Steemers, K., & Manchanda, S. (2010). Energy efficient design and occupant wellbeing: Case studies in the UK and India. *Building and Environment, 45*, 270-278. doi: 10.1016/j.buildenv.2009.08.025

Stokols, D. (1992). Establishing and maintaining healthy environments: Towards a social ecology of health promotion. *American Psychologist*, *47*(1), 6-22. doi: 10.1037/0003-066X.47.1.6

Stokols, D., & Altman, I. (Eds.) (1987). *Handbook of environmental psychology*. New York, NY: John Wiley and Sons.

Stokols, D., & Scharf, F. (1990). Developing standardized tools for assessing employees' ratings of facility performance. In G. Davis, & F. T. Ventre (Eds.), *Performance of buildings and serviceability of facilities* (pp. 55-68). Philadelphia, PA: American Society for Testing and Materials.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5th ed.). Boston, MA: Pearson Education.

Thatcher, A., & Milner, K. (2012). The impact of a 'green' building on employees' physical and psychological wellbeing. *Work: A Journal of Prevention, Assessment and Rehabilitation, 41*, 3816-3823. doi: 10.3233/WOR-2012-0683-3816

Theodorson, J. (2014). Energy, daylight, and a role for interiors, *Journal of Interior Design 39*(2), 37-56.

Tucker, L.M. (2010). Environmental responsibility and interior design education. In C. S. Martin & D. A. Guerin (Eds.), *The state of the interior design profession* (pp. 42-48). New York, NY: Fairchild.

United Nations. (2002). *Report of the world summit on sustainable development.* New York, NY: United Nations. Retrieved from http://www.un.org/jsummit/html/documents/summit_docs/131302_wssd_report_reissued.pdf

U. S. Green Building Council (2006). *New construction & major renovation version 2.2 reference guide.* Washington, DC: U.S. Green Building Council.

U. S. Green Building Council. (2009). *Foundations of LEED*. Retrieved March 28, 2014, from http://www.usgbc.org/sites/default/files/Foundations-of-LEED_0.pdf

U. S. Green Building Council. (2013a). *The newest version of LEED*. Retrieved November 22, 2013, from http://www.usgbc.org/articles/newest-version-leed

U. S. Green Building Council. (2013b). *USGBC project directory: Auburn University search results*. Retrieved November 2, 2013, from http://www.usgbc.org/projects?keys=Auburn+University&=Search.

U.S. Green Building Council (2013c). *LEED v4 user guide*. Retrieved October 12, 2014 from http://www.usgbc.org/resources/leed-v4-user-guide.

U.S. Green Building Council (2013d). *LEED reference guide for building design and construction*. Washington, D.C.: U.S. Green Building Council.

U.S. Green Building Council (2013e). *LEED professionals at a glance: March 2013*. Retrieved from http://www.usgbc.org/articles/leed-professionals-glance-march-2013

U. S. Green Building Council. (2014). *LEED v4 for building design and construction checklist*. Retrieved July 24, 2015 from http://www.usgbc.org/resources/leed-v4-building-design-and-construction-checklist

U. S. Green Building Council. (2015). *About LEED.* Retrieved July 24, 2015 from http://www.usgbc.org/articles/about-leed

Veitch, J. A., Charles, K. E., Farley, K. M. J., & Newsham, G. R. (2007). A model of satisfaction with open-plan office conditions: COPE field findings. *Journal of Environmental Psychology, 27,* 177–189. doi: 10.1016/j.jenvp.2007.04.002

Veitch, J.A., Charles, K.E., Newsham, G.R., Marquardt, C.J.G., & Geerts, J. (2003). *Environmental satisfaction in open-plan environments: 5. Workstation and physical condition effects*, report nr IRC-RR- 154, Retrieved March 18, 2014 from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CDAQFjAB&url=http%3A%2F%2Fnparc.cisti-icist.nrccnrc.gc.ca%2Fnpsi%2Fctrl%3Faction%3Drtdoc%26an%3D20378817&ei=Arc4U43qH9HMsQSZkYLgBw&usg=AFQjCNExyBrPKUNsCy6aa09fpDcZ0dmfzg&sig2=qkCSan3M9MiGutDGnwIh7A&bvm=bv.63808443,d.cWc

Vischer, J. C. (2008). Towards a user-centered theory of the built environment. *Building Research & Information*, *36*(3), 231-240. doi: 10.1080/09613210801936472

Ware, J. E., Kosinski, M., & Keller, S. D. (1996). A 12-item short-form health survey: construction of scales and preliminary tests of reliability and validity. *Medical Care, 34*(3), 220- 233.

