HOW DO GREEN BUILDINGS COMMUNICATE GREEN DESIGN TO BUILDING USERS? A SURVEY STUDY OF A LEED-CERTIFIED BUILDING

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ABSTRACT

Studies investigating the benefits of green buildings can be approached by the affordance theory—the perceived properties of a thing that determine how it could possibly be used. This study focuses on the sustainable communication and education that a green building should provide. By applying the affordance theory, we examined whether a LEED-certified university campus building effectively communicates green design and sustainability to its users and if so, then how? We employed a questionnaire survey targeting campus users of a LEED-certified building by examining their awareness of the building's LEED status and perception of green design elements at multiple spatial scales, as well as their general knowledge on green building topics. We collected 177 questionnaires, of which 153 were qualified for statistical analysis. The results suggested that the building itself can afford to promote awareness among users, but cannot afford to educate users on general green building knowledge. We found that building users perceived green design at different spatial scales, preferring either product or space-related design. Our results indicate that future design should continue promoting the use of educational signage, which was found to be the most effective communicator of sustainability. The communication of green design to users with different spatial preferences remains a future research focus. Further studies on the innovative use of green building design as effective communicators are needed to promote sustainability education among the building users.

KEYWORDS:

green buildings, green design, affordance theory, sustainable communication

1. INTRODUCTION

The past two decades have witnessed widespread green building development (USGBC 2009), partially due to their healthier and more resource-efficient models of design, construction, operation, renovation, maintenance, and demolition (US Environmental Protection Agency 2016). The benefits of green buildings have been studied extensively, mostly using post-occupancy

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evaluation (POE), covering a wide range of topics (Lee and Kim 2008, Altomonte and Schiavon 2013). In POE and other relevant studies, the fundamental question focused on the characteristics that a green building offers users, including better indoor environmental quality, improved user satisfaction, well-being, and productivity, effective communication of green design, facilitation of sustainable behaviors, and public sustainability education.

The influence of a green building on users' awareness and knowledge about sustainability, as well as their perception of green design, remain unclear due to limited empirical evidence. While voluminous literature exists on POE topics regarding users' experience, few studies have examined the role of green buildings and green design in communicating sustainability to building users. Deuble and Dear (2012) attempted to understand the links between green buildings and their occupants. Others investigated sustainable behaviors among occupants in green buildings (Daniel et al. 2014, Azizi and Wilkinson 2015). While these studies offered intriguing insights, they were not based on a strong theoretical foundation.

The affordance theory, originated by Gibson (1979) and enriched by Norman (1988), has great potential to guide the development, design, and evaluation of green buildings. This study adopts Normanian perceived affordance, which has been widely applied in product design (Norman 1988, Tweed 2001, Galvao and Sato 2005, Hsiao et al. 2012). Normanian affordance is a result of the mental interpretation of a thing and the perceived properties which determine its possible use (Norman 1988).

Pertaining to architecture, several studies have proposed the affordance-based design approach (Clark and Uzzell 2002, Koutamanis 2006, Maier et al. 2009). The concept of affordance can be expressed through "x-able" (Maier et al. 2009), such as "walk-able, step-able, sit-able, lean-able, eat-able" (Kim et al. 2011). The implication of the affordance theory in architecture to date is largely based on the functionality of a designed building object. However, investigating design as a communication medium (i.e., communicator) has not been extensively explored. By applying the affordance theory to green buildings and sustainable communications, our study is designed to fill this knowledge gap.

Following the concept of "x-able" in the affordance theory, this study aimed to identify whether and how a green building affords to communicate its green design and educate sustainability to its users. We took a quantitative approach through employing a questionnaire survey and extracted three "x-abilities"—aware-ability, know-ability, and perceive-ability—to investigate whether the green building of study promotes awareness of its green status, if it facilitates green building knowledge among users, and how users' perception of green design is expressed at multiple spatial scales.

2. AFFORDANCE THEORY IN BUILT ENVIRONMENT RESEARCH

The key concept of the affordance theory and its implication in architecture is exemplified in (green) buildings (Table 1). According to Gibson (1979, p. 129), "An affordance is neither an objective property nor a subjective property. … It is both physical and psychical, yet neither." The affordance in our survey study is related to subjective property, perceived affordance (Norman 1988), and "artifact-user affordances" (Maier et al. 2009) (Table 1). Users must perceive a design before it can communicate a certain message (e.g., sustainability). Koutamanis (2006) separated affordances in a building into two categories—product and space—that imply different spatial scales, thus laying the theoretical foundation to investigate perceive-ability in our survey study at multiple spatial scales.

TABLE 1. Key concepts of affordance theory and examples of its implications in (green) building design.

