ILLUMINATING GREEN HOTELS: UNIVERSITY STUDENTS' REAL-WORLD EDUCATIONAL ACTIVITIES

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ABSTRACT

Hotels can play an important role in tourists' experiences. Illumination is a critical component in hotel design. The objective of this study is to document appropriate educational activities which advocated the design of green (sustainable and healthy) hotels while specifically addressing relevant illumination issues, (i.e., reducing energy consumption through the use of Light Emitting Diodes (LEDs) and state-of-the-art lighting controls; and using "daylight harvesting") so as to prepare University students to understand and improve hotel designs of the future. This presentation will explore three very different, faculty-led, educational activities (Part 1, Part 2 and Part 3) related to green hotels, all conducted with the ultimate goal of understanding and improving tourist experiences: Part 1). Graduate student workshop at international conference: document hotel guest room temporary LED conversion and determine light spectra and light level measurement activity using spectrometers; Part 2). Undergraduate student in-class field study: document LED replacements in an on-campus hotel guest room's temporary conversion and light spectra and light measurement activity using spectrometers and light meters; Part 3). Six-week undergraduate student design studio class project to renovate lighting of an existing hotel such that it was sustainable. Use of energy-efficient light sources and lighting controls while minimizing watts/square feet were important considerations. Students utilized spectrometers and AutoCAD Enscape software to explore existing conditions or develop hotel renovation recommendations. N=61 students participated in the three activities. Students gained knowledge of "real-world", appropriate lighting design approaches for green hotels which could influence tourists' future experiences.

Keywords: lighting, hotel, energy efficient, LED, green, sustainable, tourism.

1 INTRODUCTION

A "green" hotel may be known as a(n) "sustainable," "eco-friendly" or "environmentally friendly" property [1]. The United States Environmental Protection Agency [2] defines sustainability in terms of "people, planet and prosperity". When considering sustainable tourism and green hotel illumination, the "people" reference may include assuring the health and safety of tourists at hotels (i.e., safety from slips and falls caused by inadequate light levels on stairs; freedom from eyestrain caused by inadequate light levels or glare; mitigation of circadian rhythm disruption associated with international travel/disruption of day/night cycle through the utilization of light level "doses" and light color spectra specification. For example, light spectra high in blue have been perceived as having a waking effect.) The "planet" reference could be addressed in hotels through the utilization of energy-efficient light sources; lighting controls which turn off or dim lighting when it is not needed. "Prosperity" could be found in the economy enjoyed by a hotel through reducing waste (i.e., turning off lights through daylight sensors and "harvesting daylight" when it is available to lower electric lights and resultant energy bills).

A green hotel incorporates environmental attributes such as conserving energy through its lighting system. A lighting system includes luminaires (light fixtures or fittings), light bulbs, wiring and lighting controls (dimmers, occupancy sensors etc.). Verma and Chandra [3] found that the guest rooms which utilized energy efficient light bulbs were perceived as most favorable by guests. The most energy efficient light bulb, whose use is trending and

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anticipated to become the hotel industry's standard, is the Light Emitting Diode (LED) [4]. LEDs consume less energy for light produced (lumens per wat) as compared to other light sources and need less replacement bulbs as they last 20,000 hours [5].

Some published hotel building standards intend to limit the amount of lighting energy consumed in different types of interior spaces to encourage sustainability. Large hotels incorporate guestrooms and function areas but may also include retail stores, museums and galleries, etc. The 2013 Building Energy Efficiency Standards [6] for Allowed Lighting Power Density Values prescribe the Watts/Square Foot allowed for various types of building spaces. These values range from 0.6 to over 2 watts per square foot for various space types within hotels. In some areas, these or similar standards may be adopted as law.

Also concerned with sustainability, the LEED Certification program, the USGBC (United States Green Building Council [7], a volunteer 3rd party organization, awards points to buildings which comply with its performance measures. Their hotel standard includes energy saving categories which appear to be applicable to lighting: "*Energy and Atmosphere*" (Prerequisite 2: "Minimum Energy Performance"; and "Credit 1: Optimize Energy Performance"); and "*Indoor Environmental Quality*" (Credit 6.1: Controllability of Systems – Lighting").

Instructor-guided, hotel lighting field studies have been shown to be effective in engaging students in learning "real world" lessons. Portable instruments, i.e. spectrometers have been found to be useful in capturing empirical data of existing conditions [8]. Nussbaumer has long advocated "evidence-based design" which consists of observation and documentation of existing conditions in order to inform future design projects [9]. Digital tools, such as AutoCAD, SketchUP and Enscape allow users to portray graphically complex images [10], and have proven useful for design students to convey their design solutions.

