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The business of design is in a state of flux. The roles, the tasks and the personae of designers are changing.

No longer the technical expert, the heroic aesthete or the inspired individual of our earlier modern past, the contemporary designer draws upon dispersed sources of creativity and innovation. Collaboration, today, is key. For design practitioners, a central paradox of our times is the increasing specialization, on the one hand, but on the other, the need for more broadly ranging and holistic integration of design tasks, working between and across design disciplines. Design is becoming an ever-more social, indeed sociable, process.

The imperative to collaborate, moreover, extends well beyond the domain of professional interaction and working in design teams. It also extends to the relationship with the users, clients and consumers of design. Designers today need to build deeply collaborative relationships with their ‘public’. Participatory design and user-centered design are just two key phrases that capture the spirit of this imperative.

Broadly speaking, the balance of design agency is shifting from the all-knowing designer who creates things that are good for passively grateful consumers, to a dialogue which involves more careful and systematic processes of user consultation, research, co-design, testing, evaluation and continuous redesign. The emerging design democracy turns the designer into conversationalist, facilitator, mentor and pedagogue. As a consequence, the legacy self-understanding of the designer as artist, technocrat and expert is thrown into question. The new politics of design plays through tensions between historical roles and contemporary expectations. Along the way, what’s lost and what’s gained? What is inherently difficult about the new designer-user relations, and what is intrinsically liberating?

As soon as the balance of agency shifts, a polymorphous, polyvalent social world presents itself. ‘Any color you like, as long is it’s black’, said the heroic Henry Ford, who conveniently assumed that every consumer in his mass market had identical needs and interests. But as soon as you start talking niche markets, usability and customization, you discover diversity in an ever more dazzling range of hues and shades—local and global, of different abilities and disabilities, of ages and cultures and genders and affinities. The paradox of today’s design democracy is that designing for everybody means designing for many different interests and uses.

Then there are some new lines of social insistence: that designers work to objectives of sustainability, access, safety and the social good. These are matters of increasingly intricate regulation and compliance. Or, if you will internalize these insistences, they become matters of self-regulating professional ethics.

These are some of the things that are, quite simply, changing the job of being an architect, urban planner, industrial designer, engineer, visual designer, web designer, knowledge manager, communications or media designer, fashion designer, usability researcher or instructional designer – to name just a few of the design vocations.
DESIGN MODALITIES

Design’s modalities are also in a state of flux, its working tools of representation, communication, visualization and imagination. Digitization of text, sound, and still and moving image is one important site of transition. This has spawned new practices of modeling and simulation, of prefiguring the real in the virtual. It has also introduced the virtual as a design end-in-itself.

The result is a new multimodality and synesthesia. Design conceptualization requires that designers move between modalities of language, image, sound, space, touch and gesture. The meaning of their design might be articulated one way, then another, or all at one time in a deeply integrated process of synesthesia.

Designers need to able to ‘do’ a multimodal professional design discourse. They must speak and write their way through complex collaborations with co-designers and interactions with users. They need to be able to ‘do’ visualization as they explore design alternatives through mental images and picture their visions into reality. They need to be able to represent spatial realities, prefiguring the three dimensional through the two dimensional and turning plans into tactile artifacts, manipulable objects, architectural spaces and navigable landscapes. The new, digital media provide newly flexible and accessible tools for multimodal and synaesthetic thinking. Today’s media inventions have become the mothers of design necessity.

Such innovation is not simply for innovation’s sake. It is also for the most practical of reasons. There is an increasing need to document for the purposes of planning and project management, regulation and compliance, risk assessment and risk management, and project specification and contractual clarity.

DESIGN PRINCIPLES

So, what is this thing design? What is the design of something? And what does it mean to ‘do’ design?

The word ‘design’ has this fortuitous double meaning, simultaneously describing intrinsic structure and the willful act of making. Design is at once morphology and construction.

Morphology: design is inherent, whether its sources be organic, unconscious, common sense or the carefully premeditated product of the professional work of the designer. Design in this sense is structure, form and function.

Construction: design is also an act, a manifestation of agency, a process of transformation. The narrative of design runs like this: take the available designs in the world, inherent to found objects, architectures, landscapes, processes, human relationships, cultures. Then engage in the act of designing, or rework and revoice these designs. This is never just a business of reproduction and replication. It always involves an injection of the designer’s social interests and cultural experiences—their subjectivity and identity, no less. The residue, as the narrative draws to a momentary close, is the world transformed, no matter in how small a way. But the world is never quite the same again, and the redesigned is returned to the world. Design agency traces of transformation that join the repertoire of available designs—new openings to new design narratives.

Such a view contrasts with older understandings of design in which designers were passive recipients of expert routines. Their apprenticeship into professional practice had led them to learn to reproduce received, sanctioned and authoritative design forms. This may have been appropriate for a world that set store on stability and uniformity.
But today’s world is a place of change and diversity. Designing, in a dynamic, transformative sense, can be enabling, even emancipatory. It is a process of changing the world.

In this spirit, the Design Conference, the Design Journals, the On Design Book Imprint and the Design News Blog move between theoretical reflection on the nature of design and case studies of design practice, and from research-based perspectives to the experience-based perspectives of design insiders.

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Designing Blended Spaces: Historical Echoes, Testing a Framework for Digital Tourism

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Abstract: The project was created in Edinburgh, Scotland, and aimed to produce and evaluate a visitor experience that enabled them to serendipitously discover digital content when visiting an attraction, to be led to the exact location of the content by audio, and to have an engaging and satisfying experience interacting with the blended space of a physical location.

Keywords: Blended Spaces, HCI, Tourism, Audio, User Experience, Location Aware, Context Aware

Section Heading

Digital tourism is a growing field in everyday life. Just in the UK, overseas visitors spend more than £18 billion a year and delivers £3 billion in the taxes. The overall tourism industry in UK is supposed to be worth nearly £115 billion a year and this creates %9 of overall UK economy (Introduction to Britain's Tourism). Technology is becoming a critical factor in everyday life including the vacations and visits. Reading books through different devices such as Amazon Kindle are becoming more popular (Guardian, 2012), as well as new mobile devices sell millions on their first week in the market (Engadget, 2012). From this perspective technology and tourism are growing in parallel with each other. But even though this situation is true, there are still gaps between the two industries. We think that serendipity is an important part of the tourist experience that is often disregarded. Most tourist applications that are available on smart phones and tablets lack interactivity and surprise and create the feeling of reading a simple textbook about the sights around the user. Narrative is nonexistent apart from some literary tours and the overall user experience (UX) of using tourist apps is still quite poor.

In this project we are addressing the generic problems of serendipity and user experience (UX) in mobile digital tourism. We address tourists who own a smart phone who wish to experience an enhanced visitor experience through engaging with digital content relevant to the geographical location they are in.

Succinctly put, the problem is:

• Knowing that digital content exists in a location
• Accessing that content with the appropriate orientation and
• Consuming content in a way that enhances the visitor experience

The problem has been expressed by Historic Scotland, a major provider of tourism experiences in Scotland. They have to deal with the twin problems of providing engaging experiences for tourists at content-intensive sites such as Edinburgh Castle and at unstaffed remote rural locations. The Centre for interaction Design at Edinburgh Napier University have encountered the problem in developing an iPhone app for the Unesco City of Literature where GPS functions poorly in the wynds (small alleyways) of the Royal Mile. A solution based on QR codes can be used and branded as part of a literary trail. However this solution is not suitable in another project where we are looking to digitally enhance an outdoor art park. In this case, as in many historical sites, QR codes would intrude on the visitor experience. There are many other areas where GPS or QR codes are inappropriate mechanisms for indicating the existence of
digital content. These include obtaining accurate locations (particularly indoors), battery life of devices on long tours and the desire not to interfere in an inappropriate method with the geographical location.

We have prototyped a solution to this at the St Andrews University’s summer school on digital tourism that was held during June 2011. We developed an Android app that provided audio augmentation of the city using GPS. This alerted people to the existence of digital content at an approximate geographical location by vibrating the phone. A single tap on the phone brought up the audio that got louder as the tourist approached the exact location of the content. As soon as the tourist was in the correct location the actual content – historical sounds relevant to the location – was delivered.

**Background**

Our approach to developing visitor experiences builds on blended space theory trajectories approach previously done in this field. Fauconnier and Turner’s book *The Way We Think* (Fauconnier, 1997) introduces their approach of conceptual blending. It has been argued that cognition can be seen in terms of mental spaces, or domains. Cognition involves the projection of concepts from different domains and their integration into new ones. Blending theory also develops and extends the ideas of Lakoff and Johnson on the importance of metaphor to thought (Lakoff, 1999). There is now extensive work on blending theory applied to all manner of subjects that offer different insights into the way we think.

Imaz and Benyon (Imaz & Benyon, 2006) have introduced the ideas of conceptual blending to analyze developments in HCI and software engineering. Analyzing a number of well-known examples of user interfaces, including the trash can or windows icons also the device eject function in Mac OS and critical HCI concepts such as scenarios and use cases. Imaz and Benyon argue that in interaction design, designers need to reflect about the concepts that they are using and how these concepts affect their designs. This is also fundamental in this research. They emphasize the physical grounding of thought by arguing that designers need to find solutions to problems that are ‘at a human scale’. When creating a new interface object, or new interactive product designers will often create a blend from existing designs. Benyon suggests that designers should aim to preserve an appropriate topology for the blend, allowing people to unpack the blend so that they can understand where the new conceptual space has come from.

Hoshi and Waterworth (Hoshi & Waterworth, 2011) (Hoshi & Waterworth, 2009) use conceptual blending to design devices for elderly people. Using concepts such as background awareness, peripheral perception, they call this tangible presence.

Markussen (Markussen, 2009) uses blending in this way to design a blood-taking device for a hospital. He contrasts the emotional appraisal of the device (it is rounded, and curvy and looks generally very pleasant) with its use and the unpleasantness of the needle taking the blood sample.

For the purpose of designing mixed reality experiences, physical and digital space can be usefully conceptualized in terms of four key characteristics. The ontology of the spaces concerns the objects in the spaces. The topology of the spaces concerns how those objects are related to one another. The dynamics or volatility of the spaces concerns how elements in the spaces change over time. The agency in the spaces concerns the people in the spaces, the artificial agents and the opportunities for action in the spaces.