Key concepts	Descriptions	(Green) building examples
Gibsonian affordance (1979)		
Affordance is independent of perceptions and does not change as needs and goals do (linking to actual physical affordance).	An affordance is a stable property of the artifact and its existence does not depend on our interpretation or experience. This means affordances do not need to be visible, known or desirable to exist in a particular context. It implies that an affordance is a constant that may not vary at the same rate as our motivations and actions do (Gibson 1979).	G.1 On-site renewable energy produces on-site clean energy regardless of whether or not the building user is aware, and/or understands their technologies. G.2 The natural light provided in an atrium is independent of the user awareness and perception. G.3 The automatic solar shading is provided regardless of the building user's interpretation of the technology.
It exists relative to actions (linking to Norman's perceived affordance).	Mutual relationships between our actions and the artifacts around us. These relationships are only conceivable when paired with actualizing agents (e.g., users) that can make use of these relationships or acknowledge their existence (Gibson 1979).	G.4 The individual lighting control can only be achieved through users knowing how to use them. G.5 Adjustable thermostat must be controlled by users.
Normanian affordance (1988)		
Perceived affordance	Affordance as the result of the mental interpretation of things—the perceived properties of the thing that determine how it could possibly be used (Norman 1988).	N.1 Waste categorization bins must be recognized by the users prior to its use. Correct use of bins also depends on the users' perceived properties of the bin.
Koutamanis (2006)		
Affordance of building elements/ products (Kp)	The affordance of building elements is similar in Norman's affordance.	Kp.1 The operational windows allow natural ventilation. Kp.2 A door mat avoids debris entering a building.
Affordance of space (Ks)	Space generally lacks an interface that allows interaction with 'solid' objects. A higher degree of abstraction is necessary for dealing with the complexity that is caused by the flexibility and adaptability of space in relation to user activities (Koutamanis 2006).	Ks.1 The open space in a building affords social interaction, a place to retreat when feeling discomfort. Ks.2 A solar house can afford the natural buffering of extreme external climate, reducing in-house energy load.
Maier et al. (2009)		
Artifact-artifact affordances	The interaction between two inanimate agents (e.g., walls affording support to a roof, sprinklers affording suppression of fires) (Maier et al. 2009).	M.1 The thermal mass is part of the building structure. M.2 Windows with lower U-value afford isolation. M.3 Low VOC paint affords healthier indoor air quality.
Artifact-user affordances	Interactions between a living agent and an inanimate agent in which perception is needed (Maier et al. 2009).	G.4, G.5, N.1

Using a building in a higher-education institution as an example, affordances of a conventional versus a green building can be differentiated (Table 2). We focused on a higher-education building because "colleges train the next generation of leaders who will ultimately be responsible for putting green ideas into practice." (Princeton Review 2015, p. 3). To promote sustainability within higher-education, the U.S. Green Building Council (USGBC) has been certifying an increasing number of university buildings under the Leadership in Energy and Environmental Design (LEED) certification program.

In our literature search, no study was found to have applied the affordance theory in the context of sustainable communication via green building design. Nevertheless, previous studies have compared pro-environmental attitudes and/or behaviors of occupants in a conventional building to those in a green building (Deuble and de Dear 2012, Brown and Gorgolewski 2014, Azizi et al. 2015, Wu et al. 2017). We argue that before a building's capability to influence attitudinal and behavioral changes can be justified or causality can be extracted, a study of the building's role in communication must be completed. Furthermore, among all the extra affordance identified for a green building (Table 2), our survey study focused on sustainable communication and education by investigating the green building's three "x-abilities": aware-ability, know-ability, and perceive-ability.

TABLE 2. Shared affordance of a conventional and green building and extra affordance of a green building, using a university academic building as an example.

Shared affordance (SA)	Extra affordance (EA) of a green building
SA1: Afford intellectual productivity (IP) • SA1-IP1: Space for formal and informal interaction and work-related conversation • SA1-IP2: A comfortable (thermal, visual and auditory) environment • SA1-IP3: Productive working/studying space for building users • SA1-IP4: Easy access to information (e.g., on-site libraries, showrooms)	**EA1:** Afford sustainability—criteria according to LEED • EA1-LD1: Sustainable site and alternative transportation • EA1-LD2: Water and energy efficiency and consumption reduction • EA1-LD3: Pollutions reduction and waste reduction • EA1-LD4: Materials and resource conservation • EA1-LD5: Improved indoor environmental quality
SA2: Afford daily activities: • SA2-DA1: Open space for rest • SA2-DA2: Easy way-finding • SA2-DA3: On-site or close-to-site food/convenience store	**EA2:** Afford sustainable communication and education (SCE) • EA2-SCE1: Presence of green-building related information within and outside of the building that communicates/educates building users and passerby
	EA3: Afford sustainable behaviors (SB) (an example) • EA3-SB1: Proper design and location of waste bins for correct waste categorization

3. THE SURVEY STUDY

Users' aware-ability (quantified awareness), know-ability (knowledge testing), and perceive-ability (articulated perception) toward a university's LEED building were investigated with the following research questions. For aware-ability, we asked "What is the general awareness level among the building users and through which communication mediums do they gain awareness?" and "How does personal background (i.e., users characteristics) affect users' awareness?" For know-ability, we asked "What is the knowledge level about green buildings among the building users?" and "Is it independent of their awareness?" Lastly, for perceive-ability, we asked "What is the most perceived green design?" and "Do users perceive green design differently according to the design's spatial scale (i.e., product or space-related), as well as to their awareness of the building's LEED status?"