2 METHODS

A three-part methodology was utilized to provide learning experiences related to sustainable interior building illumination in hotels. The three activity sessions supported the overall goal of these educational activities, to improve tourists' experiences at hotels: Part 1). Graduate student workshop at an international lighting conference: light measurement activity documenting LED replacements in a conference hotel guest room's temporary conversion; Part 2). Undergraduate student in-class field study: light spectra and light level measurement activity documenting LED replacements in an on-campus hotel guest room's temporary conversion; Part 3). Six-week undergraduate student studio class project to design a lighting upgrade an existing hotel.

2.1 Part 1: Graduate student workshop

Graduate students attended a lecture in hotel meeting rooms about sustainable lighting design and circadian rhythm entrainment and then met in two designated hotel rooms for a hands-on data collection workshop. In hotel guestrooms A and B at an international conference, light color spectra and light level measurement activities were conducted in this graduate student field study. Light spectra measurement activities documented LED replacements in in a temporary conversion at a resort on the Western coast of Mexico. Room A utilized the existing hotel lighting. Room B was retrofitted with lightbulbs at the desk area in gooseneck lamps and the bedroom area in nightstand lamps. Prior to collecting lighting data, the students were trained in how to use and document readings a Lighting Passport ALP-01 spectrometer. Refer to Fig. 1 for image of students and instructor in retrofitted hotel room setup. Students worked in two-person teams and took turns using

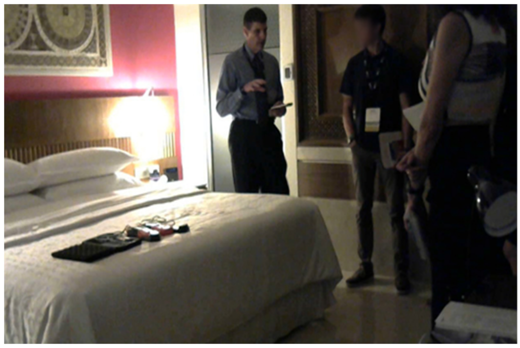


Figure 1: View of retrofitted light bulb in nightstand.) (Left) and retrofitted light bulb at desk (Lower Right) in hotel at graduate student workshop with instructor and students.

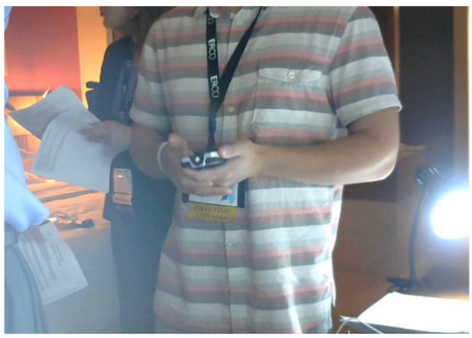


Figure 2: Students-in-action at graduate student workshop. (Left and Middle) Students take spectral readings; (Right) Image of retrofitted desk lamp.

the instruments in Room A (existing) followed by Room B (retrofit) and documented readings between the two hotel rooms in their field notes. Refer to Fig. 2 for images of students-in-action in hotel room setup.

2.2 Part 2: Undergraduate student in-class field study

Light spectra and light level measurement activity documented LED replacements in an on-campus hotel guest room's temporary conversion. Undergraduate students met at a designated university hotel room during their regularly scheduled class period. Before conducting the field study, the students were provided with a tour of two adjoining hotel rooms. After the tour the students were trained in how to use and document readings from two instruments including an Extech HD450 light meter and a Lighting Passport ALP-01 spectrometer. Students worked in two-person teams and took turns using the instruments and documenting readings between the two hotel rooms. Room A used the existing LED hotel room lighting and Room B was retrofitted temporarily with various LED lightbulbs. The adjoining hotel rooms allowed the researchers and students to move freely between Room A

Figure 3: Images of existing lighting in Room A for undergraduate student lighting activity.

Figure 4: Images of retrofit lighting in Room B for undergraduate student lighting activity.

Figure 5: Students measure light levels in hotel room with spectrometer and light meter.

and B and discuss their readings as the student teams collected lighting data. Refer to Fig. 3 for images of existing Room A. Refer to Fig. 4 for images of retrofitted Room B. Refer to Fig. 5 for images of students-in-action during educational activity.