Warr, P., Cook, J., & Wall, T. (1979). Scales for the measurement of some work attitudes and aspects of psychological well-being. *Journal of Occupational Psychology, 52,* 129–148.

Wilks, D. C., & Neto, F. (2013). Workplace wellbeing, gender and age: Examining the 'double jeopardy' effect. *Social Indicators Research, 114*, 875-890. doi: 10.1007/s11205-012-0177-7

World Health Organization (1948). In *WHO definition of health*. Retrieved April 22, 2014 from http://www.who.int/about/definition/en/print.html

World Health Organization (2013). In *Mental health: A state of well-being*. Retrieved April 22, 2014 from http://www.who.int/features/factfiles/mental_health/en/

Winchip, S. M. (2011). *Sustainable design for interior environments.* New York, NY: Fairchild.

Wright, T. A., & Bonett, D. G. (2007). Job satisfaction and psychological well-being as nonadditive predictors of workplace turnover. *Journal of Management, 33*(2), 141-160. doi: 10.1177/0149206306297582

Zagreus, L., Huizenga, C., Arens, E., & Lehrer, D. (2004). Listening to the occupants: A web-based indoor environmental quality survey. *Indoor Air, 14*, 65–74. doi: 10.1111/j.1600-0668.2004.00301

APPENDIX A

Objective Measurement Tool: On-Site Record

LEED New Construction (version 4): IEQ

Building: _____ Reviewer: _____

Date: _____ Time: _____

IEQ CREDITS / ROOMS				
EQc5: Thermal Control				
EQc6: Interior Lighting (2 credits) [Lighting control & Quality (1 per)]				
EQc7: Daylight (3 credits)				
EQc8: Quality Views (1 credit)				
EQc9: Acoustic Performance (1 credit)				
COMMENTS				

Key: 1= yes, 2= no, 3= unknown

Note. Adopted from "*LEED for BD+C: New Construction IEQ Credits",* by USGBC. Copyright 2013 by USGBC.

APPENDIX B

Objective Measurement Tool – Facility Verification

LEED New Construction (version 4): IEQ

Building: _____

Yes	?	No	Indoor Environmental Quality		13 Points
Y			Prereq 1	Minimum IAQ Performance	Required
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	Required
			Credit 1	Enhanced Indoor Air Quality Strategies	2
			Credit 2	Low Emitting Materials	3
			Credit 3	Construction IAQ Management Plan, During Construction	n/a
			Credit 4	Indoor Air Quality Assessment	n/a
			Credit 5	Thermal Comfort	1
			Credit 6	Interior Lighting	2
			Credit 7	Daylight	3
			Credit 8	Quality Views	1
			Credit 9	Acoustic Performance	1

Note: Adopted from "*LEED for BD+C: New Construction IEQ Credits",* by USGBC. Copyright 2013 by USGBC.

EQp1 minimum IAQ performance (required)

Notes:

EQc1 Enhanced IAQ strategies (2 points)

Mechanically ventilated spaces: Comply with all requirements (1 point)

1. entryway systems; [site visit confirmed]
2. interior cross-contamination prevention
3. filtration

Option 2. Additional enhanced IAQ strategies (1 point)

Comply with the following requirements, as applicable.

4. Mechanically ventilated spaces (select one):
5. exterior contamination prevention;
6. increased ventilation;
7. carbon dioxide monitoring; or [extensive system room to room level]
8. additional source control and monitoring.

Notes:

EQc5 Thermal Comfort (1 point)

Must comply with **both** control and design.

1. Thermal Comfort Control
2. Thermal comfort design

   Notes:

EQc6 Interior Lighting (2 point)

Select one or both of the two options.

1. Lighting Control (1point)
2. Lighting quality (1point)

   Notes:

EQc7 Daylight (3 point)

Must comply with both control and design.

