DIY BIOPHILIA: DEVELOPMENT OF THE BIOPHILIC INTERIOR DESIGN MATRIX AS A DESIGN TOOL

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ABSTRACT

Biophilic design seeks to connect people with nature in the built environment. Growing research supports such nature-based inclusion in the built environment, yet little detailed guidance exists for how to integrate it. This study used systematic development, testing, and expansion of the Biophilic Design Matrix (BDM) for the incorporation of biophilia specifically for interior design. McGee and Marshall-Baker developed the original BDM based on Kellert's proposal of biophilic attributes, and it was initially applied in a healthcare setting. To make it more valid and reliable, this study further developed the BDM through cognitive testing with interior design practitioners in another setting type. This included the participants assessing the BDM and completing pre- and postquestionnaires. It also guided the finalized BDM development that now contains six elements and 54 attributes. The findings demonstrate that the interior design practitioners' use of the BDM increased perceived knowledge of biophilic design. The modified version is now called the Biophilic Interior Design Matrix (BID-M), which is valid for biophilic interior design identification. The BID-M also offers assistance with biophilic inclusion throughout the design process and, as such, can support the more integral incorporation of nature-based features in the design of interior environments. The finalized biophilic interior design vocabulary should be useful to help designers include thoughtful biophilic variety for unique application, thus assisting with a "do-it-yourself" approach.

THE NEED FOR NATURE

People have an innate need to connect with nature and natural systems, or what has become known as biophilia (Wilson, 1984). Biophilic design is serving as a "rediscovering" of the connection between people and the sensorial environment around them that has been occurring throughout the millennia (Salingaros & Masden II, 2006). For most of human history, the creation of buildings involved local materials and forms relating to the site conditions including ornament representing a memetic abstraction of nature (e.g. Greek ornamentation with carved plants and fruits) (Llorens, 1982). The process of building today is often usurped by the process of design, with the tectonic expression of architecture using greater abstraction and increased physical separation from nature (Salingaros & Masden II, 2006).

In addition, "people's relationship to the physical world was further complicated with twentieth-century advances in technology and industrialization" (Salingaros & Masden II, 2006, p. 2). People are now spending significant time inside interacting with technology and have limited direct contact with nature (Klepeis et al., 2001; Pergams & Zaradic, 2006; Roberts, 2016). More than half of all people live in urban areas (United Nations, 2014), further limiting their connection with nature. The incorporation of nature features in our daily lives offers a positive affect on physical and psychological well-being (Heerwagen & Hase, 2001; Kahn, 1997; Ulrich et al., 2008; van den Berg, Hartig, & Staats, 2007), for example, vegetation cover with bird abundance reduces depression, anxiety, and stress (Cox et al., 2017). In addition, a spiritual connection with nature and places fosters connections that can last a lifetime (Hoffman, 1992).

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> The crux of the biophilic effect in the artificial environment is that science has discovered and demonstrated patterns in building that either objectively contribute to, or detract from our psychological and spiritual well-being. Current Western-inspired architecture not only lacks such patterns; it teaches architects and planners to build in such a way that the biophilic patterns aren't present. (Salingaros, 2011, para. 8)

Thus, decreased nature exposure is a growing concern as connecting with nature offers a variety of positive influences on physical, psychological, and spiritual well-being (Berman, Jonides, & Kaplan, 2008; Beukeboom, Langeveld, & Tanja-Dijkstra, 2012; Brook, 2000; Hoffman, 1992; Joye, 2007; Taylor, 2006). While nature exposure is necessary in the interior, there has been little to guide interior designers in how to incorporate biophilic design inside the built environment. There has not been a single tool created specifically for, and validated by, interior designers that offers a wide variety of nature-integration strategies. There has not been a single tool created specifically for, and validated by, interior designers that offers a wide variety of nature-integration strategies. This study shares the crafting of such an instrument to help interior design practitioners identify biophilic design attributes in interiors.

NATURE BENEFITS

Research has shown that active and even passive viewing of nature is beneficial to human health and well-being (Hensley, 2015; Kahn, 1997; Ulrich, 1984). Cognitive benefits, such as improved directed attention abilities (Berman et al., 2008), exist in direct or indirect contact with nature. Active engagement with nature is optimal, but even viewing features found in nature within the interior built environment, such as artwork or wall murals containing complex fractal patterns, allows the mind to shift from directed attention to fascination and contributes to mental and physical well-being (Hagerhall, 2004; Joye, 2007; Kaplan, 1995; van den Berg, Joye, & Koole, 2016). This type of natural stimulation generates "neurological nourishment" as our brains effortlessly process complex information (Salingaros & Masden II, 2008). In contrast, people react negatively to neurologically non-nourishing spaces that are extremely uniform or too chaotic with distress and anxiety. The built environment needs to offer organized complexity, a balance between extreme uniformity and extreme complexity. True biophilic design needs to mimic this natural complexity. In a recent study, greater biophilic variety was associated with experts' selection of the "best" playroom (Weinberger, Butler, McGee, Schumacher, & Brown, 2017). This preference for nature-based variety suggests that organized complexity can be exhibited through the thoughtful application of a variety of nature-based features.

The benefits of biophilic design extend beyond the more well-known health benefits. There are economic benefits associated with biophilic design across building sectors demonstrating fiscal advantages of nature, while disregarding nature can even include profit loss (Browning et al., 2012; Heerwagen & Hase, 2001). Browning et al. (2012, p. 3) argued that "incorporating nature into the built environment is not just a luxury, but a sound economic investment in health and productivity, based on well-researched neurological and physiological evidence." Their literature review identified additional benefits of biophilic design, including increases in healing rates, learning rates, productivity levels, and property values, as well as reduced absenteeism, medical costs, stress, and even prison costs. As the importance of nature for human and fiscal health increases in public awareness, appreciation and protection for nature becomes imperative (Kellert, 2008).