The conceptualization of blended spaces illustrated in Figure 1 relies on a generic way of talking about spaces – ontology, topology, volatility and agents. This is the generic space of spaces and places that is projected onto both the physical and the digital spaces. The correspondences between the physical and the digital are exploited in the design of the blended space. The job of the designer is to bring the spaces together in a natural, intuitive way to create a good user experience. The designer should design the blended space according to the principles
of designing with blends (Imaz & Benyon, 2006) such as drawing out the similarities between the topology of the physical and digital spaces, integrating them to deliver a whole experience and designing at a human scale.

![Figure 1: Diagram Explaining Blended Spaces](image)

Also when designing blended spaces it is important to perceive that the physical and the digital spaces rarely co-exist. There are anchors, or touch points where the physical is linked to the digital, but there are many places where the physical and the digital remain separate. QR codes or GPS are examples of anchor technologies that bring the physical and the digital together. An iPad running some augmented reality software will take a person into a blended space for the period that they are looking at or through the device, but the connection is lost once they turn to talk to a friend when they return to the physical space, or make some adjustments to the software when they move into the digital space. Thus people move between the physical, the digital and the blended spaces as in the idea of a hybrid trajectory (Benford, Greenhalgh, & Kolva, 2009) (Benford, et al., 2009).

Benford explains that user experiences can be described in terms trajectories. Those trajectories vary in each different experience. And each experience is ecology. He describes ecologies involving space, time, roles and interfaces. He also refers to the “anchor” points as transitions. Those key moments include, beginnings, endings, role transitions, handing over interfaces, managing access to limited physical resources, dealing with “seams” (e.g., lack of coverage, or accuracy in wireless sensing and communications) in the underlying technical infrastructure (Galani & Chalmers, 2004), and episodic engagements with long-term experiences.

He claims that user experiences can be described in terms of three fundamental kinds of trajectory: canonical trajectories are created by authors to guide participants through an experience; participant trajectories describe each individual participant’s personal journey through the experience and may diverge from and reconverge with canonical trajectories due to the respective “forces” or interactivity and orchestration; and historic trajectories, that select and then represent recorded participant trajectories in order to provide a retrospective view of what happened in an experience (Benford, Giannachi, Koleva, & Rodden, 2009).

He also thinks that these various trajectories pass though hybrid ecologies of space, time, roles and interfaces that define the underlying structure of an experience.

He discusses that while ideally continuous, the trajectories through an experience must in fact negotiate various key transitions, moments when the coherence of the user experience is at risk and to which authors or orchestrators therefore need to pay special attention. Significant transitions in his work include: beginnings, endings, role transitions, handing over interfaces, managing access to limited physical resources, dealing with “seams” (e.g., lack of coverage, or accuracy in wireless sensing and communications) in the underlying technical infrastructure (Galani & Chalmers, 2004), and episodic engagements with long-term experiences. (Benford S., et al., 2011)
And finally he suggests that the social fabric of the experience can be expressed by the ways in which different participants’ trajectories are brought together or sometimes steered apart enabling them to pass between moments of collaboration and moments of isolation. (Benford S., et al., 2011)

Benford also suggests that the structure of interactive user experiences consists of four key facets that then combine together: space, time, roles and interfaces (Benford, Giannachi, Koleva, & Rodden, 2009). Since this is quite important both in his work and in ours, we should discuss it in more detail.

**Design**

Historical Echoes is first and foremost a mobile application designed for the iPhone. Demographically this project is aimed at 18-35 year old people owning a smartphone and travelling to other cities. Even though this application can be used by local people as well, the target audience is the tourists. The space is mainly the selected city area because the main narrative points given to the user are in selected areas. But this application can be used locally as well. The users are browsing through real spaces to access the digital content. GPS technology has been used to locate the user on the map.

What we did not change from the start, was to make people move in a physical space. For this reason we designed the application so that the users would not unlock the content unless they were in that specific location. We adjudged that the users would move through the space, since they pick the data they want in the first place through the provided channels.

![Figure 2: Navigation Window](image)
The final design of Historical Echoes involves four different locations on Edinburgh’s Royal Mile, between St. Giles Cathedral and Edinburgh Castle Esplanades. They are all picked as public areas in order not to have a problem with permissions. The testers receive audio and visual data related to these spaces. So for us it was really important to really understand the spaces and
create content according to these characteristics. The design process lasted between March and May 2012.

**Evaluation**

Evaluation of Historical Echoes took place between July–August 2012 in Royal Mile. A total of 11 people participated in the evaluation. Users from a pool that does not know English as their native language participated. During the experience, we have used four different data gathering process simultaneously. Those methods are GPS Data, Interviews, Photo/Video and finally a tool called AttrakDiff in order to measure the attractiveness of the interactive product created. Each test took around 40 minutes and conducted different times of the day. Different tests were made before and during the Edinburgh International Festival, so people around the users varied greatly. At the beginning of the test, the experimenter explained the overall experience and how the application works. After telling them what to do, and what the software actually involves, the user takes a walk from beginning to the end. Two participants wanted to walk back as well. The rest, after finishing the route, took the interview. By the end of the interview, they also completed the semantic differential test proposed.

The Historical Echoes application used an add-on in order for us to gather GPS data of the users as they went through the test. We know where each test subject was and later on put all the data into a map to visualize it. Despite this technical problem, we can assume that the GPS data is strong and is a very valid method to show where the users were and how much time they spent in one place.

In order to follow the user movement we used GPS technology. The biggest issue about the GPS was the accuracy. Apple iOS uses a mixture of method to create the location information of a user. It uses GPS, WiFi networks and cell towers around to triangulate the longitude and latitude. Throughout the process the accuracy of the tracking was around 5 meters, but varied between 5-50 meters, maxing out in the alley from Royal Mile to Writers Museum courtyard.
The interview is built around vague questions about specific features of the experience. The questions asked are designed to make the participants comment around desired subject. The interview took around 15 minutes and consisted of four different aspects:

- Physical World
- The Content
- The Transition
- Digital World

In the end of the interview we asked people to pick 3 pictures out of 15 given pictures. We wanted the participants to select whichever represents the experience best. The questions asked to users are as follows:
The users described the overall experience as isolating. Some users moved fine through the space, while some had difficulties since they looked at their screens. Almost all of the users found the application easy to use. They also claimed that they could approach the point of interest easily due to audio clues.

We used AttrakDiff as a small test for evaluating the overall experience. The test consists of numerous word-pairs which simplify the rating procedure. Each word of a pair represents the extreme opposite. There are other possible gradations to choose from between the two extremes.

A theoretical work model illustrates how the pragmatic and hedonic qualities influence subjective perceptions of attractiveness resulting in respective behavioural and emotional responses. The model separates the four essential aspects:

- The product quality intended by the designer.
- The subjective perception of quality and subjective evaluation of quality.
- The independent pragmatic and hedonic qualities.
- Behavioural and emotional consequences.

![Figure 8: A Theoretical Work Model](image)

The theoretical work is said to be based on Hassenzahl and colleagues’ work. The test is applied as an instrument of measurement in the format of semantic differentials. It consists of several seven-step items whose poles are opposite adjectives (e.g. "confusing - clear", "unusual - ordinary", "good - bad"). Each set of adjective items is ordered into a scale of intensity. Each of
the middle values of an item group creates a scale value for pragmatic quality (PQ), hedonic quality (HQ) and attractiveness (ATT).

During the Historical Echoes user experience we have completed this test and the results are as follows:

**Diagram of average values**

![Diagram](image)

**Description of word-pairs**

| Technical | Human | Impractical | Practical | Complex | Simple | Unpredictable | Predictable | Confusing | Clearly structured | Unruly | Managable | Isolating | Connective | Unprofessional | Professional | Bady | Stylish | Cheap | Premium | Alienating | Integrating | Separates me | Brings me closer | Unpresentable | Presentable | Convolutional | Inventive | Unimaginative | Creative | Cautious | Bold | Conservative | Innovative | Dull | Captivating | Undemanding | Challenging | Ordinary | Novel | Unpleasant | Pleasant | Ugly | Attractive | Disagreeable | Likeable | Rejecting | Inviting | Bad | Good | Repelling | Appealing | Discouraging | Motivating |
|-----------|-------|-------------|-----------|---------|-------|--------------|-------------|----------|-------------------|--------|----------|-----------|-----------|----------------|--------------|------|--------|-------|---------|-----------|----------|------------|---------------|--------------|-----------|----------------|---------|----------|--------|---------|-------|-------------|-----------|--------|--------|---------|--------|--------|----------|---------|--------|--------|---------|--------|--------|----------|---------|--------|--------|---------|--------|--------|----------|---------|

**Figure 9: Initial Results of Historical Echoes experience.**

**Discussion**

This project answered a couple of questions asked in the first place, but raised so much more for future work. The aim of the project was to move people from one point of interest to another and make them move to access the data, rather than just to use it like a website. The specific design decisions made earlier created a paradigm so that the users have to stay at a certain distance from the point of interest. We have seen that the users stand in similar points during the experience, which is pretty much the point where they can click on the content. Placing those points of interests is one of the most important things when building an application like this.

The real question is: can we replace those points so that we move the users around? Can an application like this be used as a tool for people to stand at a specific location: in front of the church, inside the courtyard, inside the church? If this is possible, it would mean that applications...
like these can be used to move people to specific locations, even without using any other piece of technology than GPS. The distance where the user can activate the data is another issue related to this: creator of the application should decide how close they want the users to be to a specific place. If this place is a building it would be natural for the user to stand in front, but if it has a specific view, then the distance to the actual spot is irrelevant. For example, the user can be in front of St. Giles Cathedral to access the data, and then enter the building, but for the Edinburgh Castle, Princes Street Gardens can be a better place for the content, since it might be a more panoramic view of the building.

During the tests of Historical Echoes, we have realized that moving in the space is a huge part of the experience. We wanted to create a serendipitous experience in a city environment, and for this, we have used the audio tools. When asked, the users agreed that music helped them to detach from the actual space. We think that this is something to consider. Music and use of earphones helped the users to concentrate on the experience and not the space around them. There are two issues coming up from this point.

One of them is the health and safety precautions: If on the design, the application separates the users from the actual physical space, it might create some problems, such as crossing the street, not hearing the warning around them etc. This can be avoided by asking from people to be more careful, which we did, or playing with the volume of the audio, so that people can actually hear the surrounding up to a certain level.