1.1 Research Setting

Brody Hall (hereafter Brody) was selected as the study site. It is located on the main campus of Michigan State University, East Lansing, Michigan, U.S. Built in 2011, it serves as a multi-functional addition (33,832 Gross Square Feet) to the original residential hall. The structure now houses classrooms, study rooms, as well as the largest dining hall on campus with a diverse user profile. It was certified at the silver level by the LEED rating system in 2014.

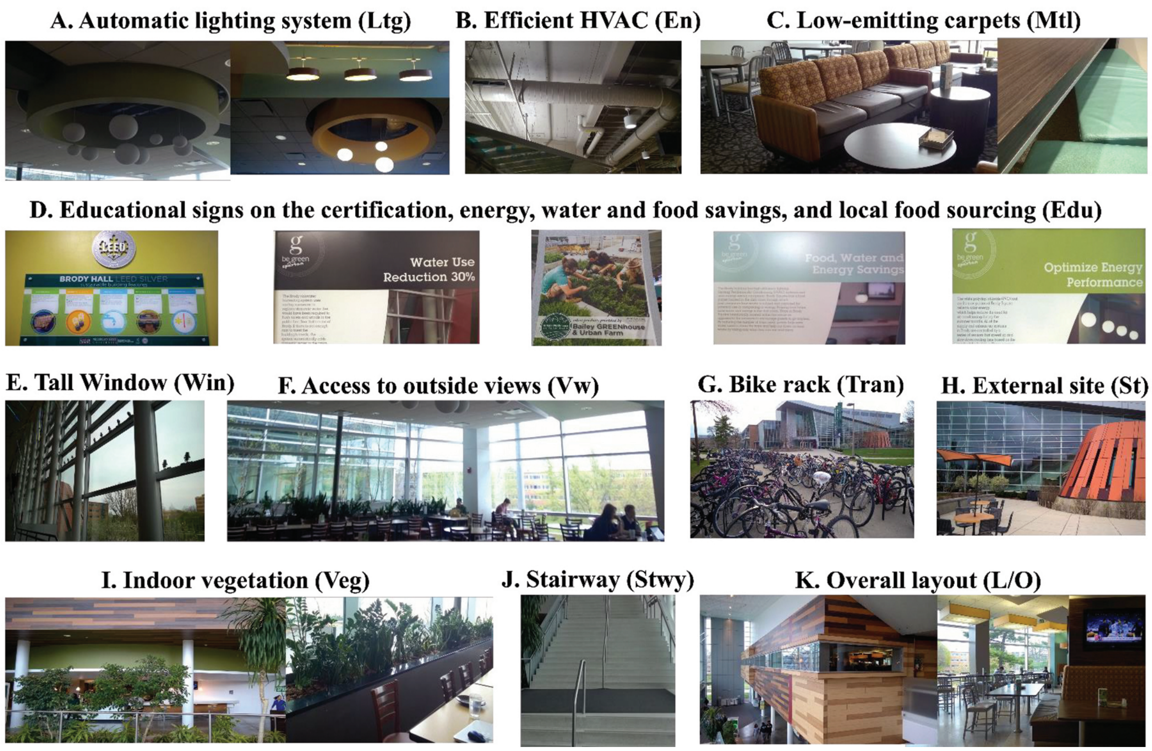
The campus sustainability manager offered the research team an on-site visit and introduced the green design implemented in Brody. A comprehensive signage program is applied on each floor in the building to highlight key features of the green design. The lighting system is automatic, with artificial light used after daylight levels fail to reach pre-defined illuminance settings. Over 75% of the entire space has access to natural light, providing users with sufficient outside views. The building achieved 4 out of 5 credits in the water efficiency category of LEED (USGBC 2016a) and the kitchen employs a 100% food waste recycling system. In addition, the layout and the furniture in the dining hall were intentionally designed for multi-purposes catering, improving the user experiences.

1.2 Survey

This study was explorative and observational in nature. A questionnaire survey was conducted to identify associations among variables without extracting casual relationships. Following a site visit guided by the sustainability manager, we identified a total of eleven green design elements that can be perceived by users (Figure 1).

Brody is primarily used as a dining hall. Survey participants were mostly part-time occupants, consisting mainly of university students and faculty, as well as local residents and non-local visitors. The survey was carried out in May of 2016 using the convenience sampling method. Convenience sampling was chosen because the uses of Brody is dynamic and unpredictable (i.e., the researchers could not seek out a target population that uses Brody regularly). For three days, the research team was present at the building entrance from 11:00 AM to 6:00 PM and approached each person upon entrance. The questionnaire was distributed in person, and the respondent could either provide their answers on-site or return it at a later time. We specifically instructed the respondents that they should complete the questionnaire on their own to assure the independence of sampling.

FIGURE 1. Photos of the eleven green design elements implemented in Brody that were shown to survey participants. The short-name for each feature follows the full name in the bracket.



1.3 Questionnaire and Measurement

The questionnaire included three sections, dividing and targeting research question on aware-ability, know-ability, and perceive-ability. It also included information to identify the respondents' demographic and user characteristics. The study objective and glossary were provided on the cover page to familiarize the respondents with the study purpose and their rights as a participant. We distributed 230 questionnaires and a total of 177 questionnaires were returned (77.0% return rate). The questions were coded before analysis. For data quality assurance and control, samplings with less than 80% completion on any section were eliminated. This process narrowed the responses to 153, among which nine had one to two missing values. For these occasionally missing data, we used single-value imputation (Pigott 2001) and replaced them with the overall mean calculated from the remaining responses.