Currently, people are valuing nature through their attempts at preserving the natural world by limiting resource use. A new approach, restorative environmental design, goes well beyond simple resource use reduction and was defined by Kellert (2008) as:

> … an approach that aims at both a low-environmental-impact strategy that minimizes and mitigates adverse impacts on the natural environment, and a positive environmental impact or biophilic design approach that fosters beneficial contact between people and nature in modern buildings and landscapes. (p. 5)

Designers of interior environments are, in large part, responsible for contributing to the developing interior/exterior connections and interior design features (Kellert, 2008). Offering nature-based features to users in buildings should ultimately increase exposure to biophilia, which may also result in health benefits (Beute & Kort, 2014; Hartig et al., 2011) and well-being (Kahn, 1997; Matteson, 2013). The restorative environmental design approach goes beyond minimizing negative environmental impacts to increasing ecological health by connecting sustainability and biophilia together, thereby creating globally aware citizens who love nature and seek to restore it to an optimal condition. In this regard, it is becoming apparent to many in the design community that the next step for the sustainable design movement is incorporating biophilic design and mimicking natural habitats that humans innately prefer (Cama, 2013). However, how interior design can best mimic nature remains elusive without clear strategies or guidelines. Currently, little support exists for best practices on ways to create interior habitats humans innately prefer.

BIOPHILIC INTERIOR DESIGN AND TOOLS

Kellert (2008), as a professor at the Yale School of Forestry and Environmental Studies, first operationalized biophilia to guide designers and other building stakeholders in integrating landscapes and buildings. He proposed a list of 72 features, which he labeled attributes. These attributes were organized into six categories, he called elements. An example of an element is *environmental features*, with one of its attributes being *air*. This inclusive list of landscape and architectural biophilic design attributes was based on a career of exposure to a wide number of authors and researchers.

Based on Kellert's attributes, McGee and Marshall-Baker (2015) developed the Biophilic Design Matrix (BDM) to start to operationalize biophilic design for interior design applications. To develop this inaugural BDM as a tool for interior design applications, they (McGee & Marshall-Baker, 2015) examined a scoring procedure to indicate the variety of biophilic design features present in interior pediatric hospital play rooms. Some of Kellert's list of 72 biophilic design attributes covered landscape and architecture application but appeared inappropriate for interior design, specifically in a pediatric healthcare application; consequently, only 52 attributes were included, yet the 52 still retained opportunities for connection to local and regional landscapes and referents.

The impetus to continue to develop the BDM as a design tool for interior design applications is also, in part, because few other tools are available. The Terrapin Bright Green list of 14 Patterns of Biophilic Design is the most widely known alternative tool with a focus on familiar patterns, nature–health relationships, and nature design relationships and was based on a literature review (Ryan, Browning, Clancy, Andrews, & Kallianpurkar, 2014). This smaller list of 14 attributes, however, limits the creative application of the wider original list of 72 attributes proposed by Kellert. Leadership in Energy and Environmental Design (LEED), as one of the most popular green building programs, has increased sustainable design and general awareness (LEED green building certification | USGBC, n.d.) but has not specifically offered design strategies for biophilic design holistically. WELL Building (International WELL Building Institute, n.d.) and the Living Building Challenge (Living Building Challenge | Living-Future.org, 2016) are innovative in providing specific directives for biophilic design, and both reference Kellert's original list of design attributes. This study further developed Kellert's vocabulary for interior designers and, as such, can support WELL and Living Building Challenge.

DEVELOPMENT OF THE BDM

The following is an overview of the six biophilic design elements used at the beginning of this study, which were adapted from Kellert's (2008) definitions. The first element was the category "Environmental Features." Attributes in this category are well-recognized characteristics in the interior environment. They are most easily recognized as "nature," such as living *plants*. Research highlights plants as an impactful example of biophilia with stress-reducing and perceived attractiveness qualities (Dijkstra, Pieterse, & Pruyn, 2008), enhancing pain management (Bringslimark, Hartig, & Patil, 2009), and increasing subjective well-being (Raanaas, Patil, & Hartig, 2010).

The second element was "Nature Shapes and Forms," which are representations and simulations of nature. This includes images of plants and attributes that represent "organic" shapes, which have been shown to be a preferred form (Vartanian et al., 2013).

"Natural Patterns and Processes" addresses properties derived from natural features and processes. An example of this is *natural ratios and scales*. These are patterns such as natural arithmetic or geometric ratios or scales. Fractals are a preferred nature-based scale that captures core natural geometric qualities that people prefer, and using these forms allows for creative application of nature-based design (Joye, 2007).

"Light and Space" covers qualities of light and spatial relationships. Individual preference for the quality of the light in a space can vary by culture but are important factors to consider in design (Park & Farr, 2007; Park, Pae, & Meneely, 2010). Spatial qualities, such as apparent spaciousness, exhibit cultural preference (Ham & Guerin, 2004).

The fifth element, "Place-Based Relationships," which is rooted in geography, unites culture and ecology. Connecting to the locale is considered here along with the *spirit of place*, a metaphorical place given life. This occurs when a place becomes cherished by people, giving rise to and sustaining human culture and ecology over time (often referred to as place attachment, e.g. Mount Vernon and gothic cathedrals). Interestingly, the degree of place attachment is connected to the perception of nature in the built environment (Daneshgarmoghaddam & Bahrainy, 2014).

The final element, "Human-Nature Relationships," pairs biological needs with nature, such as *prospect and refuge*, where wider room widths are more comfortable than narrow rooms and views from low toward high ceilings are preferred (Stamps, 2006).

The initial validity and reliability of the BDM was good, with the average total score of the spaces being 21.5 of 52 or 41% average inclusion of the attributes, SD = 6.45 with interrater reliability agreement of 89 and 94% among the two raters (McGee, 2012). The scores ranged from 14 to 39 of 52 possible points. The limitations of the initial BDM (McGee & Marshall-Baker, 2015) as a design tool for interior design applications included developing the original attribute *color*, the length of time for completion, the jargon-heavy language, and applying it to other setting types beyond the initial hospital playrooms.

STUDY PURPOSE

The purpose of the study was twofold. The first study goal was to explore interior design practitioners' perceptions about biophilic design. Although the concept has been a topic in research and media since the 1980s (Finnegan, 2011; Kellert, 2008; Wilson, 1984), understanding the current perceptions in relation to interior design practice was unknown and necessary to inform supporting the integration of biophilic design. To accomplish this, the current study looked at self-perceived knowledge and perceptions of interior designers about biophilic design. The second study goal was to test and develop an updated BDM as a design tool to increase the usability in applying it to designing interior environments.

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Therefore, this study's research questions were as follows: How do designers perceive biophilia? What is a more useable biophilic design tool for practitioners? How valid and reliable does the BDM appear to be in effectively measuring the range of biophilic attributes in interior environments?

METHOD

This study integrated a mixed-methods approach in an exploratory manner to further operationalize the BDM for interior design practice. The process used participatory design by including interior design practitioners to better inform the development of the tool in response to their needs and wants. This included using an initial phase of cognitive interviews and then testing the resulting redesigned BDM in a second phase. All participants completed pre- and postquestionnaires immediately before and after using the BDM to assess a given space. This process more precisely formulated the concepts and also honed the measurement process in order to capture a more adequate representation of the phenomenon (Adcock & Collier, 2001).