The second issue is this: The use of earphones and the phone in general creates a personal experience. So unless the user is alone in the city, it is hard for him/her to communicate with the people around them. This is another design decision to be made rather than a problem. Also, this personal experience creates a bubble around the user, with the current state of the city the user is in a personal artificial world. This prevents the user to notice some stuff that other tourists are experiencing. We had this as an example at the Edinburgh Castle Esplanade.

We also realized that designing this application forced us to use some distance between two points of interest. In order to create the feeling of whispers disappearing in the background and a new one beginning, we had to put at least 50 meters between two points of interest. This led us to a different problem; what if there are two items closer than 50 meters to each other? During the design, playing between the distances is possible, as well as putting two contents back to back on the same spot.
In the initial tests, we had some bug issues with the audio. The whispers did not stop during the narration and that according to users broke the experience. We realized that a smooth technical experience is essential in creating an ongoing and fun walk. Our assumptions were built around the argument that immersive experiences require fully working piece of software and equipment, even a small bug can break the desired state of immersion.

There was also a technical difficulty in front of the Witchery about the GPS technology. The buildings at that specific location are high and heavy walls prevent the GPS signal from being strong. Also the street is quite narrow and crowded with people. Considering all these, the GPS therefore the map caused problems to some users. When looking at the GPS signals and check in, we realized that the signal is random around that area. For some users, it went smoothly, and for some there were big gaps between the actual location and GPS on the map.

**Conclusion**

When starting Historical Echoes, we aimed to create a serendipitous experience in a city, giving people content, and letting them browse it. We thought that audio was the obvious choice in order to create an immersive experience. We also wanted people to decide what kind of content they wished to hear. We have created the application so that it can be accessed by two interaction methods, in and out of the pocket. We tested the app with 10 people and gathered detailed information about every aspect of the application. We think that in the end the application is successful as beta status. Using the initial design such as this, we can work and create a final application, even a commercial product to propose variant institutions.
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Integrating Sociocultural Sustainability into Interior Design

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Abstract: The study proposes a pedagogical framework “a triad of sociocultural sustainability of design: context, content, and meaning,” which details the social dimension of sustainability. This article introduces the concepts and factors of the three constituents—context, context, and meaning—and explains how the framework has been used in teaching design process and programming. In design professionals’ endeavor for the public’s health, safety, and welfare, educators’ and practitioners’ commitment to sustainable design has been highly promoted and presented. Sustainability consists of economic, social, and ecological systems. However, its sociocultural aspects have often been neglected in the discussion that has mainly focused on the environmental impacts and footprints of building process and products. Since sociocultural aspects reflect the ethics and responsibilities of design professionals, it is crucial for them to reconsider the value of sociocultural sustainability.

Keywords: Sociocultural Sustainability, Design Method, Design Process, Interior Design

Introduction

Sustainability has become a significant phenomenon in the contemporary world. As part of their endeavor for the public’s health, safety, and welfare, design professionals’ commitments to sustainable design have been promoted and highlighted. In today’s interior design education, the importance of evidence-based design and sustainable design has been stressed increasingly. In the US particularly, sustainable design has been rigorously promoted and is one of the required subjects in the curricula for interior design programs to be accredited.

Sustainability, which is “fundamentally about adapting to a new ethic of living” (Duxbury and Gillette 2007, 1), can be sufficiently achieved in the interaction of ecological, economic, and social systems. However, its sociocultural aspects have often been neglected in the discussion that has mainly focused on the environmental impacts and footprints of building process and products. Since sociocultural aspects well reflect the ethics and responsibilities of design professionals, it is crucial for them to reconsider the value of sociocultural sustainability.

In such regards, this study was conducted 1) to provide interior design students with an applicable framework for an evidence-based design approach to sociocultural aspects of sustainability that influence design identity and the public’s welfare and 2) to reiterate the commitment of the interior design profession to occupants’ quality life in the social and cultural contexts.

Sustainability in Interior Design

Sustainable design should not only be environmentally friendly but also contribute to improving the quality of occupants’ life and maintaining social and cultural identity. Sustainable design that “utilizes essential aspects of cultural identity, can serve to synthesize the past with the present for the benefit of the future” (Matthews and Herbert 2004, 2). However, as aforementioned, its social dimension has not been sufficiently considered in the existing guidelines for sustainable design despite that the fundamental concept of sustainability involves social aspects as well as environmental and economic (Figure 1). A statement by National Council for Interior Design Qualification (NCIDQ) implies that the ecological—also referred as environmental—dimension has mainly been highlighted in discussions on sustainable design: “Sustainability” means the use...
of resources in [...] a way that they are not depleted [and] is a method of practice or use of materials” (NCIDQ 2004). In the same vein, of the eight criteria of the LEED for New Construction (USGBC 2009), six indicate the standards for use of resources and energy consumption, and the remaining two criteria, ‘innovation and design process’ and ‘regional priority credit’, appear as least defined and not at all specified. As such, it is apparent that, regardless the discipline, there is a lack of guidelines and standards that comprehensively discuss sustainability including its social and cultural dimensions.

There have been concerns that the interior design profession’s obligations to social and cultural contributions have not been addressed sufficiently by interior designers so that it has affected the profession’s status (Anderson, Honey, and Dudek 2007). As a response to such concerns, interior design education highlights designers’ social responsibilities that promote the public’s health, safety, and welfare. As NCIDQ defines, it is clear that social and cultural responsibility of the interior design profession is considered as a significant role:

Interior design […] solutions […] enhance the quality of life and culture of the occupants; designs […] acknowledge the physical location and social context of the project (NCIDQ 2004).

However, as the pragmatic aspects of sustainable design are increasingly highlighted in guidelines, students tend to show weaknesses in integrating social and cultural aspects into their design projects. Another issue is that the ‘three sphere model’ to which has been most commonly referred does not specify cultural aspects of sustainability. Although, more recent models (Shen, Kyllo, and Xulin 2013; O’Connor 2006; Stieg 2006) of sustainability have been published, those models seem to need further clarification to be directly applied as a framework for interior design studio teaching. Therefore, the importance of this study is significant as it is to propose a framework of sociocultural sustainability that is easily understandable in learning design process and directly applicable in programming interior design projects.

Figure 1: Three Spheres of Sustainability
Source: Rodriguez, Roman, Sturhahn, & Terry, 2002.
Sociocultural Sustainability—Concepts and Definitions

This study proposes a pedagogical framework ‘a triad of sociocultural sustainability: context, content, and meaning’ (Figure 2) and shows how the framework can be used in interior design courses while supplying the existing sustainable design guidelines. This triad particularly details the social dimension of the existing ‘Three Spheres’ model (Figure 1) and includes cultural aspects that are significant lacked in the existing model.

The fundamental concept of this framework is based on a book essay “Glocalization” (Kwon 2011) in The Language for Space Design, which discusses about localized design identity in the global context. The initial model of the framework was completed in 2011 and further developed and refined in 2012. In the initial development phase, the framework was introduced in three interior design studio courses and used by 12 undergraduate and eight graduate students. The refined framework proposed in this article was introduced to 16 undergraduate students in a residential design studio, prior to the programming phase. Of the 16 projects, three are presented as examples in this article. More details are explained in the next section, Applications in the Interior Design Process, in this article.

As it represents the value of human life, consideration of sociocultural sustainability in interior design process may positively affect the quality of design outcomes. The framework proposed in this study explains that sufficient status of sociocultural sustainability can be achieved when the environmental setting fulfills the quality of three constituents: context, content, and meaning (Figure 2).

**A Triad: Context, Content, and Meaning**

Of the three constituents that affect sociocultural sustainability of design, “context refers to the surrounding circumstances and conditions” (Kwon 2012, 306) such as location, climate, natural setting, culture, and history, which affect design process and outcomes. “Content is defined as a compound of occupants’ characteristics and activities/behaviors” (Kwon 2012, 306) that interior environments contain on a daily basis. “Meaning of interior environments is based on the occupants’ perception, interpretation, and social interaction within cultural boundaries or circumstances” (Kwon 2012, 306). Meanings include various conceptual components such as brand image, organizational missions, and symbolic messages, which design conveys to enhance people’s experiences in the environments.

**Environmental Quality, Value System, Identity**

In the model below, environmental quality—the practical factors of sustainability such as material uses and energy consumption—posits in the conjunction of context and content. Content and meaning contribute to establish an individual’s or a group’s sociocultural identity, and value systems such as beliefs, ethics, norms, and policies are established where context and content overlap (Figure 2).
Application in the Interior Design Process

Students tend to better understand the sequence of the curriculum when a consistent framework is used. The triad framework has been used in various interior design courses despite that each course has its own topic area(s) and emphases as shown in Table 1.1. Depending on the course-level, the main constituents of sociocultural sustainability considered are varied (Table 1.1): In undergraduate courses, the framework was used to teach how to approach site-specific projects, design for special populations, and sustainable design; in graduate-level courses, students learn comprehensive programming including research methods and methodological—e.g., phenomenological and semiotic—approaches to meanings of built environments.

Table 1.1: Emphases in the Interior Design Course Sequence

<table>
<thead>
<tr>
<th>Course Levels &amp; Topics: Constituents of Sociocultural Sustainability</th>
<th>Undergraduate: Universal Design</th>
<th>Undergraduate: Sustainable Design</th>
<th>Graduate: Research Methods and Programming</th>
</tr>
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<tbody>
<tr>
<td>Context</td>
<td>X</td>
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<tr>
<td>Content</td>
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<td>Meaning</td>
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Course Project: Residential Interior Design

As the constituents of the triad framework correlate design phases, using the framework in interior design projects helps students understand the rationale of their design process including research and programming. Depending on the course-level and the project-type, students are required to produce 30-100 pages of program documents for their projects. In this article, how the framework is introduced and applied particularly in Studio II, an undergraduate residential design studio course. In Studio II, students learn the concepts of universal design and sustainable design while they develop technical skills and gain basic knowledge about residential building codes, building system, and contract documents.

In spring 2013, 16 students conducted a renovation project for a residential building located on Manitoulin Island in Canada. The site is on the south side of the island, nestled in a wooded area and looking down Lake Huron. The owners provided students with the basic information about the property and their needs and desire. The owners, a retiree couple, have an active and nature-friendly lifestyle, host a number of visitors year-round, and are aware of aging-in-place issues. In such regards, consideration of barrier-free and sustainable design was stressed throughout the design process.