1. Provide manual or automatic glare control devices
2. Measurement (75%=2 points, 90%=3 points)

   Notes:

EQc8 Quality Views (1 point)

1. Provide views for 75%

   Notes:

APPENDIX C

Web-based Questionnaire: "*Workplace Indoor Environment Quality and Occupants' Wellbeing*"

(NOTE: DO NOT AGREE TO PARTICIPATE UNLESS IRB APPROVAL INFORMATION WITH CURRENT DATES HAS BEEN ADDED TO THIS DOCUMENT.)

INFORMATION LETTER

for a Research Study entitled

"*Workplace Indoor Environment Quality and Occupants' Wellbeing*"

You are invited to participate in a research study to explore indoor environmental factors that may influence occupants' workplace wellbeing. The study is being conducted by Amber Ortlieb, master's student, under the direction of Dr. Wi-Suk Kwon and Dr. Amanda Gale, in the Auburn University Department of Consumer and Design Sciences. You are invited to participate because you work in one of the selected AU buildings in this study and are age 19 years or older.

What will be involved if you participate? Your participation is completely voluntary. If you decide to participate in this research study, you will be asked to complete an online questionnaire. Your total time commitment will be approximately 20-25 minutes.

Are there any risks or discomforts? The risk associated with participating in this study is a breach of confidentially. Participants will be assigned a randomly generated participant ID number, which will be linked to their data. The participant ID data will be used only to identify non-respondents in order to send reminders to them. To minimize the risk of a breach of confidentiality, the participant ID data will be erased for good from the survey data immediately following the completion of data collection and never be linked to the survey data during the data analysis. All survey data will be analyzed and reported anonymously.

Are there any benefits to yourself or others? No specific personal benefits are expected from participating in this study. However, your data are expected to contribute to generating evidence-based insight that can improve workplace interior design.

Will you receive compensation for participating? As a small token of appreciation for your time, we enclosed $1.00 in our previous letter which we sent to your campus mailbox during Thursday, September 18, 2014.

Are there any costs? Besides the time required for completing the online survey, no costs are expected for participating in this study.

If you change your mind about participating, you can withdraw at any time by closing the online survey browser window. If you choose to withdraw, your data can be withdrawn as long

as it is identifiable. Further, you can skip any questions that cause discomfort to you. Once we remove your participant ID from the data, your data cannot be withdrawn since it will be unidentifiable. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University, or the Department of Consumer and Design Sciences.

Any data obtained in connection with this study will remain anonymous. We will protect your privacy and the data you provide by separating the participant ID data from the survey data and deleting them for good upon the completion of data collection. Information collected through your participation will be used to fulfill the principal investigator's master's degree requirement and may be published in professional journals and/or presented at professional meetings/conferences.

If you have questions about this study, please contact Amber Ortlieb at aro0003@auburn.edu, Dr. Wi-Suk Kwon at kwonwis@auburn.edu, or Dr. Amanda Gale at agale@auburn.edu.

If you have questions about your rights as a research participant, you may contact the Auburn University Office of Research Compliance or the Institutional Review Board by phone (334) 844-5966 or e-mail at IRBadmin@auburn.edu or IRBChair@auburn.edu.

HAVING READ THE INFORMATION ABOVE, YOU MUST DECIDE IF YOU WANT TO PARTICIPATE IN THIS RESEARCH PROJECT. IF YOU DECIDE TO PARTICIPATE, PLEASE CLICK THE '*NEXT'* LINK BELOW.

_____

Investigator Date

_____

Co-Investigator Date

The Auburn University Institutional Review Board has approved this document for use from September 15, 2014 to September 14, 2015. Protocol # 14-270 EP1409.

NEXT

1: The following set of statements relates to your satisfaction in your Auburn University assigned office workspace over the last 4 weeks. Your workspace is the place (desk, cubicle, office, etc.) where you do the majority of your office work on the AU campus.