PHASE ONE: BDM REFINEMENT

Phase one required five steps to refine the BDM. Afterward, phase two was intended to test the revised BDM. See Figure 1.

Step One: Refining the BDM

Step one of phase one started with a literature review and the assessment of previous comments from users of the BDM regarding Kellert's original list of attributes. All of Kellert's (2008) original 72 features were represented in the beginning of step two, where the cognitive testing began. Based on prior user feedback, the list was slightly condensed due to obvious replication or lack of interior application to hone the list for interior design. Four attributes were represented within other attributes. *Sunlight* was represented in *natural light*; *Façade greening* in *plants*; *Geology and landscape* in *geographic connection to place* and *landscape ecology growth*; and *Efflorescence* in *age*, *change*, *and the patina of time*. In addition, the researchers merged six attributes for similarity within interior design. *Sensory variability* and *information richness* were merged because of the overlap of information richness with the sensory experiences required to gather information. *Simulation of natural features* and *biomorphy* were merged as biomorphy is a form that is suggestive of a natural form and a type of simulation. *Landscape orientation* and *landscape features that define building form*, while considerations usually outside of the scope of interior design, were present in *landscape ecology* to further express indoor to outdoor connections.

The attribute *color* in the original BDM was simply described as "any color" and did not describe the multidimensionality of color—including hue, value, and chroma—as well as considering its interconnection with light and materials (Bosch, Edelstein, Cama, & Malkin, 2012). The inextricable relationship between color and nature also has been well substantiated (Lynch & Livingston, 2001). Therefore, to strengthen the color and nature connection for interior design, the concepts of color, light, and materials were developed more completely within the revised BDM for interior design application by adapting the Color Planning Framework (Portillo, 2009). Portillo's framework was the only known color framework specific for interior design that moved beyond color theory and was supported by evidence. This framework uses five color planning criteria or categories for holistic color planning that considers the broad, behavioral, cultural, historic, psychological, and social roles of color in designed spaces. These criteria now better represent color, light, and material concepts more distinctly in the fourth element group of the revised BDM, and thus, this element was retitled from *light and space* to *color and light*, with space still represented among several attributes.

Portillo's framework was the only known color framework specific for interior design that moved beyond color theory and was supported by evidence.

The five new attributes from the Color Planning Framework include composition (color shaping space), communication (color creating meaning), engagement (color arousing feelings and responses), preference (color reflecting individuality or market trends), and pragmatics (color driven by resource parameters). The authors adapted the definitions. To illustrate these further, an example of *communication* is color and material selection inspired by the site for telling a visual story connecting the inside with the outside. This reflects the human inclination to assign associations and interpretive meaning through design, just as nature communicates messages, like warnings, for sensory responses. In the built environment, using color for landmarks

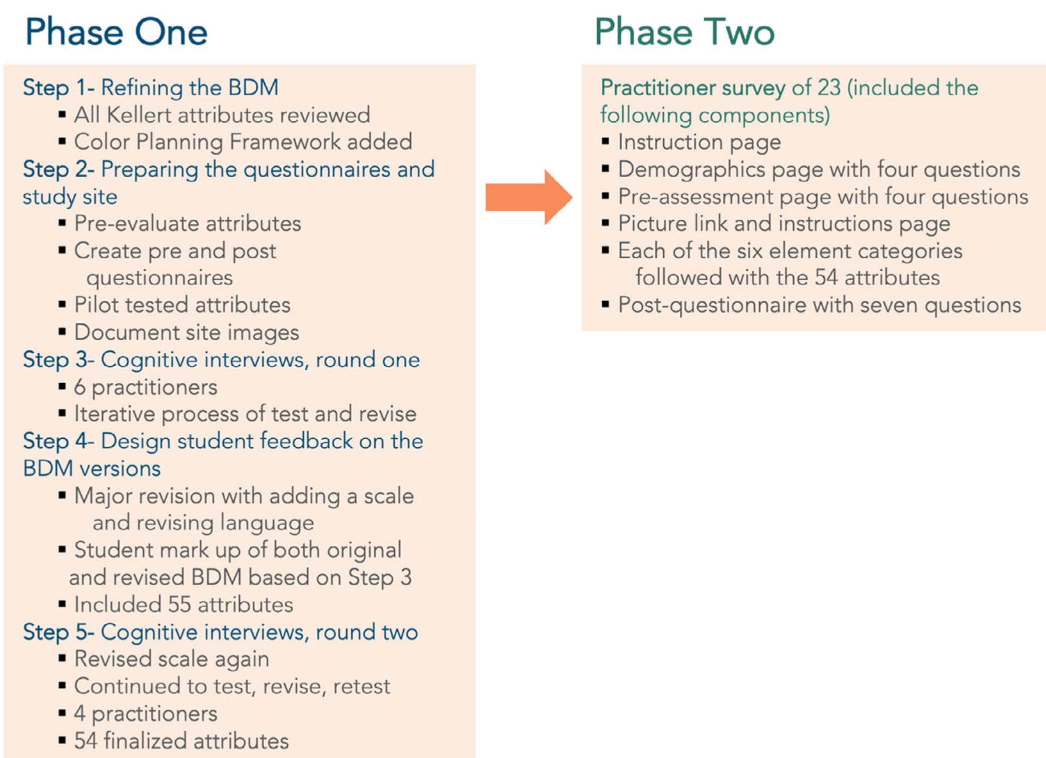

Figure 1 Sequential method process diagram.

increases the readability of a space, with warm colors and high brightness levels facilitating memory of spaces (Hidayetoglu, Yildirim, & Akalin, 2012).

Color and material selection as *composition* enables the designer to create focal points and shape spaces. Designers should study natural compositional rules (Joye, 2007). "[Designers] working with color compositionally requires objective problem-solving to integrate color, lighting, and materiality" (Portillo, 2009, p. 7). An example is that the composition of plants, visual posters, and overall organization influences how people feel and perceive others (Campbell, 1979).

Engagement with the natural environment is an innate reaction, and designers can use colors and materials by reflecting nature-inspired palettes to involve psychological and behavioral responses. Cultural dimensions and physiological and psychological responses have been found with nature-based color and materials (Bosch et al., 2012).