At the beginning of the semester, students were introduced to the framework, a triad of sociocultural sustainability, and instructed to conduct programming in consideration of the framework. Although the subjects in programming were categorized based on the three constituents of the triad as shown in Table 1.2, students were not required to use the specific terms of the constituents.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Subjects in Programming</th>
</tr>
</thead>
</table>
| Context     | Site and Building Analysis  
Research on Community Culture and History |
| Content     | Client and User Analysis  
Research on Occupancy Type  
Theoretical Study |
| Meaning     | Conceptual Development  
Branding  
Approaches to Paradigm |

In regard to its context, site and building analysis was particularly important in the programming process as the project involved was in a foreign site unfamiliar to the US students. Students conducted research on the climate in the region, characteristics of the building site, and the culture of the Manitoulin Island community (Figure 3).
In consideration of content, students conducted research on residential building types, universal design, and sustainable design—including materials and energy efficiency—while analyzing the client’s daily routine and leisure activities to determine the required and desired features in the design and the adjacencies between interior spaces (Figure 4). Students were instructed to consider the practical aspects of sustainable design as part of environmental quality (Figure 2). As the client was a retiree couple, aging-in-place issues were taken in consideration in the residential design project.

To assign meaning to their designs, students developed their design concepts with regard to the clients’ and the community’s social and cultural identities (Figure 5) so as not to overweigh environmental concerns or compromise the functions, meanings, and aesthetic quality of the design outcomes. Figure 6 and 7 are two examples of students’ project outcomes.
Figure 5: Concept Map and Sketches
Student Project: Avery Castellow, 2013.

Figure 6: Rendered Floor Plan
Student Project: Paristu Alizadeh, 2013.
Conclusion

This paper proposed a framework of sociocultural sustainability, which has been applied in teaching interior design courses. When clear and consistent frameworks are used across the curriculum, students at various levels may have better understandings of the logic, rationale, and interrelationship of design theories, methods, process, and further, sociocultural value of sustainable interior design. As students often seem to have the misunderstanding that sustainable design is the same as environmentally friendly design or green design, the fundamental concept and principles of sustainable design needs to be carefully re-examined and adopted in interior design education.

Discussions of sustainability often lack of considerations of social and cultural values. Sustainability is not merely a practical standard system. It is a contemporary phenomenon that reflects the norms, value-systems, and beliefs of the global society. In teaching interior design students, such a perspective needs to be addressed while highlighting the interior design profession’s responsibility for social and cultural sustainability that significantly affects the public’s welfare.

The proposed framework, a triad of sociocultural sustainability, was developed initially for teaching interior design courses at various levels. This study is ongoing, and further assessment of the effectiveness of the framework will be conducted. Further refinement and detailing may also follow based on the findings from the assessments.

Acknowledgement

The student projects used as examples in this article were conducted by UGA students, Paristu Alizadeh, Avery Castellow, and Audrey Vander Veen.
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From Rating Tool to Design Tool: How Green Guidelines Are Affecting Today's Architecture Practice

Juan Blanco, Universidad Autónoma de Chile, Chile

Abstract: Green guidelines, i.e., LEED or Green Star, have been widely adopted and its scale of implementation continues to rise; they are a factor that cannot be ignored in today's architecture practice. Despite that, the adoption of such guidelines tends to be perceived by practitioners more like a restriction—or checklist exercise. This research project aims to test such assumption by analyzing the effect of green guidelines in the design process of certified buildings. It is expected to prove that green guidelines tend to standardize proven design solutions instead of fostering innovative practices. The following is a working list of research questions: 1) To what extent do green guidelines alter design methodologies in today's practice? What is the nature of such alteration in terms of knowledge generation? For example do they restrict or promote innovative solutions? 2) How has architecture practice responded to the introduction of green guidelines in their design methodologies? Are there any effective responses that can be adapted to different contexts? Do internal characteristics (e.g., size, approach, technology) promote better outcomes? This research will be conducted via case studies. The context of the study is Melbourne's CBD (Victoria, Australia), where a pool of practices had already worked with the local guideline: Green Star (developed by the Green Building Council of Australia, GBCA). In the early stages of the research, one project will be presented: “Council House 2.” The framework of analysis will trace the changes in the design process of this particular case, through by-product data and personal interviews, to identify the response of the design team to green guidelines criteria.

Keywords: Rating Tools, Design Process, Green Design

Introduction

Green building can be defined as the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and deconstruction. Although new technologies are constantly being developed to complement current practices in creating greener structures, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water, and other resources
- Protecting occupant health and improving employee productivity
- Reducing waste, pollution and environmental degradation

Following this trend, many countries have developed their own standards for green building or energy efficiency for buildings. At the same time, several international frameworks and assessment tools complement those national initiatives, like: IPCC Fourth Assessment Report, UNEP and Climate change, GHG Indicator, Agenda 21, FIDIC's PSM, IPD Environment Code, and ISO 21931.

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2 http://www.ipcc.ch/
3 http://www.unep.org/climatechange/
4 http://www.unep.org/energy/
5 http://www.un.org/
6 http://www.fidic.org/
Despite its benefits, green ratings do not seem to take care of long-term sustainability problems. As Birkeland (2008b: 472) points out, “green approaches reduce impacts, but still increase total resource flows and externalize impacts. For example, most green buildings increase the ‘urban heat island’ effect, where cities are much hotter than their regions”. On the other hand, the confusing array of codes and green buildings standards that have emerged are more a consequence of competing interests than a direct response to contemporary environmental conditions\(^7\).

The role of design disciplines in this context has for long been left behind under the ‘eco-efficiency’ imperative. Current methods “do not encourage re-thinking design purpose or adding value to ecological and social goods and services. That is to say, mere eco-efficiency gains are not likely to enhance the conditions for whole system sustainability” (Birkeland 2008: 98). In fact, as the same author points up, the novelty of green building can be summed as a ‘form without content’ problem, where the lack of a new approach can be seen in the use and reuse of

\(^{7}\) Steven A. Moore and Nathan Engstrom, *The social construction of green building codes*, In: Guy and Moore (ed.) , Modelling design, 2005, p. 52

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<th>CONTINENT</th>
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<td>Singapore</td>
<td>IGBC LEED India</td>
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<td></td>
<td>Peru</td>
<td>LEED AP</td>
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*Source: Author (Internet Search, July 2010)*
conventional design methods; the maintenance old industrial frameworks in which buildings are produced; and finally, an unquestioned dogma about durability and efficiency.

In term of design outcomes delivered by this ‘eco-efficiency’ approach, criticism has also arisen. Mostafavi (2010: 12) focus this in two main areas: the quality of the design outcome and its scale of implementation. The so-called sustainable architecture has not contributed to design discipline due poor quality of its outcomes (does not represents neither design excellence or design innovation); on the other hand, the limitation of scales of implementation detected in rating certifications systems that has contributed to focus its influence manly with on the architectural object, and not with the larger infrastructure of the territory.

In a professional environment where green ratings and long-term sustainability seems to be diverging from each other, design disciplines has been called to take on a central stage: to fully apply the finer points of green ratings, design professional must understand sustainable construction principles beforehand to set a layout where sustainable aims can be met.

**Green Building Codes**

A building code, or building control, is a set of rules that specify the minimum acceptable level of safety for constructed objects such as buildings and non-building structures. The main purpose of building codes are to protect public health, safety and general welfare as they relate to the construction and occupancy of buildings and structures. The building code becomes law of a particular jurisdiction when formally enacted by the appropriate authority.

Since 1990, when the first version of BRE Environmental Assessment Method (BREEAM) was launched, the measurement of green buildings performance has been one of the leading fields for achieving a sustainable development. In fact, the emergence of several organizations aimed to implement these tools, constant improvements and diversification has expanded their influence worldwide. Nowadays, the total number of green building certification systems arise a total of 31, covering all the 5 continents. All these efforts have lead to the creation of the World Green Building Council (WGBC), a coalition of national Green Building Councils and “the largest international organization influencing the green building marketplace”.

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8 Building codes have a long history. What is generally accepted as the first building code was in the Code of Hammurabi which specified:

229. If a builder builds a house for someone, and does not construct it properly, and the house which he built falls in and kills its owner, then that builder shall be put to death.
230. If it kills the son of the owner, the son of that builder shall be put to death.
231. If it kills a slave of the owner, then he shall pay, slave for slave, to the owner of the house.
232. If it ruins goods, he shall make compensation for all that has been ruined, and inasmuch as he did not construct properly this house which he built and it fell, he shall re-erect the house from his own means.
233. If a builder builds a house for someone, even though he has not yet completed it; if then the walls seem toppling, the builder must make the walls solid from his own means.


10 11 are founded in Asia, 11 in Europe, 5 in North America, 2 in South America and 1 in each Oceania and Africa

SOURCE: Author (internet search, July 2010)

11 Source: http://www.worldgbc.org
These tools have successfully introduced a set of certainties that simplifies the complex process of measuring sustainability. Firstly, most of them cut across the three pillars approach of sustainability—whose aim is to reconcile environmental, social and economic demands—to be entirely focused on its environmental consequences. Secondly, they fix its action on one defined industrial sector (building industry). Thirdly, they define the environmentally-friendly concept of green building and then establish a common standard of measurement. And finally, the results of applying these tools are translated into a language of best practices that allows its repetition and international transfer.

Despite been tools thought and designed for the building sector, they have greatly influence contemporary design practice. Indeed, one of the most successful rating certifications - LEED, has evolved to become a properly design tool, including education programs and basic requirements to meet for been use by design professionals. Its impact on the design discipline has re-established the leading role of the designer during the green building process, increasing its use into the building industry. As a matter of fact, since 1998 LEED certification has been implemented in more than 14,000 projects in the United States and 30 countries covering 1.062 billion square feet (99 km²) of development area.