For your office workspace, please indicate your level of satisfaction with each of the following:

	Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very Satisfied
the aesthetic appearance	❍	❍	❍	❍	❍	❍	❍
the style of your office furniture	❍	❍	❍	❍	❍	❍	❍
the color in your office	❍	❍	❍	❍	❍	❍	❍
the comfort of your office chair	❍	❍	❍	❍	❍	❍	❍
the adjustability of your office chair	❍	❍	❍	❍	❍	❍	❍
the cleanliness of the facilities at work	❍	❍	❍	❍	❍	❍	❍
your safety coming and going from work	❍	❍	❍	❍	❍	❍	❍

2: The following set of statements relates to your satisfaction in your Auburn University assigned office workspace over the last 4 weeks. Your workspace is the place (desk, cubicle, office, etc.) where you do the majority of your office work on the AU campus.

For your office workspace, please indicate your level of satisfaction with each of the following:

	Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very Satisfied
your opportunity to personalize your office	❍	❍	❍	❍	❍	❍	❍
your ability to organize and change the appearance of your office	❍	❍	❍	❍	❍	❍	❍
your office to adapt for accommodation of your various activities (i.e. impromptu meetings)	❍	❍	❍	❍	❍	❍	❍

3: The following set of statements relates to your satisfaction in your Auburn University assigned office workspace over the last 4 weeks. Your workspace is the place (desk, cubicle, office, etc.) where you do the majority of your office work on the AU campus.

For your office workspace, please indicate your level of satisfaction with each of the following:

	Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very Satisfied
the quality of lighting	❍	❍	❍	❍	❍	❍	❍
the amount of lighting on the desktop (desk surface)	❍	❍	❍	❍	❍	❍	❍
the amount of light for computer work	❍	❍	❍	❍	❍	❍	❍
the amount of reflected light or glare on the computer screen	❍	❍	❍	❍	❍	❍	❍
the ability to control the lights by turning them off and on	❍	❍	❍	❍	❍	❍	❍
the flexibility to adjust the levels of lighting for your activities	❍	❍	❍	❍	❍	❍	❍

4: For your office workspace, please indicate your level of satisfaction with each of the following:

	Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very Satisfied	I do not have a window
your ability to adjust the amount of light from the exterior windows (i.e. blinds, curtains)	❍	❍	❍	❍	❍	❍	❍	❍

5: The following set of statements relates to your satisfaction in your Auburn University assigned office workspace over the last 4 weeks. Your workspace is the place (desk, cubicle, office, etc.) where you do the majority of your office work on the AU campus.

For your office workspace, please indicate your level of satisfaction with each of the following:

	Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very Satisfied
the air quality	❍	❍	❍	❍	❍	❍	❍
the smells	❍	❍	❍	❍	❍	❍	❍
the humidity	❍	❍	❍	❍	❍	❍	❍
the air movement	❍	❍	❍	❍	❍	❍	❍
the temperature	❍	❍	❍	❍	❍	❍	❍
your ability to control the temperature	❍	❍	❍	❍	❍	❍	❍

6: The following set of statements relates to your satisfaction in your Auburn University assigned office workspace over the last 4 weeks. Your workspace is the place (desk, cubicle, office, etc.) where you do the majority of your office work on the AU campus.

Please indicate your level of satisfaction with each of the following:

	Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very Satisfied
the size of your office workspace to accommodate your work, materials, and visitors	❍	❍	❍	❍	❍	❍	❍
your options to adjust your office workspace to increase your physical comfort	❍	❍	❍	❍	❍	❍	❍
the storage space at your office workspace	❍	❍	❍	❍	❍	❍	❍

7: The following set of statements relates to your satisfaction in your Auburn University assigned office workspace over the last 4 weeks. Your workspace is the place (desk, cubicle, office, etc.) where you do the majority of your office work on the AU campus.

Please indicate your level of satisfaction with each of the following:

	Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very Satisfied
the amount of noise from other people's conversations while you are at your office workspace	❍	❍	❍	❍	❍	❍	❍
the amount of background noise (i.e. not speech) you hear at your office workspace	❍	❍	❍	❍	❍	❍	❍
your ability to control the noise in your office workspace	❍	❍	❍	❍	❍	❍	❍
your ability to concentrate on your work while in your office workspace	❍	❍	❍	❍	❍	❍	❍
the frequency of distractions from other people while in your office workspace	❍	❍	❍	❍	❍	❍	❍
the degree of enclosure of your office workspace by walls, screens or furniture	❍	❍	❍	❍	❍	❍	❍
the level of visual privacy within your office workspace	❍	❍	❍	❍	❍	❍	❍
the distance between you and other people you work with	❍	❍	❍	❍	❍	❍	❍
the level of privacy for conversations in your office workspace	❍	❍	❍	❍	❍	❍	❍

8: The following set of statements relates to your satisfaction in your Auburn University assigned office workspace over the last 4 weeks. Your workspace is the place (desk, cubicle, office, etc.) where you do the majority of your office work on the AU campus.