Aware-ability: awareness of Brody as a green building

Respondents self-reported whether they were aware that Brody is a green building. If so, the respondents would provide answers regarding which communication medium relayed this message, including IPF (Infrastructure, Planning, and Facilities) website of the university, Brody's website, media reports, word of mouth, and educational signage in Brody. We coded awareness with a value of one if the respondent was aware and zero otherwise.

Know-ability: knowledge on general green building topics

The respondent's knowledge about green buildings was quantified with two questions. First, they were asked to select the logo representing the green building certification scheme most widely adopted in the U.S. (i.e., the LEED logo). Three additional choices were presented including the logos for Energy Star, Green Seal, and Green Star rating system. Alternatively, they could choose "I do not know," which allowed them to skip the second question, which asked for the certification level of Brody. During data analysis, the first question was abbreviated as "LEED" and was coded with a value of one for the correct answer and zero for all other answers. The second question was abbreviated as "level" and was coded with a value of one for the correct answer and zero otherwise.

Perceive-ability: perception of green design in Brody

The eleven green design elements (Figure 1) can be categorized as either product-related or space-related to address the variation in underlying spatial scales (Koutamanis 2006). The features Vw (outside view), St (external site), and L/O (overall layout) exclusively relate to building space, while Ltg (lighting), En (efficient HVAC), Mtl (low-emitting furniture), Edu (educational signage), and Veg (indoor vegetation) specifically relate to building products. The remaining design, including Win (tall window), Tran (bike rack), and Stwy (stairway), do not exclusively relate to either dimension, as they are products incorporated into the building space.

Of the eleven green design elements listed, respondents were encouraged to choose no more than five items that were the most perceivable and recognized as green design. They were also requested to rank the selected design to indicate the relative perceive-ability of each design. Regardless of the number of design elements chosen by a respondent, our coding scheme ensured that all elements were summed to a total of 15 points. For example, if five design elements were chosen, we would assign values of five, four, three, two, and one to each in order of rank. Similar numerical assignments were applied when different numbers of design were selected. If more than eight elements were selected, the first eight were used for analysis and the remaining ones were discarded (i.e., considered less perceivable), with following scores: 3.275, 2.875, 2.475, 2.075, 1.675, 1.275, 0.875, and 0.475 point. This ensured a sum of 15 points as well as a consistent gap between each selection. The points were used to calculate the perceive-ability score of each selected design.

Background factors

Respondents reported their access frequency of Brody, the time since their initial visit, the reason(s) for their access, as well as their age, gender, role/occupation, prior knowledge of green building/design topics, and self-reported environmental consciousness on a scale of 0–5.

For qualitative factors, answers were coded as: usage (one = food only, two = other); gender (one = female, two = male, three = other); and prior knowledge (one = layman, two = familiar with the topic, three = expert). The original counts of frequency were further grouped into three levels for analysis: level one totaled 23 samples and combined first time visits (n = 2) and occasional users (n = 21); level three totaled 40 samples, combined monthly users (n = 19) and weekly users (n = 21), and level five totaled 90 samples and consisted of daily users.

1.4 Data analysis

The R programming language was used for statistical analysis (Rdevelopmentcoreteam 2008). For descriptive correlational analysis, all categorical data were treated as factors, using the *mixed.cor()* and *pairs.panels()* functions (Revelle 2014). No data transformation was performed because many variables are categorical. Non-parametric statistical methods were performed (i.e., Mann-Whitney U Test) due to the non-normality of most data.

Aware-ability

We first counted the number of people who were (or were not) aware that Brody is a green building. The selection of each communication medium was then counted to identify its effectiveness. The percentage of respondents per user groups was also calculated.

To extract the effects of background factors on user awareness, a descriptive correlation matrix was constructed. Factors with significant correlations with awareness were explored further. Chi-square test was carried out between awareness and extracted factors, resulting in shortlisted factors that were not independent of awareness. Consequently, conditional associations were performed on shortlisted factors.

Know-ability

Knowledge level was quantified as the percentage of people responding correctly to each of the two questions/variables (i.e., "LEED" and "level"). The relationships between awareness and the two knowledge variables were explored with conditional independence tests using three-way contingency tables. Furthermore, log-linear models (Meyer et al. 2015) were fitted against all possible combinations of independence, including mutual independence, joint independence, conditional independence, all two-way associations, and saturated three-way associations (Friendly 2016). The best-fitted model was identified through analysis of deviance during model selection process (Sakate and Kashid 2014).

Perceive-ability

The top five perceived green design elements were identified through frequency analysis. The mean score of perceive-ability for each design was calculated to identify its relative perceive-ability order. Exploratory factor analysis was carried out on the eleven green design elements to examine users' perception of green design at different spatial scales. Two latent factors—the product or space-related green design—representing each spatial scale were then extracted. Two algorithms were performed: varimax rotation, which returns orthogonal factors; and oblimin rotation, which allows non-orthogonal factors. The latter algorithm is specifically useful for the factor structure of categorical items (Revelle 2011). The underlying assumption to conduct two rotation algorithms was that no confirmatory hypothesis regarding orthogonality could be constructed regarding the relationships between the two latent factors—space and/or product-related perceive-ability.