1990, first version of BREEAM
13 The current problems of measuring sustainability can be defined as a problem with the scale of the phenomenon, the boundaries of its measure and the time of that measure, according to Bell and Morse (1999; 2003)
The material exposed in this paper is part of a research project focused on analyzing the effect of green guidelines in the design process of certified buildings located in a specific location: Melbourne, Victoria. Cases have been selected for its outcome in using the local rating tool: Green Star (developed by the Green Building Council of Australia, GBCA). Launched in 2002, the GBCA (Green Building Council of Australia) is a national, not-for-profit organisation that is committed to developing a sustainable property industry for Australia by encouraging the adoption of green building practices. It is uniquely supported by both industry and governments across the country.\footnote{GBCA (Green Building Council of Australia) webpage (http://www.gbca.org.au/)}

For the purposes of this paper, preliminary findings on one case study will be presented: ‘Council House 2’. The data collected will be use to trace the changes in its design process, in order to identify the response of the design team to green grating criteria.

**Council House 2 (CH2): Pushing the Boundaries**

In 2004, the City of Melbourne was faced with an accommodation dilemma. Staff was housed in dated office buildings which although centrally located to the Town Hall, were nearing the end of their lifespan. Rather than relocate staff to alternative offices, the Council embarked on a plan to construct a new office building, Council House 2 (CH2), that would meet its spatial requirements and “lead the way in the development of a holistic green environment” (Fox, 2004).\footnote{Stephen Webb interview conducted by the researcher during July 2011}

For taking on the design of these new facilities, The City of Melbourne brought together a group of consultants led by DesignInc Melbourne Architects with the City of Melbourne in-house design team and Advanced Environmental Concepts (AEC) Engineers. The South African-born expert in sustainable design, Mick Pearce, was brought to work within DesignInc team through Rob Adams, who, as Melbourne's director of city design and urban environment, was trying to champion the high-performance design goals of the building. (Fortmeyer, 2008)

From its beginning, Council House 2 (CH2) was conceived to be a *lighthouse project*\footnote{Developed by the U.S. Green Building Council (USGBC), and spearheaded by LEED founding chairman Robert K. Watson, LEED is intended to provide building owners and operators a concise framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions (SOURCE: USGBC)} for the sustainable practices in the Australian context, a characteristic that, according to the design team involved, helped to push the limits of the design. Thanks to Adams's advocacy, CH2 was one of the first building in using ‘Green Star for office building’ (which is roughly equivalent to LEED Platinum\footnote{http://www.gbca.com.au}), an environmental rating tool developed by the –back then, recently created Green Building Council of Australia (GBCA). (Fortmeyer, 2008)

In Australia, Green Star is the most widely accepted environmental rating system for buildings. It was launched in 2003 and contains nine categories of assessment: management, indoor environment quality, energy, transport, water, materials, land use & ecology, emissions, innovation. The resulting score is translated into *Green Stars* as follows:

- **Score 45-59:** 4 Star Green Star, signifies 'Best Practice' in environmentally sustainable design and/or construction
- **Score 60-74:** 5 Star Green Star, signifies 'Australian Excellence'
- **Score 75-100:** 6 Star Green Star, signifies 'World Leadership'

\footnote{http://www.gbca.com.au}
The GBCA used CH2 as one of its pilot evaluations for the untested ‘Green Star office rating tool’, receiving a preliminary rating of six stars for its design stage (Fox, 2004). This tool only became available to CH2 during the design development phase, however as the design team moved into the construction stage this benchmarking proved to be a valuable tool for monitoring alternatives.

The Design Process of CH2

During such process the design team began to implement sustainable criteria based on the recently created ‘Green Star’ guideline. It meant that rather than grouping areas of expertise under the traditional consultant disciplines, such framework fostered the integration of different types of knowledge such as health; art and behavior were fed into the early phases of the design, though conducting a series of charrettes.20

The final outcome of this process is quite remarkable: CH2 was Australia’s first Green Star rated building to be awarded 6 Stars which carries an international leadership status. It was conceive to provide healthy and productive workplace for its occupants whilst reducing the building's impact on the environment through design innovation.

CH2 Design Concept

In 2003 CH2 was one of the first buildings in Australia in conducting several workshops between the design team, consultants and users of green building (Webb, 2005). The design process included an initial two-week workshop followed by regular design sessions that ran for eight months. The workshop itself was made up of a series of presentations, discussions and working parties. These documents and the outcomes were then summarised in a series of internal publications. The project team included architects, engineers, artists, environmental experts, future occupants, the CSIRO and the Sustainable Energy Authority of Victoria. The principal consultants were:

- City of Melbourne (design and project management)
- DesignInc (architectural design and documentation)
- Lincoln Scott (services engineering)
- AEC (Advanced Environmental Concepts)
- the Bonacci Group (structural and civil engineering)
- Marshall Day (Acoustics)
- Donald Cant Watts Corke (quantity surveying)
- Hansen Yuncken (Builders) (CH2 article)21

DesignInc had devised a preliminary scheme that called for tearing down an existing building adjacent to CH2's site, but they scrapped the idea based on the recommendation of the engineers at Lincoln Scott, who were brought in to help rethink the project (Fortmeyer, 2008).

Over the three-week charrette in 2003, the team developed a schematic design incorporating many of the strategies eventually realized in CH2. According to Ché Wall (Fox, 2004), managing director of Lincoln Scott and its Advanced Environmental Concepts group, "after the charrette, we had 85 percent of the engineering design done." But the more ‘risky’ items were isolated in the design so they could be replaced by conventional strategies in case they failed to perform as expected (Fox, 2004).

20 The charrette method can accept this multitude of often conflicting objectives without becoming paralyzed by complexity (Condon, 2007)
21 Webb, 2005
To help to provide a direction during this process, the design team began to make use of a tree as an analogy for the building. A tree also served as an apt representation for the entire design process itself (Figure 1). The design workshop phase (shown on Figure 1 below the line) consisted of seeding the idea. Rather than grouping areas of expertise under the traditional consultant disciplines, types of knowledge such as health, art and behaviour were fed into a framework or root system.

The framework consisted of three aspects of the environment – the natural, social and economic. A design concept emerged after the two-week workshop that the project team then tested and reviewed. Following on from this the building would then be constructed and finally monitored.

**Seeding the Idea**

Following the two-week intensive workshop and subsequent design sessions a design concept emerged that used the guiding analogy of the tree and living systems. It had been found that using analogy in the design process could provide clarity and allow designers to understand complex systems quickly. “Analogical design results from the designer using analogies with other fields or contexts to create a new way of structuring the problem” (Lawson, 1997).
For the CH2 team the most compelling model for the buildings of the future was nature. Mick Pearce openly acknowledge the use of Biomimicry\textsuperscript{22} as source of inspiration for these ideas. A guiding diagram developed that visually captured many of the natural analogies of the design concept (Figure 2). It was based on the concept of synergy – a building comprised of many overlapping systems, each being more than the sum of its parts (Groak, 1992). Building fabric, people, engineering systems, energy flows, natural and man-made landscapes all combined to form an inter-related whole.

Figure 2. The Emergent Design Concept: Epidermis


These comparisons to parts of the world that evoke similar emotional responses can quickly sum up the intent of the architectural expression. What is particularly revealing with architecture is how a guiding analogy or key idea can set goals that can guide the design process for all involved – designers, consultants, builders, clients and users. For example, on the west façade – an epidermis (the outer living layer of an animal or plant) inspired the way the western façade moderated external climate and on the north and south, bronchi (wind pipes) came to symbolize expressed air ducts on the outside of the building. These ideas were summarized as an image in Figure 3.

\textsuperscript{22} Janine Benyus (1997) has described the term in three parts:

1. Nature as model. Biomimicry is a new science that studies nature’s models and then imitates or takes inspiration from these designs to solve human problems, e.g. a solar cell inspired by a leaf.
3. Nature as mentor. Biomimicry is new way of viewing and valuing nature. It introduces an era based not on what we can extract from the natural world, but on what we can learn from it.”
The specific use of the nature analogy in the design process proved beneficial for many reasons. Nature became a:

- Prompt to always look for integrated solutions
- Functional model for complex processes
- Way of valuing the natural world
- Measure or ecological standard
- Source for visual expression – e.g. the repetition of similar shapes at different scales.23

The rapid establishment of clear environmental values and goals set the basis for effective ongoing design review. For example, the early decision to incorporate north balconies for occupant access to nature became the primary generator of north shading and façade review.

**CH2: Architecture and Environmental Comfort**

The original plan for CH2 called for a naturally ventilated building, but once it became clear that the building would need to meet the highest standards for occupant comfort when compared to commercial offices in the local market, they decided against natural ventilation because of noise and air-quality concerns in the busy central business district location.

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Instead, to maintain 75 degrees Fahrenheit in the building, the designers embraced a combination of passive and active HVAC systems. This meant the floor plate—with a width of nearly 69 feet—was not as narrow as originally proposed (a narrow floor plate assists in cross-ventilation), but it also meant the designers needed to take a more holistic view of how the HVAC systems would be integrated into the structure and architecture. (Architecture, hot and cold (The Council House 2)

From analysing Mick Pearce’s early sketches for the overall shape of the building, it is possible to identify an exploration in the layout of the building and its correlation with the structural system—following a traditional approach to architectural design, the relation between columns and roof. But from the moment some of the ideas from the workshop started to been assimilated, the sunlight catchment became a driving force in the generation of the building’s plates (Pearce, 2002).

All these alterations were made to achieve a flexible and regular floor plate. Once it was defined, the design team introduced small elements in the perimeter of the plate, in order to achieve maximum results in environmental control with the minimum disruption of the internal space. As an example, the western core was treated as a highly transparent and accessible element through the use of glazed lifts and connecting stairs. The idea of a winter garden to the north and a summer terrace to the south started to define the characteristic of each facade. At the same time, northern breakout balconies give opportunity for daily interaction within nature.
This is a period of great interaction between the design team, exemplified by the inclusion of the shower towers in the southern façade, brought by the consulting team (AEC). The final layout – or parti of the building, can be understood as the result of inputs made from different disciplines brought together by the design. As an example, light shelves, chilled beams, vertical gardens, balconies and an internal ‘up-blinds’ all combine to moderate external climate.

As consequence of conceiving a façade design inspired by natural systems that work with the external conditions rather than excluding them, two kinds of responses were developed:

- On the west an epidermis that inspired the way the façade moderated external climate. Epidermis (outer living layer of an animal or plant).
- On the north and south the idea of bronchi came to symbolise expressed air ducts on the outside of the building (bronchi= wind pipe).
Material Selection – Testing and Adaptation

The goal of the design team was to produce a revolutionary office building that would propel the industry forward. However the team also acknowledged that many of the technologies and methods of integration that are required for a “nature inspired building” haven’t been developed yet (ABC, 2006). As a result, nature is used primarily as a source of inspiration rather than as a true functional model. One of the stages specially created to cope with this issue was a ‘comprehensive materials assessment process’, which was first explicitly addressed from the two week-long design charrette.