Another dimension of color centers on *preference*, which can include the client/end user's personal preferences for coloration inherent in natural fabrics or dyes (over synthetic ones). In addition, art preferences favor pieces with references to images of nature or fractal patterns (Eisen, Ulrich, Shepley, Varni, & Sherman, 2008; Salingaros & Masden II, 2006).

Pragmatic concerns include sustainability and maintenance considerations. An example would be specifying resilient fabrics in a medium value hue to mask wear in high-traffic areas. Another example is that cool colors and high brightness levels can help people orientate themselves in a space (Hidayetoglu et al., 2012). These five color criteria further develop the BDM as a tool focused for biophilic interior design (Figure 2).

Step Two: Preparing Questionnaires and Study Site

After amending the elements and attributes for the BDM in step one, a pre-and post-questionnaire in an online survey format was developed to better understand perceptions of designers and their experiences before and after using the BDM. Along with the development of the pre-and postquestionnaires, the researcher selected a study site and incorporated it into the

Figure 2 Finalized elements and corresponding attributes.

assessment of the revised BDM. The site was a multiuse, LEED platinum building lobby that was photographed to show 360 views (see Figure 3). It seemed an appropriate location as it was inspired by biophilic design with an understanding of the surrounding context and local wetlands (University of Florida Clinical Translational Research Building, 2014).

Participants referenced the photo images to assess each of the attributes in the BDM. For each attribute, a definition and examples were provided. For instance, *complementary contrast* is the blending of contrasting features, or opposites. Examples include light and dark areas, open and closed spaces, and high and low ceilings.

Figure 3 Sampling of given site images.

The entire data instrument was then pilot tested with an interior design doctoral student, with experience in practice, research, and teaching interior design in order to test for readability, use of images, time to completion, and general flow. The process used throughout the entire research project included the use of the BDM surrounded by pre- and postquestionnaires. These were administered together in one instrument online. The student feedback helped revise the instructions and reduced the number of images, which helped prepare for the first round of cognitive interviews. The study also obtained IRB exempt approval.

Step Three: Cognitive Interviewing, Round 1

Cognitive interviewing overview

The next step of the method involved the cognitive interview process. Cognitive interviews are the administration of a draft version of an instrument that includes additional collection of verbal and physical information about the participants' responses and their mental processes (Beatty & Willis, 2007). This approach emerged in the 1980s in the cognitive sciences and has proven effective in ensuring the instrument makes sense to the users completing the assessment. Indeed, "cognitive testing should be a standard part of the development process of any survey instrument" (Collins, 2003, p. 229). In addition, "cognitive interviewing can play an important role answering the demand about empirical and theoretical analyses of the response processes as a source of validity evidence in psychological testing" (Castillo-Díaz & Padilla, 2013, p. 963). This is important to reduce measurement error where respondents may misunderstand questions or concepts.

The cognitive interviews were conducted in two rounds with a total of 10 participants, 6 in the first round (step three) and then 4 in the second round (step five). An additional design student feedback session and instrument revision occurred in between the two rounds (step four). All 10 participants completed the online instrument along with the first author either in person or via a conference call. They helped develop the BDM, as well as the pre- and postquestionnaire, through their individual verbal process that provided valuable feedback.

The cognitive interview sample process used convenience and snowball sampling. Typically, in cognitive interviewing, the sampling needs to "reflect the detailed thoughts and problems of the few respondents" (as cited by Beatty & Willis, 2007, p. 295), which may not necessarily be representative of the population. A higher level of expertise, 10 years' practice experience minimum, was desired here due to the mental demand of the lengthy instrument. Participants were from four companies. The sample size required for cognitive interviewing has been a debated topic, with current practice finding that a small sample of participants demonstrates the most critical questionnaire problems (Beatty & Willis, 2007). Interviews were conducted until relatively few new insights were garnered. Consequently, the authors ended up interviewing 6 people in the first round and 4 people in the second round, for a total of 10 unique individuals. While it might have been short of the point when all insights might stop emerging, it is based on the principle of diminishing returns (Beatty & Willis, 2007; Charmaz, 2014; Willis, 2005).

Cognitive interview procedure and outcomes

The in-person cognitive interviews were structured around the use of the online instrument and included the "think-aloud" process. A manual with a script was followed to first provide an overview of what the participants were going to be doing and what the "think-aloud" process entailed. The term think-aloud describes when participants are instructed to "think aloud" as they attempt to answer the question and describe the process of how they arrived at the answer while the interviewer records the processes and issues encountered (Willis & Research Triangle Institute, 1999). The "think-aloud" method often includes verbal prompting by the interviewer when it is clear that a participant is struggling with something but not verbalizing it. After the initial greetings, participants were given an exercise to practice "thinking aloud." This type of exercise is a common technique used to help the participant understand what is expected of them (Willis, 2005). If the participants needed prompting, the interviewer would prompt them, such as "what are you thinking?" After the interviews were completed, the session notes were recorded and compiled. Minor adjustments were made to the instrument between sessions. The first six cognitive interviews identified a few larger common issues that required a major revision. These responses included confusion about wording, some repetition, and not wanting to give the site credit for the purposeful use of the attribute with the existing scale. The initial scale was not present (0) or present (1). This was adjusted to a scale of not present (0), moderately present (1), and strongly present (2) after the first round of cognitive testing.

The in-person cognitive interviews were structured around the use of the online instrument and included the "think-aloud" process.

The pre- and postquestionnaires were also modified based on the feedback from the cognitive interviews. The finalized version had four demographic questions, five prequestions, the BDM, and nine postquestions. The finesse of the wording and clarity of the choices improved through the cognitive testing process. The initial questions for the questionnaires were developed by the authors, with multiple versions of each question created and then evaluated to see which version seemed to be clear and concise, but it was through the cognitive testing process that this was finalized. After responding to the first six cognitive testers' feedback, the researchers