Based on frequency analysis and the exploratory factor analysis, the data dimension of the eleven original design variables was reduced by combining some of them into a new variable (e.g., product or space-related design). The average perceive-ability score from the original variables was used when they were combined to form the new variable. Two-sample test of proportion and Mann-Whitney U test were then performed to evaluate whether users perceive green design differently in accordance to their awareness group (i.e., awareness = 0 or = 1). Specifically, two-sample test of proportion compared the frequency of people who selected a specific feature and Mann-Whitney U test compared the distribution shape and the locations of the perceive-ability scores.

4. RESULTS

The majority of respondents (n = 122, 79.7%) were undergraduate students, of whom 73.0% (n = 89) accessed Brody on a daily basis. Another 76.5% of respondents (n = 117) came to Brody only for food, while others visited the building for other purposes (e.g., accessing the lecture rooms). When asked about their prior knowledge of green buildings, five respondents claimed to be experts, 89 respondents said laymen, and the remaining claimed a familiarity with the topic. Half of the respondents stated their environmentally conscious as moderate (n = 76, 49.7%), followed by very (n = 36, 23.5%) and somewhat conscious (n = 22, 14.4%). The differences between user characteristics and their potential effects on aware-ability, know-ability, and perceive-ability were not statistically tested, partially due to the significantly unequal sample size of the user group (Table 3). The potential effects of background factors were investigated under each "x-ability" independently.

TABLE 3. User characteristics and the percentage of respondents who were aware (awareness = 1) or not aware (awareness = 0) that Brody is a green building.

		Number of respondents	Awareness = 1 (n = 92)		Awareness = 0 (n = 61)	
			Frequency	%	Frequency	%
Frequency of access	First time	2	1	1.1	1	1.6
	Occasionally	21	6	6.5	15	2.5
	Monthly	19	15	16.3	4	6.5
	Weekly	21	11	12.0	10	16.4
	Daily	90	59	64.1	31	51.0
Time since their first visit	≤ 1 yr	80	50	54.3	30	49.2
	> 1 yr, ≤ 2 yrs	37	21	22.8	16	26.2
	> 2 yrs, ≤ 3 yrs	19	10	10.9	9	14.8
	> 3 yrs	17	11	12.0	6	9.8
User profile	Undergraduate	122	77	83.6	45	73.8
	Graduate	5	3	3.3	2	3.3
	Faculty/staff	6	3	3.3	3	4.9
	Local residents	11	6	6.5	5	8.2
	External visitors	9	3	3.3	6	9.8
Reasons to visit Brody	Meals	117	73	79.3	44	72.1
	Other reasons	36	19	20.7	17	27.9
Age	≤ 25	128	81	88.0	47	77.0
	> 25, ≤ 40	7	3	3.3	4	6.6
	> 40	18	8	8.7	10	16.4
Gender	Female	84	51	55.4	33	54.1
	Male	68	40	43.5	28	45.9
	Other	1	1	1.1	0	0.0