For your office workspace, please indicate your level of satisfaction with each of the following:

	Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very Satisfied
the amount of natural light	❍	❍	❍	❍	❍	❍	❍
your access to a view of outside from where you sit	❍	❍	❍	❍	❍	❍	❍

9: Please indicate your level of satisfaction with each of the following:

	Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very Satisfied	I do not have a window
the view outside your exterior window	❍	❍	❍	❍	❍	❍	❍	❍

10: The following set of statements relates to your satisfaction in your Auburn University assigned office workspace over the last 4 weeks. Your workspace is the place (desk, cubicle, office, etc.) where you do the majority of your office work on the AU campus.

Overall, how satisfied are you with the function of your workspace to accommodate your work activities?

Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very Satisfied
❍	❍	❍	❍	❍	❍	❍

11: Please identify things you would CHANGE in your AU office workspace in the box below.

12: If your primary office area is NOT your AU assigned office; please indicate WHY you do not use your AU assigned office in the box below.

13: The following set of statements relates to your health.

In general, would you say your health is:

Poor	Fair	Good	Very Good	Excellent
❍	❍	❍	❍	❍

14: During the past 4 weeks, how much did pain interfere with your normal work (including work in and out of the office)?

Not at all	A little bit	Moderately	Quite a bit	Extremely
❍	❍	❍	❍	❍

15: Given your current health, please indicate your level of limitation with each of the following:

	Extremely limited	Limited quite a bit	Moderately limited	Limited a little bit	Not limited at all
performing moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	❍	❍	❍	❍	❍
climbing several flights of stairs	❍	❍	❍	❍	❍

16: The following set of statements relates to your health. Based on the past four (4) weeks, please indicate your agreement with the following:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I have accomplished less than I would like due to my physical health.	❍	❍	❍	❍	❍
I was limited in the kind of work or other activities due to my physical health.	❍	❍	❍	❍	❍
I have accomplished less than I would like due to emotional problems.	❍	❍	❍	❍	❍
I was limited in the kind of work or other activities due to emotional problems.	❍	❍	❍	❍	❍

17: The following set of statements relates to your health. Based on the past four (4) weeks, how often have you experienced the following:

	None of the time	A little of the time	Some of the time	Most of the time	All of the time
feeling calm and peaceful	❍	❍	❍	❍	❍
having a lot of energy	❍	❍	❍	❍	❍
feeling downhearted and blue	❍	❍	❍	❍	❍
physical health or emotional problems interfering with your work activities	❍	❍	❍	❍	❍

18: Please identify ways you believe your AU office workspace impacts your health in the box below.

19: The following set of statements relates to your level of satisfaction with work. How satisfied are you with your work life at present?

Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied
❍	❍	❍	❍	❍

20: Over the last 4 weeks, how often have you suffered from nervousness at work (felt irritable, anxious, tense or restless)?

None of the time	A little of the time	Some of the time	Most of the time	Almost all the time
❍	❍	❍	❍	❍

21: How do you usually feel at work?

	1	2	3	4	5
Dejected:Happy	❍	❍	❍	❍	❍
Tired and Worn Out:Strong and Fit	❍	❍	❍	❍	❍

22: The following set of statements relates to your level of satisfaction with work.

Please indicate how often you experience the following:

	Very rarely	Rarely	Sometimes	Fairly often	Very often
Having too much to do at work	❍	❍	❍	❍	❍
My relationship with your closest supervisor working out positively	❍	❍	❍	❍	❍
The goals at your work challenging and realistic at the same time	❍	❍	❍	❍	❍

23: How do you perceive the cooperation with your own work group?

Very Bad	Fairly Bad	Neither Good nor Bad	Fairly Good	Very Good
❍	❍	❍	❍	❍

24: How satisfied or dissatisfied are you with your work?

Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied
❍	❍	❍	❍	❍

25: This next set of questions asks about your personal Auburn University workspace location.

In which building is your AU primary office workspace?

- ❍ Information Technology Building
- ❍ Kinesiology Building
- ❍ Tichenor Hall
- ❍ M. Miller Gorrie Center
- ❍ Thach Hall
- ❍ Miller Hall
- ❍ Spidle Hall
- ❍ Other _____

26: On which floor is your office workspace located?

- ❍ Basement
- ❍ First (1st) Floor
- ❍ Second (2nd) Floor
- ❍ Third (3rd) Floor
- ❍ Fourth (4th) Floor

27: How many years have you been working in your current office workspace? [For example, if you have worked in your office for two and a half years, enter 2 years, 6 months].

Number of years _____
Number of months _____

28: Which best describes the space in which your work area is located?

- ❍ Single person private office
- ❍ Shared private office
- ❍ Open space with partitions
- ❍ Open space without partitions
- ❍ Other: _____

29: How many exterior windows are located in your office workspace?

- ❍ None
- ❍ 1 to 3
- ❍ More than 3

30: Can you open any of the exterior windows in your office workspace?

- ❍ Yes
- ❍ No

31: Does your work area have a functioning light switch?

- ❍ Yes
- ❍ No

32: Does your work space have multiple lighting switches for you to adjust the amount of light in the space?

- ❍ Yes
- ❍ No

33: Does your office workspace offer a secondary light source (such as a desk light)?

- ❍ Yes
- ❍ No

34: Does your office workspace have a working thermostat?

- ❍ Yes
- ❍ No

35: This next question asks about your Auburn University work description.

How would you describe the work you do?

- ❍ Administrative support
- ❍ Technical staff
- ❍ Instructor
- ❍ Professor
- ❍ Research Professor
- ❍ Adjunct Professor
- ❍ Managerial/supervisory
- ❍ Other _____

36: How many hours do you work in a normal work week? Please choose only one of the following:

- ❍ Less than 1 hour
- ❍ 1- 5 hours
- ❍ 6- 10 hours
- ❍ 11- 15 hours
- ❍ 16- 20 hours
- ❍ 21- 25 hours
- ❍ 26- 30 hours
- ❍ 31- 35 hours
- ❍ 36- 40 hours
- ❍ 41- 45 hours
- ❍ 46- 50 hours
- ❍ 51- 55 hours
- ❍ More than 55 hours

37: On average, how many hours per week do you work in this building? Please choose only one of the following:

- ❍ Less than 1 hour
- ❍ 1- 5 hours
- ❍ 6- 10 hours
- ❍ 11- 15 hours
- ❍ 16- 20 hours
- ❍ 21- 25 hours
- ❍ 26- 30 hours
- ❍ 31- 35 hours
- ❍ 36- 40 hours
- ❍ 41- 45 hours
- ❍ 46- 50 hours
- ❍ 51- 55 hours
- ❍ More than 55 hours

38: On average, how many hours per week do you spend in your workspace? Your Auburn University workspace is the place (desk, cubicle, office, etc.) where you do the majority of your work on campus. Please choose only one of the following:

- ❍ Less than 1 hour
- ❍ 1- 5 hours
- ❍ 6- 10 hours
- ❍ 11- 15 hours
- ❍ 16- 20 hours
- ❍ 21- 25 hours
- ❍ 26- 30 hours
- ❍ 31- 35 hours
- ❍ 36- 40 hours
- ❍ 41- 45 hours
- ❍ 46- 50 hours
- ❍ 51- 55 hours
- ❍ More than 55 hours

39: What is your age (in number of years)? _____

40: What is your gender?

- ❍ Male
- ❍ Female

41: What is the highest grade of school you have completed?

- ❍ 8th Grade or Less
- ❍ Some High School
- ❍ High School Diploma
- ❍ Some College or Technical School
- ❍ Bachelor's Degree
- ❍ Some Graduate School
- ❍ Graduate Degree (Master's, Doctorate, etc.)

42: How would you describe your ethnicity?

- ❍ American Indian/Alaskan Native
- ❍ Hispanic
- ❍ Asian/Pacific Islander
- ❍ Black, Non-Hispanic
- ❍ White, Non-Hispanic
- ❍ Other _____

43: From all the sources of income you have (e.g., including your spouse or partner, if you have one), what was your total household income in 2013?