The architectural design process typically starts from preliminary or ‘Schematic Design’, literally the schema or rough placement of spaces and shapes, through to Design Development, where buildings are typically drawn to scale and resolved in some detail, to contract documentation, which involves the documentation of the project in all respects to allow its construction. Materials selection, even in ‘green’ projects, is often considered at the stage of design development - or even contract documentation. A combination of aesthetic/functional/cost drivers and the designers’ familiarity with broadly available products drives implicit and explicit decisions: ‘I know we can do this in brick, this in steel and this in timber’ (Hes & Walker-Morison). The exact specification is typically resolved near the end of the projects life in the designers’ office.

However this ‘business as usual’ process can carry a high cost that can limit Environmental Sustainable Design (ESD) to the ecological impacts of individual building materials. For example it is common industry practice to use plasterboard or fibre-cement sheet wall lining in most buildings. This practice allows cables, pipes and services to be routed over the building structure but hidden by the wall and ceiling finishes. However it can eliminate opportunities to use a concrete structure for effective thermal mass, as detailing to have a concrete structure as the finish requires completely different design of services and construction detailing – not something readily done after schematic design.

Green Star Standards – Challenging Building Industry

The introduction and launch of Green Star in 2003 marked the start of a whole new learning curve for the project team. Having substantially designed the project, they now had to ensure that it would meet the highest levels established by the Australian Green Building Council’s new rating tool. Green Star attributes a relatively modest 15% of available credits for the base building materials, and there is no doubt that tool focused the broad attention of the project team to meeting the particular relevant requirements: reducing PVC use, avoiding the use of rainforest and old-growth timber; using recycled content in concrete and steel. The following table identifies the Green Star credit and the actions taken to ensure CH2 complied so far as was possible.

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24 Under Section 516A of the Environment Protection and Biodiversity Conservation Act 1999, Commonwealth organisations have a statutory requirement to report on their environmental performance and how they accord with and advance the principles of ecologically sustainable development (ESD).
Table 2. Green Star – Office Design (v1) and CH2 materials

<table>
<thead>
<tr>
<th>Green Star Credit</th>
<th>CH2 Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 2 credits for use of post-consumer recycled steel</td>
<td>Use of 100% post-consumer reinforcement steel from Smorgon Steel. No other recycled steel products could be identified for the project.</td>
</tr>
<tr>
<td>Up to 3 credits for use of high-supplementary content (cement replacements) in concrete</td>
<td>Development of matrix with up to 60% replacement depending on stress grading and curing speed constraints. Refer Case Study.</td>
</tr>
<tr>
<td>Up to 2 credits for use of sustainable timber</td>
<td>Use of plantation timber products. Use of recycled timber for louvres. Use of FSC-certified timber. Use of responsibly sourced timber with source documentation timber for window frames*.</td>
</tr>
<tr>
<td>Up to 2 credits for reduced use of PVC</td>
<td>Use of HDPE for most water and other pipework. PVC used for stormwater pipes. PVC used for power, data and communication cables.</td>
</tr>
</tbody>
</table>

*A contentious product that generated significant debate during the project’s construction.

Source: (Hes, Walker-Morison)

Conclusion

The goal of the design team was to produce a revolutionary office building that would propel the industry forward. However, the team also acknowledged that many of the technologies and methods of integration that are required for a ‘nature inspired building’ have not been developed yet. As a result, nature is used primarily as a source of inspiration rather than as a true functional model.

Therefore CH2 is a hybrid – a fully functioning building, but one belonging to its particular time and space. Many of the advances taken with CH2 will go further next time or be approached differently. The City of Melbourne was highly supportive of this ambitious approach and where possible encouraged the design team to include a ‘less-tried’ solution in parallel with a more conventional one in order to push the boundaries of sustainable design.

While the integrated design process developed on CH2 led to many beneficial and unexpected design outcomes, the majority of these outcomes represented hybrid solutions between traditional industry solutions and customized adaptation. One of the key lessons for future projects distilled from this project is that sustainable design rating tools should not only set initial project values but be embraced throughout the design process as a method of incorporating broader environmental imperatives.
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ADjustMEMBRANE: Innovative Lightweight Adjustable Partition Wall System

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Abstract: This paper presents a conceptual system for an adjustable partition wall conceived within a research project. The permanent evolution and mutation of life styles have been conducting to the rethink of living spaces and to a growing need for more evolutionary and adaptable housing units. It can be verified that a major portion of houses don’t accomplish that premise. This happens because the technological and constructive solutions used on conventional interior partition walls, such as hollow brick or plasterboard with metallic frame systems, are static and difficult to readapt without a significant cost due to the specialized work required and material loss during the assembly process. The proposed conceptual system, called ADjustMEMBRANE constitute a modular building solution of a non-load bearing partition wall, tensioned between the pavement and ceiling slabs, that are used as anchoring elements. It allows several advantages, presented in this paper, related with the weight reduction to achieve a good sustainable performance, such as: reduce costs on energy, materials and construction; easy recycling, reusing and allow self-construction.

Keywords: Lightweight, Partition Wall, Flexibility, Modular, Adjustable, Portable, Self-constructive System

Introduction

A partition wall is a thin element built to divide the indoor space into rooms or other compartments. Generally, partition walls are non-load bearing. For a load-bearing wall, compressive strength is an important factor of design; a partition, on the other hand, needs only to be strong enough to support itself under normal conditions of service. The main structural requirement of a partition wall is to have the necessary strength to support small objects and the accidental impacts resulting from the occupation of the building. The permanent evolution and mutation of life styles and familiar aggregates have been conducting to the rethink of living spaces and to a growing need for more evolutionary and adaptable housing units (Coelho and Cabrita 2003) (Gausa 1998, 31). It can be verified that a great portion of houses don’t accomplish that premise. That’s because of the constructive solutions used on interior hollow brick partitions – characterized by being heavyweight and static. This problem reveals to be more important in the refurbishment of existing buildings, but also when new buildings are conceived – knowing that, in future, the need of reorganizing interior space will become as difficult as today. The use of more lightweight solutions in buildings implies a minimum overall weight of buildings and so smaller environmental impacts due to the extraction of raw materials and to their transformation processes, as well as a proportional reduction on loss factors and transport energy (Berge 2000). With the use of lightweight solutions in dividing walls, the reduction of weight can be of up to 50%, with consequent reduction on embodied energy and transport energy costs, that allow an overall energy cost reduction associated with construction phase of almost 60%, although maintaining the functional performance in equivalent levels, even in temperate climates where thermal mass is a relevant issue to maintain passive solar strategies. These conclusions are from a previous study from the first author, where it was explored a strategy to combine lightweight and heavyweight constructive solutions and interior zoning, optimizing the overall functional performance of buildings, in a so called “mixed weight” strategy (Mendonça 2005). The mixed weight principle is also present in the solution proposed and analyzed in the present paper.
Growing necessity to save material and energetic resources, allied to a growing concern over the environmental issues and incertitude on the evolution of the economy, has impelled minimalist-approaches to Architecture and Engineering, reducing to the minimum necessary expression the constructive elements. These approaches, by some authors called "Light-tech" (Horden 1995) and Eco-tech (Slessor 1997), bets on the introduction of more materially and energetically efficient solutions. This final objective it is expected to obtain a partition that can be moveable and even portable, as household furniture.

In the following topics it is present an innovative lightweight adjustable partition wall technology designated by ADjustMembrane, conceived within a research project. There is a patent provisional application for this technology.

**Interior Partition Walls**

Weight plays an increasingly significant role when it comes to the environmental impact of a building. Addis & Schouten (Addis and Schouten 2004, 38-39) refer that partitions have emerged as building sub-systems, as result of several factors, including the development of frame construction where internal walls are no longer required to have a load-bearing function. Due to emergent aspects like: the speed of organizational and technological change; the increased number and complexity of services to be accommodated; quality and aesthetic issues and the need for acoustic separation of areas, the contemporary internal partition walls present nowadays new requirements.

The life-cycle environmental impacts of an internal partition wall solution result directly from the attributes of the used materials, such as its initial embodied energy, its thermal properties, and from the way the solution is built and maintained. Interior partition walls have the higher contribution to the material inputs, when compared to other non-load bearing construction elements, as it can be seen in figure 1.

![Environmental Impacts from Materials Use on Non-load Bearing Construction Elements of a Typical House over 60 Years](image)

*Source: Data Adapted from Addis and Schouten 2004, 38-39.*

The importance of these building elements is reflected in the global construction cost, estimated by König et al (König et al 2011, 66) in a proportion of about fifteen percent in office and administration buildings of European countries.
Evolution of the Weight in Partitions Walls Technology

Generally, partition walls are non-load bearing. In terms of structural resistance, these need only to be strong enough to support themselves under normal conditions of service. Other requirements of partition walls are: the capacity to resist to accidental impacts resulting from the occupation of the building. Weight plays an increasingly significant role when it comes to the environmental impact of a building. In general lightweight solutions present less embodied energy and save fuel on transport to the building site, and can be designed with smaller assembly fittings (Tichelman and Pfau 2007, 7-9).

In European Paleolithic period, the use of animal skins supported by large bones or wooden poles to construct interior dividing walls in caves (Kbinirsbnb 2011), constituted an important innovation for future developments of exterior artificial dwellings, where the structural supporting element is independent from the covering layer (Mendonça 1997).

By analysing the evolution of internal partition walls, shown at figure 2, it is possible to verify that an initial tendency for lightweight solutions evolved to heavyweight (Mendonça and Macieira 2011, 149-161). However, nowadays it can be verified a tendency to the return of lightweight solutions that can include easier construction/deconstruction design principles.

Figure 2: Weight evolution of the most representative type of interior partition walls in Portugal: (a) animal skin coating vegetable poles or bones; (b1) mat canes filled with reed; (b2) Wattle and daub filled with straw; (b3) wattle and daub with planks; (c) Solid Brick; (d) Hollow Brick; (e) Wooden board with timber frame; (f) Plasterboard panel with timber frame; (g) Plasterboard panel with metal frame.

Source: Scheme designed by Mendonça and Macieira 2012.