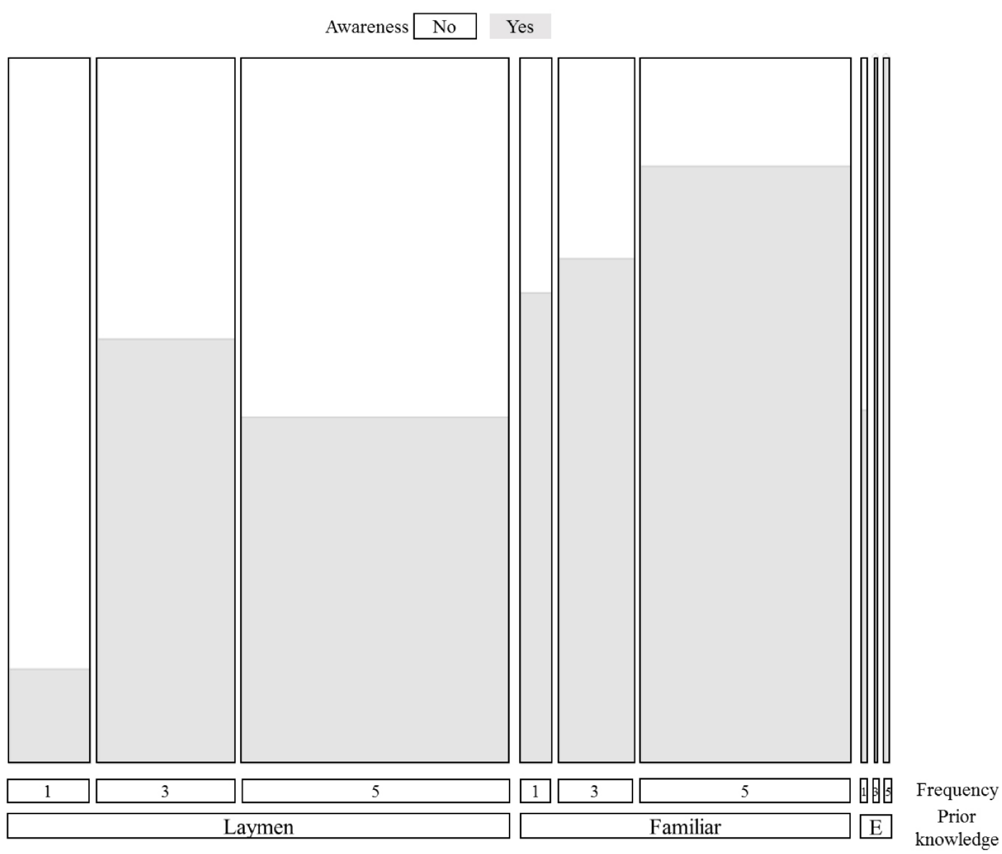
Aware-ability

Out of the 153 samples, 60.0% respondents (n = 92) were aware that Brody is a green building. Among those, 39.1% (36 out of 92) selected educational signage as the only communication medium for their awareness, followed by word of mouth (22.8%, 21 out of 92), or both (12.0%, 11 out of 92). The university websites appeared to be a less effective communicator, and media coverage was the least effective (0.03%, 3 out of 92).

Awareness was not significantly correlated with users' personal background. The highest positive correlation coefficient was with prior green building knowledge (0.32). This was followed by a correlation coefficient of 0.17 between awareness and the frequency of using Brody, as well as the environmental consciousness of the users. The p-value for the above three factors was < 0.00001, 0.046, and 0.028, respectively, all showing statistical significance. The chi-square test supported statistical independence between awareness and the environmental consciousness, however, for frequency and prior knowledge, they were not independent of awareness, both with a p-value < 0.0001.

The analysis of the conditional associations between awareness that Brody is a green building, visiting frequency, and prior knowledge on green buildings showed distinctive differences (Figure 2). For laymen, their awareness increased significantly (at 0.05 level) when frequency

FIGURE 2. Given respondents' prior knowledge about green buildings (three levels: laymen, familiar, experts (E)), the conditional independence plot visualizes the relationships between frequency (three levels: 1 = rare, 3 = monthly and weekly, 5 = daily) and awareness (two levels: yes or no).



increased from very rare (= 1) to more frequent (= 3); however, a further increase in frequency (daily users = 5) did not significantly affect awareness. In contrast, for users who self-identified as familiar or expert on green building topics, awareness and visiting frequency remained statistically independent.

Educational signage—the most effective communicator—was not independent of visiting frequency. Interactions between awareness, visiting frequency, and educational signage generated the same patterns (Figure 2). For those who did not see the educational signage in Brody, awareness increased when frequency increased from very rare to more frequent but became independent of frequency when it further increased. For those who noticed the educational signage, awareness and frequency remained statistically independent.

Know-ability

Less than a third of the respondents answered either of the two knowledge questions correctly. Less than 10% of the respondents answered both questions correctly. Overall, 109 people could not answer the first question (LEED) correctly and 49 respondents answered: "I do not know." For the remaining 60 respondents with incorrect answers, 45 chose the "Green Seal" logo, and nine chose the "Energy Star" logo.

The conditional independence test confirmed that being aware of Brody's green status was independent of knowing its certification level, regardless of whether a user recognized the LEED logo. Based on the log-linear models, we found that the joint independence model received the best model fit, indicating an association between the two knowledge variables. Meanwhile, awareness was independent of both of the two knowledge variables and their combinations. Neither the mutual nor the conditional independence model could capture the interactions between the two knowledge variables.