- ❍ Less than $10,000
- ❍ $10,000 - 29,999
- ❍ $30,000 - 49,999
- ❍ $50,000 - 69,999
- ❍ $70,000 - 89,999
- ❍ $90,000 - 109,999
- ❍ $110,000 - 129,999
- ❍ $130,000 - 149,999
- ❍ $150,000 - 169,999
- ❍ $170,000 - 199,999
- ❍ More than $200,000

APPENDIX D

IRB Approved Information Letter

Please add this approval information in sentence form to this letter. Send your updated letter to the IRB with a live link to the survey.

[Department Letterhead information]

ICIPATE UNLESS IRB APPROVAL INFORMATION WITH CURRENT DATES HAS BEEN ADDED TO THIS DOCUMENT.)

The Auburn University Institutional Review Board has approved this document for use from 9/15/14 to 9/14/15 Protocol # 14-270 EP 1409

INFORMATION LETTER
for a Research Study entitled
"Workplace Indoor Environment Quality and Occupants' Well[illegible]"

You are invited to participate in a research study to explore indoor environmental factors that may influence occupants' workplace wellbeing. The study is being conducted by Amber Ortlieb, master's student, under the direction of Dr. Wi-Suk Kwon and Dr. Amanda Gale, in the Auburn University Department of Consumer and Design Sciences. You are invited to participate because you work in one of the selected AU buildings in this study and are age 19 years or older.

What will be involved if you participate? Your participation is completely voluntary. If you decide to participate in this research study, you will be asked to complete an online questionnaire. Your total time commitment will be approximately 20-25 minutes.

Are there any risks or discomforts? The risk associated with participating in this study is a breach of confidentially. Participants will be assigned a randomly generated participant ID number, which will be linked to their data. The participant ID data will be used only to identify non-respondents in order to send reminders to them. To minimize the risk of a breach of confidentiality, the participant ID data will be erased for good from the survey data immediately following the completion of data collection and never be linked to the survey data during the data analysis. All survey data will be analyzed and reported anonymously.

Are there any benefits to yourself or others? No specific personal benefits are expected from participating in this study. However, your data are expected to contribute to generating evidence-based insight that can improve workplace interior design.

Will you receive compensation for participating? As a small token of appreciation for your time, we enclosed $1.00 in our previous letter which we sent to your campus mailbox during [WILL ADD DATES HERE].

Are there any costs? Besides the time required for completing the online survey, no costs are expected for participating in this study.

If you change your mind about participating, you can withdraw at any time by closing the online survey browser window. If you choose to withdraw, your data can be withdrawn as long as it is identifiable. Further, you can skip any questions that cause discomfort to you. Once we remove your participant ID from the data, your data cannot be withdrawn since it will be unidentifiable. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University, or the Department of Consumer and Design Sciences.

Any data obtained in connection with this study will remain anonymous. We will protect your privacy and the data you provide by separating the participant ID data from the survey data and deleting them for good upon the completion of data collection. Information collected through your participation will be used to fulfill the principal investigator's master's degree requirement and may be published in professional journals and/or presented at professional meetings/conferences.

If you have questions about this study, please contact Amber Ortlieb at aro0003@auburn.edu, Dr. Wi-Suk Kwon at kwonwis@auburn.edu, or Dr. Amanda Gale at agale@auburn.edu.

If you have questions about your rights as a research participant, you may contact the Auburn University Office of Research Compliance or the Institutional Review Board by phone (334) 844-5966 or e-mail at IRBadmin@auburn.edu or IRBChair@auburn.edu.

HAVING READ THE INFORMATION ABOVE, YOU MUST DECIDE IF YOU WANT TO PARTICIPATE IN THIS RESEARCH PROJECT. IF YOU DECIDE TO PARTICIPATE, PLEASE CLICK THE '*NEXT*' LINK BELOW.

_____

Investigator Date

_____

Co-Investigator Date

The Auburn University Institutional Review Board has approved this document for use from _____ to _____. Protocol #_____

Please add this approval information in sentence form to this letter. Send your updated letter to the IRB with a live link to the survey.