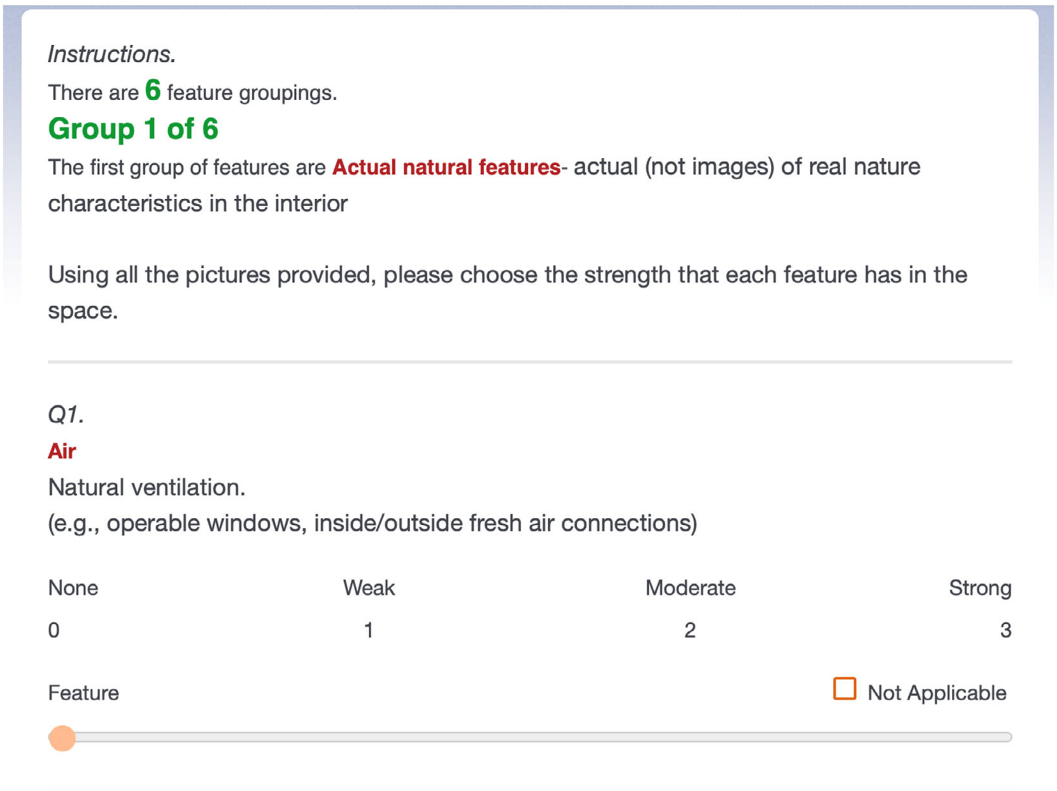

Figure 4 Sample of an attribute in the instrument showing selection choices.

conducted a student feedback session to test the revision of the scale and refined vocabulary in step four.

Step Four: Design Student Feedback on the BDM Versions

The next step of instrument development included an undergraduate assignment that compared the BDM versions. The original and new version of the BDM were tested in an interior design lecture class in an accredited interior design program to verify if design students could understand and use the BDM. Using students as a target audience was purposeful in order to assess the usability for designers with beginner expertise levels. The assignment aligned with their course content covering research instrument development.

The process began with both the primary researcher and the instructor of the class reviewing the assignment in class. Twenty-six students were tasked to use the original version of the BDM for an in-person assessment of a recreation space on campus to familiarize them with the BDM. Afterward, they gathered for an in-class activity. They were divided into groups of three to five students in six groups. The primary researcher assigned each group one of the six BDM attributes from the original BDM. Students were directed to document any issues with clarity. Next, the new version of the same element was distributed that had been developed in the first round of cognitive interviews. The researcher instructed them to do the same markup process on the new version. Afterward, each group shared their findings collectively with the class regarding how the BDM was improved and the differences they saw between the original and modified versions. There were improvements seen in the new version, including improved vocabulary and the addition of the examples. Students preferred the new scale, but they wanted another point added to the scale for greater differentiation. This was validated by comments from the first person in the second round of cognitive interviews. Overall, the development of the BDM received positive feedback.

Researchers in the past have used students and in-class activities as a type of focus group where they have also used cognitive interviews, and the two are considered complementary (Campanelli, 1997). A focus group is used to better understand the thoughts people have about a topic; they gather opinions. Similar to a standard focus group, the use of an in-class activity can collaboratively build information socially for increased diversity of perspectives and opinions (CTI - Collaborative Learning, n.d.). In the past, relying on differing perspectives of students to identify problems with validity has also uncovered issues missed by experts during cognitive interviews (Ding, Reay, Lee, & Bao, 2009). The interior design students' considerations proved insightful during the middle of the cognitive interview process and aligned with the practitioners' comments. The modified version of the BDM was then ready for the next round of cognitive interviews.

Step Five: Cognitive Interviewing Round 2

The student feedback led to the revised BDM being tested in a final group of four designers. The BDM was finalized in this process with a score range from 0 to 3 where the attribute under examination was scored as not present at all (0), a weak presence (1), moderate presence (2), or strong presence (3). An option to select "not applicable" for those features difficult to assess was also made available (see Figure 4).

The second round of cognitive interviews again highlighted justification for the BDM and its continued development. For example, the first person in round two (#7 in order of completion) mentioned in the postquestionnaire that "*I think this would be a benefit for clients to understand the long-lasting effects of the feeling of a space through biophilia*." This person saw the BDM as a reference vocabulary that could help explain their design decisions. This interviewee went on to say "*Yes—I think this would be a helpful tool to use with clients to identify how*, *not only do they see the space but also how guests/users see and feel in the space*." Another interviewee (#10) commented on how they saw themselves using this list of (BDM) features in the future if available. This interviewee said it could be a "*key design driver*, *to create connection to place*, *natural and cultural references*." After the second round of cognitive interviews, the results showed marked improvement of clarity issues and a shorter time length required for completion of the entire online instrument. Table 1 shows the cognitive interview participants' work experience level, time to completion of the instrument, and the number of issues they found regarding clarity and the scoring procedure.

PHASE TWO: BIOPHILIC DESIGN MATRIX TESTING

Phase two tested the updated BDM using the finalized instrument from Phase One.