2.3 Part 3: Undergraduate student hotel design studio project

A six-week design studio class project was assigned which required lighting upgrades to an existing, historic, on-campus hotel. Students were given lectures and numerous reading assignments regarding green hotels and their appropriate illumination. The instructor issued a project statement outlining the course requirements for green lighting statements, plans, specifications and drawings for the hotel renovation. Shortly after the hotel project renovation was introduced, but after the students toured and documented existing conditions at the project hotel, the University transitioned to an “online only” classes format due to Covid 19 concerns. Thereafter, the instructor’s guidance was delivered electronically via “announcements”; students’ design progress was submitted electronically, bi-weekly to “discussion”. Communication between instructor and students occurred on the Canvas online learning platform utilized by the University. Students posted written statements, questions and drawings to discussion board and received individual written feedback from the instructor.

Near the end of the six-week period, the students’ design solutions were reviewed by the instructor and compared to the 2013 standards for Allowed Lighting Power Density Values (Watts/Square Foot). The following were determined to be the applicable spaces and allowed values for the current study:

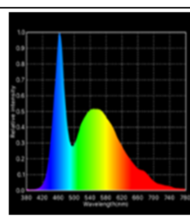
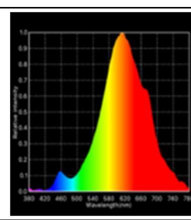
Corridors, restrooms, stairs and support areas	0.6
Exhibits, Museums	2.0
Hotel function area	1.5
Retail merchandise sales	1.6
Other	0.6

3 RESULTS

3.1 Part 1: Graduate student workshop

Nine students were able to recognize spectral profile color variances when they measured the specific lightbulbs integrated into Rooms A and B. The retrofitted lightbulbs included two Lighting Science “Aware and Awake” (LS-75WE-BR40-9W-2349K-80 CRI bulbs which were retrofitted in the desk area in gooseneck lamps and two Lighting Science “Good Night” (FG-02263-A19-9W 2231K 70 CRI) lightbulbs placed in the nightstand table lamps. The light bulbs in the existing Room A and retrofitted Room B differed in characteristics. Refer to Table 1 for lighting retrofit bulb images and details regarding color spectra which were determined by students with the spectrometer.

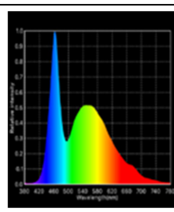
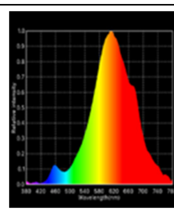
Table 1: Graduate student workshop retrofitted lightbulbs description and spectral profile.

Description	Retrofit lightbulbs	
	Lighting science aware and awake	Lighting science good night
Lightbulb image		
Spectral profile		

3.2 Undergraduate student in-class field study

A total of 36 students participated. They determined the varied spectral and illuminance differences between specific lightbulbs integrated in the retrofitted Room B. An example of differences noted included the Lighting Science "Aware and Awake" (LS-75WE-BR40, 9 Watt, 2349K, 80 CRI bulbs) which were retrofitted in the desk area in gooseneck lamps and Lighting Science "Good Night" (FG-02263-A19, 9 Watt, 2231K, 70 CRI) lightbulbs placed in the nightstand tables lamps. Refer to Table 2 for the color spectra for the retrofitted light bulbs as measured by students with spectrometer Refer to Fig. 5 for photographs of the hotel Room B lighting retrofit.

Table 2: Images and descriptions of retrofitted lightbulbs and their spectral profiles.

Description	Retrofit lightbulbs	
	Lighting science aware and awake	Lighting science good night
Lightbulb image		
Spectral profile		

Refer to Tables 3 and 4 for Correlated Color Temperature (CCT), Color Rendering Index (CRI) and Illuminance (Lux and Footcandles) for Existing Room A and Retrofit Room B.

Table 3: Descriptive statistics of existing hotel room lightbulbs for the undergraduate student lighting workshop.

Room A (Existing)	Value			
	CCT	CRI(Ra)	Illuminance (Lux)	Illuminance (Footcandles)
Closet	2387 K	77	180 lux	16.7 fc
Desk	2553 K	79	188 lux	17.5 fc
Nightstand	2387 K	77	180 lux	16.7 fc
Bathroom	3127 K	83	182 lux	16.9 fc

Table 4: Descriptive statistics of retrofitted hotel room lightbulbs for the undergraduate student lighting workshop.

Room B (Retrofit)		Value			
	Light bulb	CCT	CRI(Ra)	Illuminance (Lux)	Illuminance (Footcandles)
Desk	Lighting Science Aware & Awake	2849 K	82	3261 lux	303.0 fc
Desk	General Electric Linksmart	2101 K	75	132 lux	12.2 fc
Nightstand	Lighting Science Good Night	7413 K	78	1854 lux	172.3 fc
Bathroom	General Electric Brightstick	2828 K	83	1443 lux	134.0 fc

3.3 Part 3: Undergraduate student hotel design studio project

Sixteen students participated in this educational activity and produced lighting statements outlining the sustainable lighting design solutions they employed; lighting plans with wiring and lighting control selections; watts per square foot calculations; lighting fixture schedules with light bulb indications; 3D renderings to depict the interior space solutions. AutoCAD, SketchUP and Enscape software were utilized. Refer to Figs 6, 7, 8, 9 and 10 for examples of students' deliverables for the hotel renovation project.