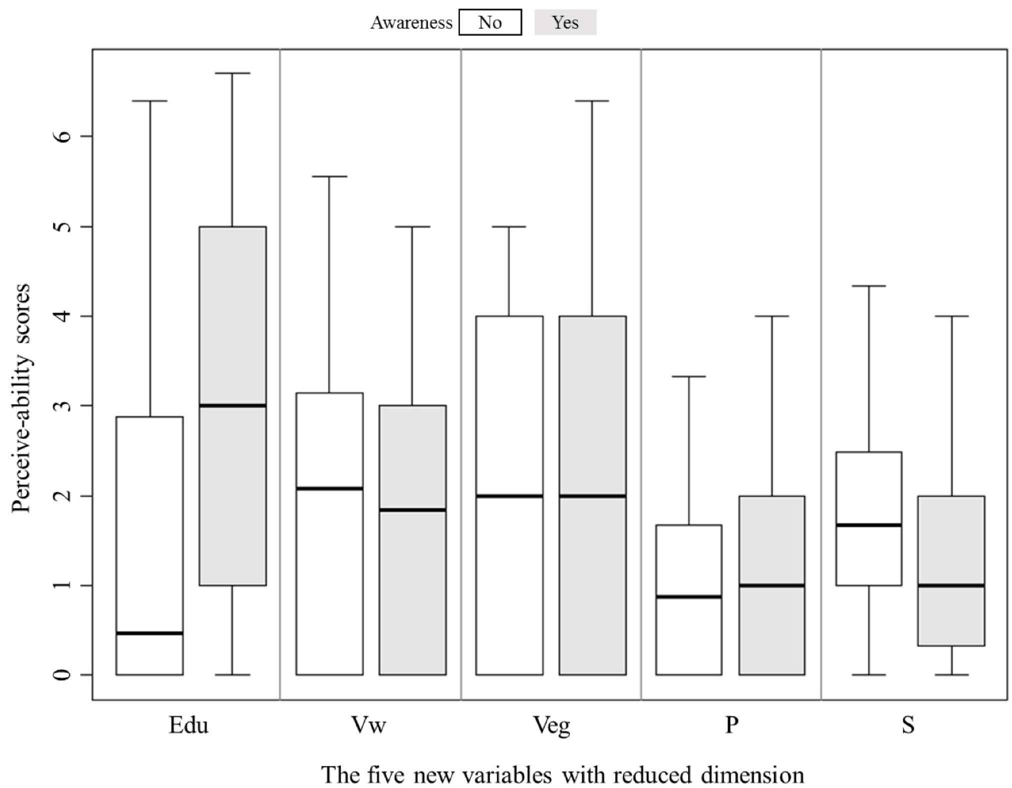
The perceive-ability

Through frequency analysis, Edu (educational signage), Vw (outside view), and Veg (indoor vegetation) were found to be most-perceived green design, with 101 (66.0%), 103 (67.3%), and 104 (68.0%) of respondents selecting them, respectively. Next was Ltg (lighting) and Win (tall window), both with 81 users selecting them. About 60 to 65 people also chose En (efficient HVAC), Tran (bike rack), St (external site), and L/O (overall layout). The least selected elements were Mtl (low-emitting furniture) and Stwy (stairway), which were selected by 40 (26.1%) and 47 (30.7%) respondents, respectively. The top five selected features also ranked the highest for their perceive-ability scores.

Pre-assumed spatial patterns were supported by the exploratory factor analysis. The first latent variable extracted was related to building space, including Win (tall window), St (external site), and L/O (overall layout) under both oblimin and varimax rotation, while the oblimin algorithm also identified Vw (outside views) and Stwy (stairway). The second latent variable extracted was related to building product, including Ltg (lighting), En (efficient HVAC), and Mtl (low-emitting furniture) under both algorithms. Edu (educational signage), Tran (bike rack), and Veg (indoor vegetation) were not categorized to either latent variable.

The original eleven green design elements were reduced to five new variables, including Edu (educational signage), Vw (outside views), Veg (indoor vegetation), S (space-related factor), and P (product-related factor) (Figure 3). The first three were original elements and the most perceived features, and thus, were not combined with any other features. S indicated the new variable combining space-related features: Win (tall window), St (external site), L/O (overall layout), and Stwy (stairway). P indicated the new variable combining product-related features:

FIGURE 3. Perceive-ability according to people's awareness of the five new variables, including original variables Edu (educational signage), Vw (outside views), and Veg (indoor vegetation), as well as combined variable P (product-related) and S (space-related).



Ltg (lighting), En (HVAC), and Mtl (low-emitting furniture). Lastly, Tran (bike rack) was not included later in the analysis because it was the least perceived and was neither a space-related nor a product-related factor.

The proportion of people selecting Edu (educational signage) differed significantly by their awareness group (p-value = 0.002) at 0.05 level, according to the two-sample test of proportion. The respondents' preference on Vw, Veg, S, and P variables did not differ significantly by their awareness. When comparing the distribution shape and center location of perceive-ability scores through the Mann-Whitney U Test, both Edu and S showed significant differences between the two awareness groups (Figure 3). However, the pattern was opposite: Edu received higher scores from users who were aware that Brody is a green building, whereas S received higher scores from users who were not aware. For Vw (outside views), Veg (indoor vegetation), and P (the product-related factor), no significant difference was found between the two awareness groups.

5. DISCUSSION

The potential usefulness of the affordance theory in green building studies was discussed and demonstrated through a survey study that derived "x-able" focusing on sustainable communication and education of a green building. The correlation matrix indicated that the use of a green building and its green design as the communicator of sustainability might not be affected by a user's gender, age, or occupation. The frequency, however, can potentially facilitate interactions with the green design (e.g., educational signage), which could, in turn, affect awareness and knowledge of the user (also see Zheng et al. 2011). Such interactions need to be studied in future research with a larger sample size and diversity, to enable a more robust statistical analysis.

Aware-ability

The overall aware-ability achieved in Brody was satisfying, with 60% of the respondents being aware of its green status. Educational signage proved to be the most effective communicator, reinforcing the purpose of integrating "a comprehensive signage program built into the building's spaces to educate the occupants and visitors of the benefits of green buildings" from the innovation category in LEED (USGBC 2016b). This finding also coincides with an earlier study (Cranz et al. 2014) where the successful communication mediums identified in a LEED-certified building in Berkeley, California, included tall windows, recycling signage, and water fixture signage.

The frequency was found to be an important factor affecting awareness. For users without prior knowledge, frequent access might increase the likelihood that they would become aware of Brody's green status. This phenomenon is supported by the significant correlation between frequency and the recognition of educational signage. For those who did not notice the educational signage, their awareness could increase from other communication mediums, e.g., word of mouth.