Participants

Design practitioners were recruited through direct email, snowball sampling, or notification through social media, such as LinkedIn and Twitter. Criteria for participation

Table 1. Cognitive interview overview

Cognitive interview order	Tester's experience in years	Complete survey time in minutes	# BDM comments: clarity issues
1	20–25	65	23
2	20–25	63	15
3	10–14	64	14
4	10–14	50	14
5	14–19	87	18
6	14–19	60	27
7	14–19	68	14
8	21–25	45	10
9	26+	46	3
10	26+	25	2
Average	20+	57	14

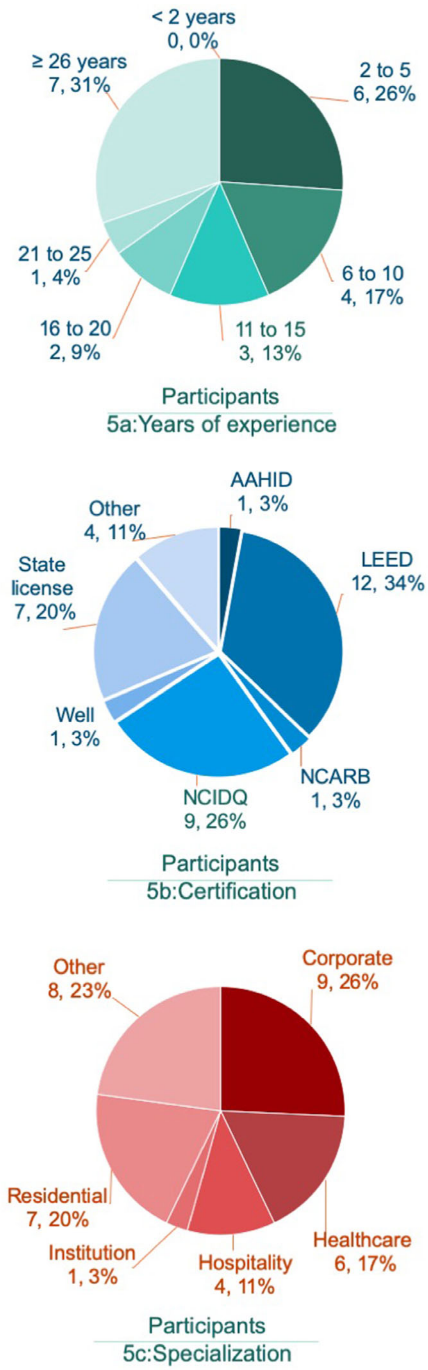

Figure 5 Demographics of participants; final phase two testing with practitioners.

included a design degree from a Council for Interior Design Accreditation (CIDA) or National Architectural Accrediting Board (NAAB) program and a minimum of 2 years of practice in interior architecture or design. Twenty-three practitioners met the full criteria (34%) of 67 respondents. Three architects and 20 interior designers met the criteria (see Figure 5).

Instrument

The goal of phase two was to test the updated BDM with design practitioners. The finalized instrument had a prequestionnaire with four questions using 5-point ordinal scales, (1) none at all, (2) a little, (3) a moderate amount, (4) a lot, and (5) a great deal. These questions were about the importance, application, confidence, and knowledge of biophilic design. The postquestionnaire included seven questions; a description of these questions follows. One question regarded seeing biophilia as important to interior design after having used the BDM and had a 5-point ordinal scale: (1) definitely not, (2) probably not, (3) might or might not, (4) probably yes, and (5) definitely yes. There was one multiselect question about when in the design process designers might use the BDM and four open-answer questions about using the BDM, change in knowledge, and changes needed in the BDM. Researchers included one 5-star rating question about the BDM quality (five being the highest score and a strength of the BDM), and this question assessed seven items: clarity of instructions, clarity of attribute definitions, clarity of the attribute names, answer options, comprehensiveness of the 54 choices, overall clarity, and helpfulness as a design tool.

Data Collection and Analysis

The data collection procedure involved three parts: (1) the prequestionnaire, (2) the BDM attribute scoring by referencing the given site photo image, and (3) the postquestionnaire. Participants could start and stop and take as long as they wanted. The open-answer questions had no minimum or maximum requirements. Thematic analysis of the open-ended questions categorized responses into themes; coding was jointly assigned by two researchers. Following the coding, related themes were collapsed. Reliability testing was conducted to analyze the BDM scoring and practitioner feedback. The congruent validity of the answers was tested by looking at item total correlation and interitem correlation with relation to Cronbach's alpha (Gliem & Gliem, 2003). Each step of this iterative method in developing the BDM was designed to build validity, reliability, and discriminatory power into the BDM.

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RESULTS

PERCEPTIONS OF BIOPHILIA

In general, before using the BDM, design practitioners viewed biophilia as moderately important to interior design (M = 4.39, SD = .72). This was on a 5-point scale, with 5 being high. They had little attempted application (M = 2.26, SD = .92) and little confidence in using biophilia (M = 2.17, SD = 1.03).

Designers' knowledge changed after using the BDM. They saw they could move beyond plants and daylight to a wide variety of choices (38% of total comments), and they showed a general appreciation for the tool and the variety of choices available for biophilic interior design (see Figure 6). One designer described, "*There are many subtle ways to bring in biophilic elements*." After the BDM, designers' impressions of the importance of biophilic design did not change statistically, but the mean increased slightly (M = 4.39, increased to M = 4.54, SD = .60).

OPTIMAL AND USEABLE BIOPHILIC DESIGN TOOL FOR PRACTITIONERS

The practitioners provided valuable feedback about the BDM quality. This was rated using a 5-point scale; the mean scores ranged from 3.8 to 4.4 (see Table 2). In addition, the BDM as an assessment tool has no set score but has a new total possible score of 162. This is based on adding up each attribute's possible score (0–3 points). The total score for the practitioner's assessment of the given space averaged 63 points. Several practitioners noted that they saw the space lacking in biophilic variety and feeling cold, which may be represented in the BDM scores. No suggested score is available at this time, but greater variety when designing would be considered more biophilic and thus, theoretically, more preferable.

The four most cited suggestions to improve the BDM and its future usefulness for design practice and education are seen in Table 2. The need for adding more examples, case studies, or other research was most noted for improvement (35%). How participants saw themselves using this list of features in the future was as an aid for the entire design process (40%), with comments