Figure 6: Example of student's lighting design solution for bar rendered in Enscape.

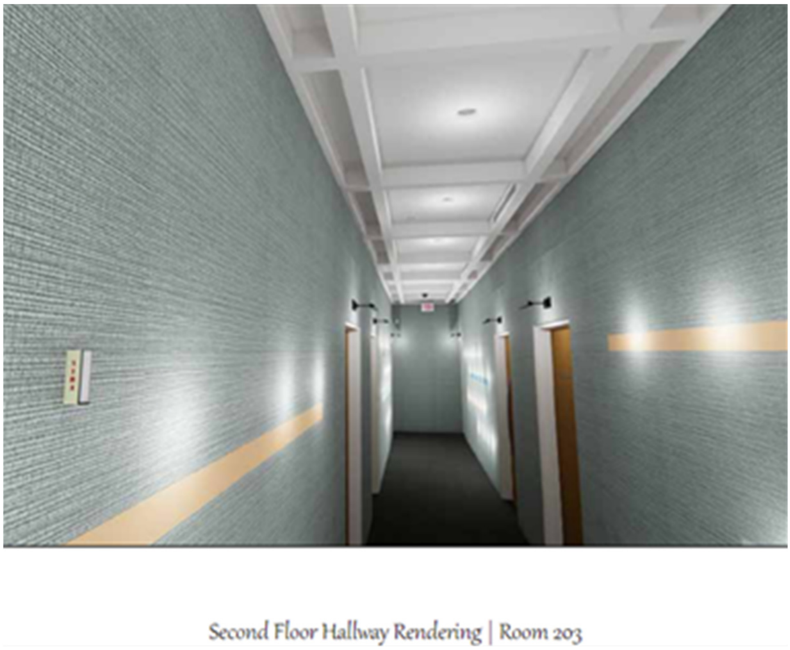


Figure 7: Example of student's lighting design solution for hallway rendered in Enscape.

Figure 8: Example of student's lighting design solution for guest room rendered in Enscape.

Hotel Lobby watts/sq.ft Recommendation: 1.1W/sq.ft.

Ketra D4R Retrofit Recessed Downlight
- 8 watts/fixture
- 9 fixtures total
- Total: 72 watts

Philips Hue
- 9.5 watts/fixture
- 10 bulbs total
- Total: 95 watts

X-Range LED Tape
- 1.0 watt/foot
- 36 feet total
- Total: 36 watts

Area of Lobby: 795 sq.ft.

Total Wattage
- 72 + 95 + 36 = 203 watts

Wattage/sq.ft.
- 203 watts/795 sq.ft. = 0.2553 watts/sq.ft.

Figure 9: Example of student's work showing hotel lobby power density recommendation for hotels compared to watts/square foot achieved in project solution.

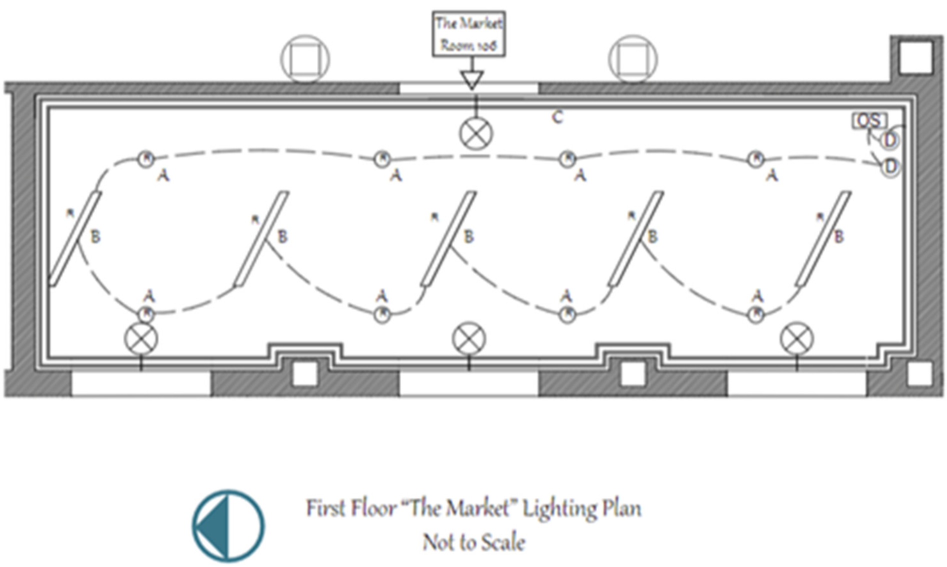


Figure 10: Example of a student's lighting plan for a retail store for the hotel design project with lighting controlled by an occupancy sensor (OS).