The most representative type of contemporary building construction in Portugal consists of steel reinforced concrete structures with hollow brick masonry walls and beam and pot slabs. The conventional system of interior partition walls is simple pane nonstructural hollow brick. This solution have demonstrated reasonable thermal and acoustic performance, fire behavior and durability, but it presents disadvantages in terms or embodied energy, lack of flexibility, recyclability and reusability.
Design of Innovative Adjustable Partition Wall System

The lightweight partition wall solution with greater implementation in the Portuguese market is the plasterboard solution (figure 2(f)) with a sub structure of light gauge frame profiles. The ADjustMEMBRANE solution (figure 3), differs from this lightweight reference solution because it is even more lightweight, it is tensioned, it allows easy disassembly, easy removal of water, electrical and other pipes without damaging the coating and it allow spatial reconfiguration reusing components entirely. In a scenario of disassembly, plasterboard solution only permits the reuse of structure but not of coating (Addis and Schouten 2004, 38-39) and the space reconfiguration becomes very constrained.

The proposed solution provides a dry assembly with mechanical fixings such as plasterboard solution, however it provides more easy removal scenarios than the last. It allows the integration of installations in its core avoiding the use of acoustic and thermal insulation of the pipes and any wet fixing elements, such as glue or mortar.

![Figure 3: Assembly Process of Proposed Lightweight Adjustable Partition Wall System: (a) Support Structure: (b) Grid and Core Fixation and (c) Integration of Pipes and Other Installations.](image)

This adjustable partition wall system - ADjustMEMBRANE - is characterized by including: a support structure composed by woven straps fixed to the ceiling slab by metallic profiles and to the pavement slab through tightening buckles or tensioning ratchet (figure 3(a)); a grid composed by cube-shaped modules with mechanical connection in each module face a circular central opening to create horizontal and vertical holes to the passage of pipes and fixing the coating (figure 3(b) and 3(c)); a core of fibrous or porous material which soaking the modules and their respective holes and an outer membrane coating on each face of the panel (figure 3(c)).

As other non-structural partition walls, the presented solution can be applied as inner panels of double walled façade solutions. It is based in the assumption that the fastening system should
be applied in situ to the building elements (floor, ceiling and walls) positioned at its boundary, that must be of a rigid type (concrete, steel or wood), that should be practically undeformable and enable a good fixing.

**Tensioned System Assembling**

Unlike the conventional partition walls, in which the structural elements operate generally in compression, at the proposed solution the stopper is tensioned between the floor and ceiling to ensure the stability of the partition wall.

The present invention provides a solution composed by light modular panels, with dimensions of 300 millimeters to 3000 millimeters, allowing easy transportation to worksite and a dry assembly (without the use of water or glue) in situ. The stability is ensured by: tensioned straps, only needing rigid elements for attachment to ceiling and pavement slabs; reinforcing the perimeter of the interior opening gaps; and trim tops, corners and links between parts of walls.

The support structure (figure 3(a)) consists of vertical lashing straps with tensors of buckle or ratchet type, which ensure an initial tension between horizontal support elements - ceiling and pavement. In the support structure is fixed the core, which is constituted by a rigid or a malleable fibrous material - in this last case having a rigid reinforcing grid - with grooves whose geometry allows the integration of networks of pipes for water and electric installations with diameters up to 40mm without opening grooves.

**Design Principles for Deconstruction To Facilitate Reuse and Recycling in ADjustMEMBRANE**

It can be verified that the proposed solution present principles of design for construction and deconstruction such as those described by Addis & Shouten for partitions walls (Addis and Schouten 2004, 38-39).

**Flexibility**

The ADjustmembrane solution presents a reduced weight, what allows great ease of handling and assembly when compared to conventional hollow brick masonry (figure 2(d)) or even plasterboard partition wall solution (figure 2(f)). The construction technology is dry, i.e. without use of water / mortar, it do not require hand labor or specialized equipment. The dry assembly with reversible mechanical fixings allows disassembly and assembly with different configurations of space, facilitating the portability and the flexibility of use.

**Modular Components**

ADjustMEMBRANE system is composed by modular components. The core is composed by modules that can be subtracted or added anytime to allow the integration of facilities such as water or electrical pipes and switches or outlets, without panel damaging. This core can also be constituted by a grid, which simultaneously serves to strengthen and give rigidity to the panel (figure 4).

To the basic structure of the partition (figure 3 (a)) - mentioned in the topic 3.1- are fixed panels, which are subdivided into modules (figure 3 (b)) and can be decomposed to enable fittings in various directions. These modules, that constitute a reinforcing grid, are compulsory included in the malleable core solution and optionally in solution with rigid core. The modules making up the grid can be divided longitudinally and transversally to the partition (Figure 4) using snap connections like male-female type.
**Detachable Coating**

ADjustMEMBRANE presents a coating in the external faces of the core that are assembled by fitting to the core grid (figure 3(b)). The panel coating may comprise a polymer, a textile material, a metal sheet or composite material with reinforcing fibbers, or other types of rigid panels or films (fibbers, polymers or composites).

An over-coating may also be placed on site. The over-coatings to be applied can be: fabrics or films. A tensioned PVC membrane attached to a frame system is available in the market, with specific profiles which make the adjustment of the membrane. The membranes are available on the market; the most common are: PVC, PTFE, silicone, and vinyl with or without reinforcing structure (usually woven polyester or fibreglass). There may also be added OSB panels, MDF, plywood, etc., mechanically fixed by "Velcro" or other fastening system, like quick coupler type which does not compromise the disassembly. While not being a solution which allows easy disassembly desired, it admits the possibility of using more conventional over-coatings such as plaster, mortar, particularly with synthetic linkers (eg acrylic).

**Integration of Installations**

The ADjustmembrane porous or fibrous core design presents vertical and horizontal grooves inside, distributed in a modular metric, to allow the integration of installations such as water, gas and electricity pipes without opening grooves on site (figure 5(a)). The modular grid design present circular holes and the dimensions of the cubic modules’ faces are designed to allow the integration of standard electrical outlets or switches only by subtract one module.

The panel has access to integrate facilities by: the front face (relative to the position of the installer) in the simple solution (with a thickness between 60 and 100 mm thick); or through both sides in the double solution (with a thickness between 120 and 250mm).

The core material can also allow the thermal and acoustic insulation of the facilities themselves in response to legal requirements of water pipes isolation, when they do not have (such as hot water metal pipes). Thus, the integration of installations is facilitated by the geometry of the core and the characteristics of the flexible material.
Comparison Analysis between Conventional Partition Walls and ADjustMEMBRANE

Analysed Partition Walls Technologies

This study compares ADjustMEMBRANE partition wall (figure 7c)) with two solutions: i) the heavyweight conventional masonry partition wall (HCM) in figure 7a); and ii) lightweight reference plasterboard partition wall (LRP) in figure 7b). These solutions have two considerable differences: the weight and the type of building technology. The heavyweight conventional masonry partition wall (HCM) is made of juxtaposed units of brick joined with Portland cement mortar. The most common interior partition system in Portugal is a single wall made of hollow brick units (0.30x0.20x0.11m), coated with a 0.02m thick cement plaster on both sides, which results in a total wall thickness of 0.15m and in a total specific weight of about 150kg/m2 (figure 7a)). The ceramic hollow brick units have horizontal holes and present a regular geometry with four striated sides which allows a good adhesion of any type of finishing. The installations are placed after building the wall and before the plaster, through the execution of grooves that accommodate the installations and that are afterwards filled in with mortar. This phase produces more material wastes, as it can be seen on figure 6, when compared with the lightweight reference plasterboard partition and ADjustMEMBRANE (here presented).

The lightweight reference plasterboard partition wall (LRP) is the lightweight solution that is normally used in alternative to the conventional one in Portugal. It is a technology based on plasterboards supported in a cold formed galvanized steel structure (figure 7b)). This structure is based in profiles placed vertically and fixed to two horizontal bars attached to the floor and the
ceiling. Installations (e.g. water pipes and electrical cables) and the necessary acoustic and thermal insulation are placed in the gap between the plasterboards.

The ADjustMEMBRANE is a technology under development within a project of R&D at the University of Minho. This solution in the configuration analysed is made of: a coating of cardboard (3mm) with a polyester fabric / PVC composite membrane (1.5mm thick); a core in cellulose fibre with a grid in cardboard (70mm); fixed between ceiling and pavement slabs by lashing straps and metallic rackets.

**Environmental Impact Analysis**

In previous studies (Mendonça and Macieira 2011, 149-161) (Mateus et al 2011) it was analysed the environmental impact of a conceptual solution, embrionary to the ADjustMEMBRANE solution here presented, with good results. In the present analysis, the results of the proposed solution are compared to conventional partition walls.

The values presented on Table 1 result from a numerical simulation based in reference data (Berge 2000, 20-21) (Santos and Matias 2007, 43-50) (Author 2005).

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**Figure 7: Horizontal Section of Interior Dividing Wall Technologies**
Table 1: Environmental Impacts of the Considered Solutions.

<table>
<thead>
<tr>
<th>Impact categories</th>
<th>ADjustMEMBRANE</th>
<th>LRP</th>
<th>HRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Weight (kg/m²²)</td>
<td>24.6</td>
<td>30.4</td>
<td>179.0</td>
</tr>
<tr>
<td>EE (kWh/m²²)</td>
<td>55.6</td>
<td>61.7</td>
<td>139.8</td>
</tr>
<tr>
<td>GWP (g/m²²)</td>
<td>3227.3</td>
<td>14386.7</td>
<td>23218.0</td>
</tr>
<tr>
<td>AP (g/m²²)</td>
<td>29.8</td>
<td>114.0</td>
<td>217.1</td>
</tr>
<tr>
<td>COD (g/m²²)</td>
<td>13.2</td>
<td>2210.9</td>
<td>2340.3</td>
</tr>
<tr>
<td>Generated Waste (g/m²²)</td>
<td>1875</td>
<td>2552.4</td>
<td>6052.4</td>
</tr>
<tr>
<td>U value (W/m²·°C)</td>
<td>0.6</td>
<td>0.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>

1EE (Embodied Energy).
2GWP (Global Warming Potential) in equivalent CO₂ grams.
3AP (Acidification Potential) in equivalent CO₂ grams.
4COD (Chemical Oxygen Depletion) in equivalent NOx grams; POCP (Photochemical Ozone Creation Potential) in equivalent NOx.
5Generated waste in production process.