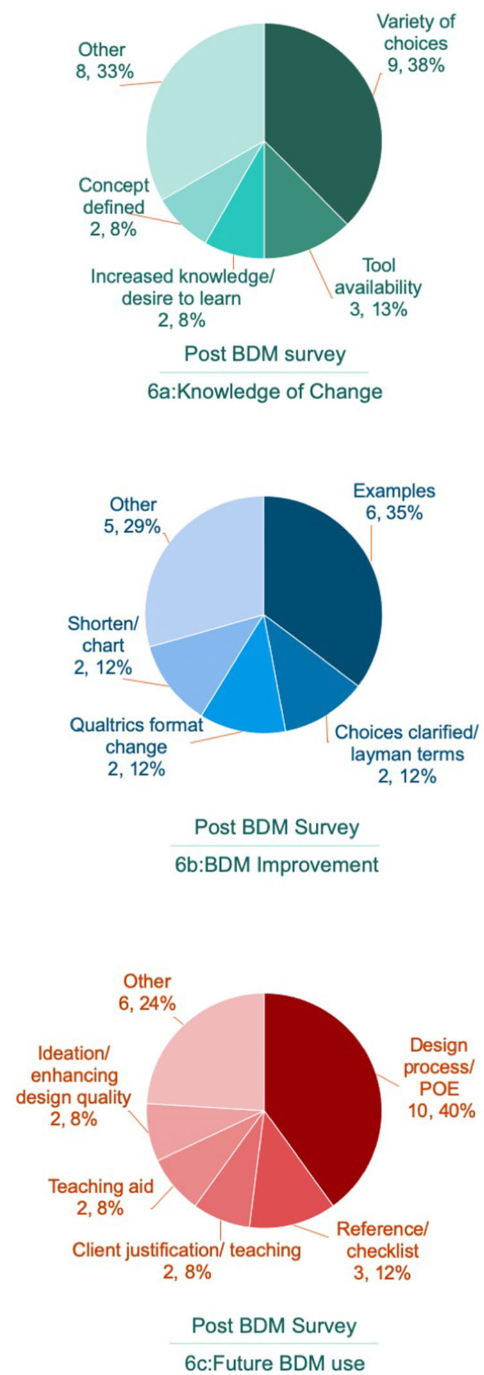

Figure 6 Post-BDM open answers. Note: 6a: Other answers with one answer each: designer-driven selection, reinforces importance, avoids sterile environments, human-centered design, greater application, meet wellness goals, client justification, and to show lack of biophilia in current practice. 6b: Other answers with one answer each: measuring factors, attributes modified, product links, definition, and scope at beginning. 6c: Other answers with one answer each: reminder, impact well-being, effective and efficient designer, ideation, enhance sustainability, and design for curiosity.

including "*it would be a useful reminder throughout a project and especially in the programming and concept design phases*." This was followed by using it as a reference or checklist (12%). One participant commented, "*This could be a great checklist to share with clients as part of the design development process*." Three comments shared an 8% frequency: helping with justifying design decisions to clients by using the BDM as a tool to teach clients about the considerations the designer considered; enhancing ideation and overall design quality; and as a teaching aid in general, including higher education. A participant commented, "*After using the BDM I feel the need to learn more about it and apply it more into my commercial projects*." One practitioner said, "*I could see using the BDM with a client interested in promoting wellness in their space without*

Table 2. Overall quality of the BDM					
Post-BDM assessments					
How would you rate the quality of the BDM as an interior design tool in the following categories?					
	n	***M***	***SD***	**Skewness**	**Kurtosis**
Instruction	22	3.82	.97	−.77	.36
Definition	22	3.93	.68	−1.43	2.23
Name	22	4.16	.63	−.97	1.19
Choices	22	3.96	.47	−.58	.04
Comprehensiveness	22	4.39	.75	−.63	−.373
Overall clarity	22	4.07	.90	−1.21	2.35
Helpfulness	22	3.96	.66	−17.95	3.40
Total BDM score of the given space					
BDM score	22	63.00	21.08	4.51	2.01

Five-point scale, 5 being high; 54 items; one person did not complete this question.

direct access to the outdoors for their employees [in a commercial setting] to create understanding for the importance of incorporating particular design elements or design decisions."

The practitioners also selected when they would specifically use the BDM in the design process among the given five phases (see Figure 7). The majority response, 15 participants (46%), selected using it in all design phases, followed by using the BDM in the conceptual design phase (n = 7, 21%), with 5 of those 7 participants also selecting programming. The desire to use the BDM as a tool throughout all of the design phases was an interesting finding. It was beyond their experience of it as an assessment tool. One designer said, "*It would be a useful reminder throughout a project and especially in the programming and concept design phases*."

BDM VALIDITY AND RELIABILITY

Overall, the BDM demonstrated solid reliability. The BDM elements were internally reliable (DeVellis, 2017) as shown in Cronbach's alpha results found in Table 3 with a range α = .77–.91. The overall BDM as a whole scored α = .94.

In addition, the individual attributes were assessed, including (1) Cronbach's alpha, greater than or equal to .70; (2) interitem correlations, greater than .15; (3) corrected item-scale correlations, greater than or equal .50; and (4) Cronbach's alpha if item deleted and decrease in alpha if item deleted. After the analysis, we excluded four attributes with lower scores: *habitats*, *composition*, *pragmatic*, and *reflected light*. None of the Cronbach's alpha scores for their associated elements was drastically different when these attributes were deleted: *habitats* (Cronbach's alpha if item deleted was .82 up from .79 for its element), *composition* (Cronbach's alpha if item deleted was .76 up from .75 for its element), *pragmatics* (Cronbach's alpha if item deleted was .80 up from .75 for its element), and *reflected light* (Cronbach's alpha if item deleted was .77 up from .75 for its element). Additional rounds of test–retesting of Cronbach's alpha by removing these items and looking at resulting correlation issues increased the alpha only slightly, but it was already strong. These items should be reassessed before removing them completely to see if revised definitions with an alternate assessment site may provide richer information. The overall reliability prompts future testing to expand on the findings here and address the potentially biased sampling of the self-identified designers being from the southern United States.

Four individual attributes had low internal reliability, and their assessment could be continued, especially the three that clustered in the color and light category deserving further consideration as a group. *Habitats* (defined as the interior of buildings and their landscapes that

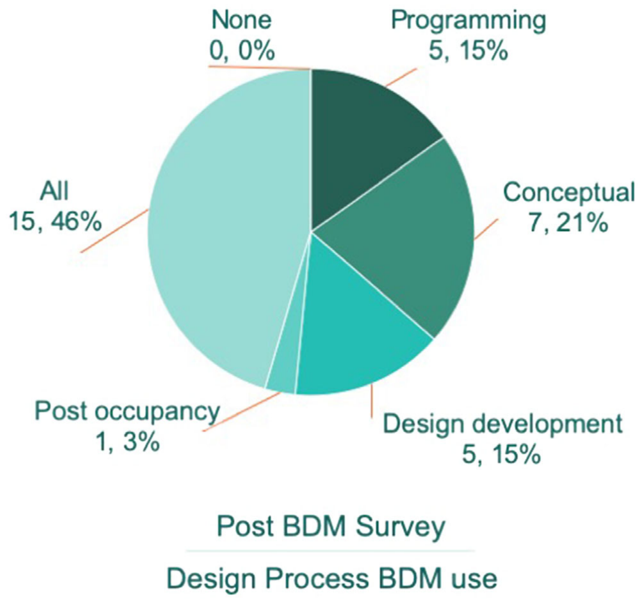

Figure 7 Post-BDM, future design process uses. Participants could select multiple answers.