Upon review of the student projects, it was determined that the majority addressed the USGBC Credit Category, *Energy and Atmosphere*. Projects addressed the prerequisite, *Minimum Energy Performance* by providing evidence of compliance with the power density allowances for hotels. The student projects' reported power density values ranged from 0.16 to 6.7 watts/square foot. Refer to Table 5 for a breakdown of project compliance.

Table 5: Student project assessment of lighting USGBC credit category inclusions.

Student project assessment								
	Lighting USGBC credit category							
	Energy and Atmosphere				Indoor Environmental Quality			
	Prerequisite				Prerequisite			
	Minimum energy performance		Optimize energy performance		Controllability of systems – lighting			
Project #	W/sq ft complies w/ rec	Watts/ square feet	Light emitting diodes	Lumens/ watt	Occupancy sensor	Dimmer	Energy mgt. system	Daylight harvest/ sensor
1	Complies	0.31	x	NR	x	x	NR	NR
2	Complies	1.5	x	NR	x	x	NR	NR
3	Does not comply	2.55	x	NR	x	x	NR	NR
4	Complies	0.88	x	NR	x	x	NR	x
5	NR	NR	x	NR	x	x	NR	x
6	Complies	0.8	x	NR	x	NR	NR	NR
7	Does not comply	2.15–6.7	x	NR	x	x	NR	x
8	Does not comply	3.6	x	NR	x	x	NR	NR
9	Complies	1.2–1.4	x	NR	x	NR	NR	x
10	Complies	0.6	x	NR	x	x	NR	NR
11	Complies	0.55	x	NR	x	x	x	x
12	Complies	1.5	x	NR	x	x	NR	x
13	Complies	0.25	x	NR	x	x	x	x
14	Complies	1.5	x	NR	x	x	NR	NR
15	Partial compliance	1.04–1.53	x	NR	x	x	NR	NR
16	Complies	0.16	x	NR	x	x	x	x
Total								

NR =No report.

A majority of the students' design solutions (n=11, 68.75%) fully complied with the energy efficiency standards. Upon review of the students' projects it was determined that only half of the projects me the prerequisite *Optimize Energy Performance*. Refer to Table 5 for a breakdown of project compliance. While 100% of students' projects utilized energy efficient Light Emitting Diodes (LEDs) (n=16), none of the student projects specifically reported the associated lumens per watt (0, 0%) for LEDs.

Regarding the USGBC Credit Category, *Indoor Environmental Quality*, the majority of student projects were found to meet the applicable prerequisite, *Controllability of Systems – Lighting.* The majority of projects used multiple types of devices. All of the projects utilized occupancy sensors (100%, n=16). The vast majority of projects (n=14, 87.5%) utilized dimmer switches. Only three of the projects used energy management systems (18.75%). One half of the projects (n=8, 50%) used daylight harvesting which incorporated daylight sensors to turn off lighting fixtures near windows.

4 CONCLUSIONS

A substantial part of a tourist's experience may happen within a hotel. The sustainability of a hotel is determined by how it addresses people, prosperity and the planet. An important and highly visible component of a hotel is its lighting system. Illumination can be analyzed with respect to various factors including light color, energy consumption, lighting controls, quantity of light and quality of light. LEDs are considered to be sustainable light sources due to the amount of light they produce as compared to energy consumed and are recommended for sustainable hotels. LEDs are also sustainable because of their long lifetimes which decrease the need for maintenance, replacements, and landfill waste. Automatic controls, such as occupancy sensors, also are considered sustainable as they don't rely on humans to turn the lights off.

There are many possible educational approaches which could successfully facilitate students' learning with regards to the illumination of hotels. This study highlights three distinct strategies implemented by one instructor. Two of the approaches involved documenting and analyzing existing hotels' temporarily retrofitted LED lighting and the third strategy required students to design a new LED lighting system for an existing hotel. Various tools, including a spectrometer, a light meter and LEED certification program sustainability criteria, were used to determine lighting sustainability. These strategies increased participating students' awareness of sustainable lighting for hotels. The tourism industry would become more sustainable if hands-on educational experiences were implemented which were targeted towards the design and implementation of sustainable hotel lighting.

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