Know-ability

The general know-ability that Brody affords was unsatisfactory compared to aware-ability, even though education is a core reason for greening schools because "tomorrow's future leaders are in school today" (USGBC 2011). This indicates that effective methods for sustainable education need to be reinforced. The low know-ability obtained in our study suggests that it is necessary to adopt a post-occupancy educational program to promote LEED buildings.

A large number of people chose the "Green Seal" logo when asked to select the most widely used green building certification scheme in the U.S. Initially, we expected that the "Energy Star" logo could be the most common incorrect answer, as people may be more familiar with it (Zheng et al. 2011, USEPA 2015). This finding could be explained that when users know enough about Energy Star, they are confident that it is not for a green building but rather for energy efficient products. Similarly, because the "Green Seal" logo is less frequently observed in consumer products directly, the word "green" might be misleading and lead to higher selection.

We found that knowing LEED as the most widely adopted green building certification scheme in the U.S. did not affect the conditional independence between being aware of Brody's green status and knowing its certification level. This might be explained by examining the building's LEED plaque in detail. While the plaque clearly indicates Brody's certification level, people might not read the sign carefully and only notice the large word "LEED" rather than the smaller font "Silver" underneath. This finding suggests that an effective method to implement a well-designed and successful "comprehensive signage program" (USGBC 2016b) remains a future endeavor.

Log-linear models indicated that two knowledge variables were not independent when users were aware that Brody is a green building. There appeared to be an interaction between users who were aware of Brody being green and those who were the most knowledgeable.

Stimulating users' desire to learn about green building and sustainability topics through awareness also needs to be further promoted.

Perceive-ability

It appeared that users' appraisal of the most perceivable green design was not affected by their awareness group. Educational signage, however, is an exception. Attention to signage differed significantly by awareness group.

Before conducting the survey, Ltg (lighting), En (efficient HVAC), Mtl (low-emitting furniture), and Edu (educational signage) were assumed to be all product-related design. The results indicated that Edu was not identified as a variable under the product-related latent factor, while the other three were grouped under the factor. An explanation is that Edu is for educational purposes and that Ltg, En, and Mtl are specific green building technologies and/or materials. Similarly, space-related features were not specifically designed to improve certain sustainable criteria. Users that were unaware that Brody is a green building appeared to prefer space-related features more than users who were aware. It remains unclear as to whether the higher priority given to space-related features might cause users to neglect smaller-scale products, such as educational signage.

The above findings raise another question regarding the different spatial preferences of a user when perceiving green design. At a regional scale, Cidell and Beata (2009) concluded that LEED credits are grouped into spatially-specific credits (e.g., sustainable sites, water efficiency, and energy and atmosphere) and non-spatial credits (e.g., materials and resources, indoor environmental quality, and innovation and design). At a building scale, Hua et al. (2014) studied user satisfaction and demonstrated the spatial differentiations among occupants in a single building. Green building practitioners are encouraged to further investigate the dichotomous spatial preference of users found in our study.

Limitations and Future Implications

The extra attention and financial resources invested in implementing the comprehensive signage program in Brody appears to be worthwhile, as our results indicate that educational signage is the most effective method to promote user awareness. However, it also appears that a green building and/or its design alone cannot promote sustainable education. To transform effective communicators (e.g., the educational signage) into a source for learning green building topics remains a future task. We suggest implementing a signage program at mixed spatial scales so that all users have a chance to perceive relevant signage, stickers, posters, murals, etc., regardless of their spatial preference.

This survey study is localized in scope, in geographic and methodological extents. The non-probability sampling method prohibits the generalization of our results to other building sites and building users. Our survey may have under-sample issues with certain user groups due to the convenience sampling method applied. There could be a non-response bias, as nearly one-fifth of surveyed users did not return their questionnaires.

The building users surveyed are from higher-education groups: college students, graduate students, or faculty members and their relatives who live nearby. The average self-reported environmental consciousness was medium to high. However, even within this highly-educated population, knowledge of green building topics was found to be low. This suggests that Brody itself is not significantly educating the campus or its greater community. Further studies are needed to examine the effective use of green buildings as a teaching tool.

6. CONCLUSIONS

Based on a survey study in a LEED certified building, we explicitly studied the three affordances that a green building conveys: aware-ability, know-ability, and perceive-ability. Brody's users achieved a satisfactory level of aware-ability. The educational signage was found to be the most effective communicator—affirming the need for LEED's "comprehensive signage program." Know-ability, however, earned a low score, and thus the goal of the signage program to "educate the occupants and visitors of the benefits of green buildings" was not achieved. It is discouraging that, given the highly-educated population surveyed in this study, the building fails to educate its users. We urge green building practitioners to invent novel solutions so that green design can effectively communicate and educate sustainability to users.

When using the affordance theory in future green building design, special attention is needed to specify affordance through building product and/or building space. Similarly, future research should investigate users' spatial preference, i.e., whether those who tend to notice green design at building-scale neglect small-scale building products. Lastly, generalizing these findings to other green buildings must be carefully reviewed due to the nonrandomized sampling method this study employed. We encourage future work to investigate the ability of green buildings to promote sustainable communication and education in different geographical areas with diverse user groups.

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