Table 3. BDM reliability element and combined results

BDM reliability testing			
	n	# of attributes	Cronbach's alpha
Actual natural feature	23	8	.79
Natural shapes and forms	23	7	.77
Natural patterns and processes	23	10	.79
Color and light	23	15	.75
Place-based relationships	23	6	.91
Human–nature relationships	23	8	.86
All elements combined	23	54	.94

possess a close and compatible relationship to local habitats) may have been an issue with people trying to decide whether to include the manufactured landscape features outside as being considered a local habitat. *Composition* (defined as color, light, and materials applied as a composition through unity and/or variety connecting with nature) was a challenge, with the overall design being mostly gray, but some did note the large window and indoor/outdoor connection of the flooring and view feeling unified with the landscape. *Pragmatic* (defined as color, light, and materials selection based on maintenance, life cycle cost, existing conditions, external weather, and/or environmental choices) could have also varied, with some people appreciating the durable materials and others not seeing this as a purposeful design decision. *Reflected light* (defined as light reflecting off surfaces) could have been an issue with some people seeing the reflections of overhead light in the floor, while others may have seen the mostly matte surfaces as not offering significant sparkle to purposefully offer reflected light. These may be examples where the assessment was difficult based on the site, use of photos, or the definitions, and/or they may not be t related close enough to the element.

CONCLUSIONS

Design practitioners see biophilic design as generally important; however, they had only moderate confidence and little previous experience in using it. Future testing with experienced users of the BDM could identify if knowledge increases correspondingly with confidence levels. This would align with other findings of a correlation between confidence and knowledge increasing among occupational therapy students as evidence-based practice experience increased (DeCleene Huber et al., 2015).

The process of developing the BDM through the use of participatory testing and development is an important differentiation of this tool. The resulting vocabulary has uniquely been refined from Kellert's (2008) original proposition to now be specifically related to the interior design process. As a result, it seems important to differentiate the tool itself and to rename it the Biophilic Interior Design Matrix (BID-M). Its development for interior design by interior design practitioners is unique. By offering specific definitions with examples targeted to interior design, the BID-M can also help with ideation for creative design solutions.

A biophilic design tool that will support interior designers is more relevant after identifying that biophilic design was moderately important to interior designers, yet many struggle to implement and feel knowledgeable about it. Participants viewed the BDM as helpful, clear, and could see themselves using it throughout the entire design process.

Using the tool throughout the design process can help educate clientele and the public about the human-centered work of interior design. It could also be used to explain design decisions. This aligns with Hamilton's view (Hamilton, 2004) of an evidence-based designer being one who makes decisions with an informed client. In this regard, it is a tool that designers can use to help clients see the diversity of the building occupants' needs by having conversations with them from the beginning of a project. This is optimal for working within the building information modeling process (DeCleene Huber et al., 2015). To ensure the future growth of the foundational work of the BDM, we encourage continued research using the BID-M to advance the knowledge base in biophilic interior design. Indeed, the findings of the present study support continued research on the concept of biophilic interior design under the biophilic design umbrella.

…it is a tool that designers can use to help clients see the diversity of the building occupants' needs by having conversations with them from the beginning of a project.

In addition, this study further validates the BID-M in another facility type beyond the play rooms explored in the BDM. The new BID-M has reduced cognitive demand from the original BDM and a more expansive inclusion of color, light, and materials. The overall quality of the assessment tool is further enhanced through the improved vocabulary. http://bethmcgee.wixsite.com/biophilicdesign

As nature is a broad sensorial experience, a layered biophilic-based interior should be the cornerstone of a nature-based design strategy. The original BDM was based on this idea; however, it used a vocabulary that was not easily relatable to designers and required too much time to complete. The new version—the BID-M—is better positioned to overcome these limitations. Designers appeared enthused about the new version of the tool and indicated it was easier to use. As the repetition and difficulty of the original vocabulary were common issues identified in this study, the ability of the revised BID-M to provide a more user-friendly vocabulary is a key development. The revised tool also has improved reliability and validity. The BID-M is now uniquely poised to aid in the identification of a variety of features, with the impetus placed on designers to use and apply the list of biophilic attributes in a thoughtful and appropriate manner. Ultimately, if continued exploration of biophilic design application in interior design is continued, the increasing knowledge base can further restorative environmental design.

Overall, the BID-M offers a systematic and holistic biophilic interior design tool and vocabulary for aiding designers in incorporating nature in the interior. Designers see biophilic design as relevant and timely to their practice, and the BID-M can make DIY (do-it-yourself) biophilic design easier. It also highlights how interior design can play a unique role in restorative environmental design. The symbiosis of sustainability and biophilic design can best be achieved when interior design practitioners work in concert with other design professionals and building stakeholders from the inception of the project and speak the same language.

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BIOGRAPHIES

Dr. McGee has developed her innovative Biophilic Interior Design Matrix to facilitate interior nature integration to optimize wellness for both people and the planet. She is a LEED AP and a licensed interior designer. She has had multiple publications and presentations regarding her interest in biophilia and restorative environmental design.

Dr. Park is an associate professor in Interior Design. She is a LEED accredited professional and NCIDQ certified interior designer. Her principal areas of research address the impact of lighting in interior environments and environmental design for special needs populations. She also examines cultural dimensions of the built environment defining environmental and social sustainability.

Dr. Portillo, FIDEC, is a Professor and Associate Dean of Research. She is active in the Engage Design Lab research. She has served as Editor-in-Chief for the Journal of Interior Design*. She has written a book on the multiple roles of color in interior design, and also co-authored a well-received IDEC conference session on calibrating color criteria across market sectors.*

Dr. Bosch is an assistant professor in the Department of Interior Design and an accomplished evidence-based design researcher. In 2014, she was named top researcher by Healthcare Design *magazine's HCD10 awards for her significant contributions to healthcare design. She also served as the Director of Research for Gresham, Smith and Partners, supporting quality, safety, and efficiency in healthcare settings.*

Dr. Swisher is a Professor of Family, Youth & Community Sciences and serves as Director of the Center for Sustainable & Organic Food Systems. Her research focuses on behavioral decision-making processes under conditions of limited knowledge, risk, and uncertainty. She has served on more than 125 graduate supervisory committees. She has graduate faculty affiliations with the Geography Department, Center for Latin American Studies, Center for African Studies, and Interdisciplinary Ecology.