NEXT

The Auburn University Institutional Review Board has approved this document for use from 9/15/14 to 9/14/15 Protocol # 14-270 EP 1409

APPENDIX E

Pre-Notice Letter

[*Name of College or Department*]
[*Name of Building*]
Auburn University
Auburn, AL 36849

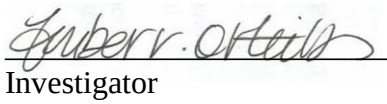
Dear [*Name of Occupant*],

This letter is to inform you that you will receive in a few days an email invitation to an online survey entitled "*Workplace Indoor Environment Quality and Occupants' Wellbeing*". This study is being conducted by Amber Ortlieb, master's student, under the direction of Dr. Wi-Suk Kwon and Dr. Amanda Gale, in the Auburn University Department of Consumer and Design Sciences. You are invited to participate because you work in one of the selected AU buildings in this study and are age 19 years or older.

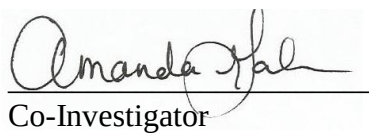
Your participation is completely voluntary. The email invitation you will receive soon will have a link to the information letter that explains the details of this study including its purpose, participation requirements, risks and benefits of participation, and data confidentiality. If you decide to participate in this study after reading the information letter, you will be asked to complete an online questionnaire. Your total time commitment will be approximately 20-25 minutes.

Your opinion provided through the survey data will be greatly valued and will be used to generate insight into workplace interior design**. As a small token of appreciation for your time, we are enclosing here $1.00.**

If you have questions about this study, please contact Amber Ortlieb at aro0003@auburn.edu, Dr. Wi-Suk Kwon at kwonwis@auburn.edu, or Dr. Amanda Gale at agale@auburn.edu.



Investigator — September 10, 2014
Date



Co-Investigator — September 10, 2014
Date

The Auburn University Institutional Review Board has approved this document for use from _____ to _____. Protocol #_____

APPENDIX F

E-mail Invitation for Online Survey

Dear [*Name of Occupant*],

I am Amber Ortlieb, a graduate student in the Department of Consumer and Design Science at Auburn University. As I mentioned in my letter sent a few days ago, I would like to invite you to participate in the survey study entitled "*Workplace Indoor Environment Quality and Occupants' Wellbeing*." You are invited to participate in this study because you work in one of the selected AU buildings and are age 19 years or older.

The survey is confidential. Your personal information will be used for the sole purpose to identify non-respondents to send reminders. Participation in this research is completely voluntary. If you decide to participate in this research study, you will be asked to complete an online questionnaire. Your total time commitment will be approximately 25 minutes. As a token of appreciation for your time in participating in this study, I included $1.00 in the aforementioned letter I sent you a few days ago to your AU mailbox.

If you would like to know more information about this study, an information letter can be obtained by clicking on the link at the bottom of this email message. If you decide to participate after reading the letter, you can access the survey from a link in the letter.

I would appreciate it very much if you could participate in the survey by [*Date*].

If you have any questions, please contact me at aro0003@auburn.edu or one of my advisors, Dr. Wi-Suk Kwon at kwonwis@auburn.edu or Dr. Amanda Gale at agale@auburn.edu.

[*LINK TO THE INFORMATION LETTER*]

Thank you for your consideration,

Amber R. Ortlieb

APPENDIX G

E-mail Reminder for Online Survey

Dear [*Name of Occupant*],

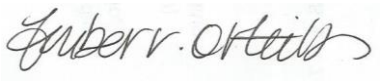
This is to remind you that you have been invited to participate in the survey entitled "*Workplace Indoor Environment Quality and Occupants' Wellbeing*."

Thank you very much if you have already completed the survey. If you have not completed the survey yet, please do so. The deadline of filling out the survey is next week, [*Date*]. Please click on the link below to complete the survey. Your responses will be very much appreciated.

[*LINK TO THE INFORMATION LETTER*]

If you have any questions, please contact me at aro0003@auburn.edu or one of my advisors, Dr. Wi-Suk Kwon at kwonwis@auburn.edu or Dr. Amanda Gale at agale@auburn.edu.

Sincerely,



Amber R. Ortlieb