Table 2: Results from the Quantification of the Functional and Economy Indicators.

<table>
<thead>
<tr>
<th>Partition technology</th>
<th>Functional indicators</th>
<th>Economic indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dₙₜₜ ,w [dB]</td>
<td>U [W/m²·°C]</td>
</tr>
<tr>
<td>HCM</td>
<td>41.0</td>
<td>1.80</td>
</tr>
<tr>
<td>LRP</td>
<td>41.5</td>
<td>0.80</td>
</tr>
<tr>
<td>ADjustMembrane</td>
<td>40.0</td>
<td>0.59</td>
</tr>
</tbody>
</table>

Analyzing the results it is possible to realize that, in accordance with the considered indicators and their respective weight, the partition wall technology with the best environmental performance is ADjustMEMBRANE. This solution is better than the conventional solution (HCM) at the environmental levels. Nevertheless, it has a higher construction cost. The higher construction cost is mainly justified by the cost of the material used in its structure: cold formed galvanized steel, such as in the LRP solution. Comparing the three solutions at the environmental level it is possible to notice that ADjustMEMBRANE presents the best indicators.

Conclusions

This paper is focused in a project which aims to develop an optimized construction technology for partition walls. For being lightweight, flexible and adjustable, the ADjustMEMBRANE solution allows the reorganization of the interior compartments’ layout in accordance with the household requirements throughout the time.

In the construction industry there are materials and products with good and bad environmental performance. Therefore, in order to reduce the whole building environmental impacts, project teams should select technologies with better environmental performance, but at the same time fulfill the necessary functional and economical requirements. At this stage it is
possible to realize that the solution under development can be better from the environmental performance point of view, than the two reference solutions used in the Portuguese building construction industry: the conventional heavyweight masonry hollow brick wall and the alternative lightweight partition solution made of plasterboard panels with cold formed galvanized steel structure. According to previous studies by Author (Mendonça 2005), with the evolution of technologies, this panel can easily incorporate other functions, such as lighting, radiant heating and cooling, sensors for real-time monitoring, thermal storage with PCM’s, etc. (Fernandez 2006, 1-14) (Macieira 2012).

Acknowledgement

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The Effects of Environmental Noise on the Behavior of Children with Autism Spectrum Disorders

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Abstract: A high percentage of children with autism spectrum disorders (ASD) experience auditory sensory dysfunction (Freed & Parsons, 1997; Grandin, 1995; Quill, 1995). This exploratory study was directed toward identifying (1) whether the design of the auditory environment affects the behavior of students with autism spectrum disorders, (2) auditory triggers in the learning environment for students with ASD, and (3) auditory design features of the built environment that decrease undesirable behavior. A focus group and questionnaire were utilized to achieve these objectives. Noise within the physical environment was found to have an effect on behavior and learning for children with ASD. Sudden unexpected sound and higher pitched sounds were found to be the main sound triggers. Auditory design recommendations included the use of music, spatial organization, technology, and building materials within the physical environment. This study presents a line of inquiry that is virtually untapped in the field of educational design and warrants further investigation.

Keywords: Autism, Auditory, Environmental Design, Educational Design

Introduction

The design of the built environment has a substantial effect on learning and behavior (Khare and Mullick 2009; Woodcock, Woolner, & Benedyk, 2009; Dunn, Griggs, Olson, Beasley, Gorman, 1995; Shabha, 2006 ). A thoughtfully planned physical environment must serve the most sensitive students by identifying and eliminating or reducing undesirable sensory impact. However, identifying sensory triggers for students with Autism Spectrum Disorders (ASD) is a complex task due to the variety and severity of symptoms that individual students exhibit.

Autism is a spectrum disorder. Two students with the same diagnosis can vary greatly in capability and severity of deficits. As a result, some students are more sensitive to the physical learning environment than others. Common identifying characteristics include difficulty with social interaction and communication skills, as well as having a small range of interests (Scott, Clark, & Brady, 2000).

Many students with ASD exhibit sensory integration dysfunction manifested as hyposensitivity or hypersensitivity to the environment. The result of this dysfunction may be a delay in the development of language, attention, organization, motor abilities, interpersonal relationships, and/or academic learning (Grandin, T.,2006). Individuals with environmental sensitivities may exhibit stereotypical or self-stimulatory behavior in order to block out or activate the sensory stimuli (Freed & Parsons, 1997). Students with ASD may become overwhelmed by stimuli in the environment and shut down (Freed & Parsons, 1997; Grandin, T.,2006). Hyposensitivity to sound is displayed by a child who fails to respond even when the background is quiet. Children with hyposensitive ASD do not seem to be aware of things going on around them and may even fail to respond when their names are called (Grandin, T.,2006). Additionally, children with ASD were also reported to be disturbed by loud noises or enjoy making strange, excessive noises (Tomchek & Dunn, 2007). This sensory dysfunction is the basis for Sensory Integration Theory.

Sensory Integration (SI) theory was developed from the work of Jean Ayres (1979) and expanded by Fisher and Murray (1991). The foundation of SI theory is that proper integration of
the sensory systems allows for the development of language, attention, organization, motor abilities, interpersonal relationships, and academic learning. Ayres (1979) explains “Sensory integration is the neurological process that organizes sensation from one’s own body and from the environment and makes it possible to use the body effectively within the environment.”

A high percentage of children with ASD experience auditory sensory dysfunction (Freed & Parsons, 1997; Grandin, 2006; Quill, 1995). However, Quill (1995) states that oversensitivity to sound is only experienced at certain pitches or types of sounds. Even small noises such as children whispering or the brushing sound of corduroy can be distracting to children with auditory hypersensitivities (Myles, Cook, Miller, Rinner, & Robbins 2000). Shabha (2006) states that auditory sensory dysfunction may manifest itself with the child tapping ears, snapping fingers, or making vocal sounds.

The environmental sensitivities exhibited by the majority of children with ASD should be considered when designing therapeutic or educational environments. Therapy spaces (speech, occupational, etc.) and classroom spaces should incorporate the same design principles. Every American general education classroom is a potential inclusive classroom; therefore, the need to understand the relationship between the sensory environment and behavior extends to every American school. This exploratory study was directed toward identifying (1) whether the design of the auditory environment affects the behavior of students with ASD, (2) auditory triggers in the learning environment for students with ASD, and (3) auditory design features of the built environment that decrease undesirable behavior.

Review of Literature

Autism and the Built Environment

Autism is a complex neurological disorder affecting the functioning of the brain that may not be apparent in infancy (Scott, 2006). Children with ASD are born with the disorder or the potential to develop it later (Tomchek & Dunn, 2007). The cause of autism is unknown; although, many theories exist. Early intervention is critical due to the flexible nature of young brains. A dramatic reduction of the symptoms and need for supports may occur by the time a child enters school with intervention services such as speech therapy, sensory integration therapy, and applied behavior analysis. The Autism Society (2013) lists early childhood warning signs which support the need for further evaluation. These include:

- Does not babble or coo by 12 months
- Does not gesture (point, wave, grasp) by 12 months
- Does not say single words by 16 months
- Does not say two-word phrases on his or her own by 24 months
- Has any loss of language or social skill at any age.

Hearing

Pitch and loudness are two terms that must be understood when measuring acoustics. Pitch is “the subjective impression of how high or low a sound is” and is measured in Hertz (HZ) (Manlove, Frank, & Vernon-Feagoans, 2001, p. 56). Children with normal hearing can hear a range of pitch tones from 20-20,000 Hz. Optimal pitches for understanding speech range from 500 to 6,000 Hz. If classroom noise falls outside of this range, it will be difficult to understand speech (Manlove, et al., 2001).

Loudness is “the subjective impression of the intensity of a sound” and is measured in decibels (dB) which are measured by a sound meter (Manlove, et al., 2001, p.56). Children can
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hears between 0 dB and 130 dB. Normal conversational speech generally ranges from 55 to 75 dB. However, for comprehension in a classroom with background noise, students with ASD need verbal instructions to be 2 to 3.5 dB louder than other students (Ashburner, Ziviani, Rodger, 2008). In some primary school classrooms, children are exposed to approximately 65 dB of classroom babble, which can interfere with learning (Shield & Dockrell, 2008). Other everyday sounds may range from a whisper (30 dB) to a jet plane takeoff (120 dB). Hearing may be permanently damaged at sustained noise levels over 90 dB (Manlove, et al., 2001).

Long reverberation times and high noise levels can interfere with understanding speech in a classroom. Reverberation is caused when sound bounces off the hard and flat surfaces in a space (Kopec, 2012). Long reverberation times increase the overall noise level of an environment.

Finally, an important factor in acoustics is the signal to noise ratio (SNR). SNR is “the difference between the decibel level of a speaker’s voice minus the level of the background noise” (Manlove et al., 2001 p.58). Children need higher SNRs than adults to develop speech and language. The SNR in a classroom should be greater than +15 (Manlove et al., 2001).

Standards for Classroom Acoustics

The United States Access Board joined with the Acoustical Society of America (ASA) in 1998 to support the established standards for classroom acoustics. The standards were recently revised as ANSI/ASA S12.60-2010, Acoustical Performance Criteria, Design Requirements and Guidelines for Schools (American National Standards Institute, Inc. 2010). The standard looks at background noise, interior acoustics, and noise transmission. Interior noise levels are limited to 35 dB. Unoccupied classrooms commonly have noise levels of 52 to 62 dB due to the sound from the HVAC systems (Manlove, et al., 2001). This demonstrates a level approximately four times noisier than the recommendation since a 10 dB increase is perceived as twice as loud. Occupied classrooms are generally 10 dB louder than unoccupied. Occupied preschool classrooms in child care centers often range from 66 to 94 dB. (Manlove et al., 2001). The standard also limits reverberation to 0.6 seconds in an average room (American National Standards Institute, Inc. 2002). Reverberation times in unoccupied classrooms range between 0.4 to 1.2 seconds. These results make it clear that typical classrooms are noisy learning environments (Manlove et al., 2001).

Acoustical Studies

Studies show that noise has an effect on learning (Lercher, Evans, & Meis, 2003; Manlove et. al, 2001). Since students with ASD experience auditory processing difficulties and sensory integrative dysfunction regarding hearing, the control of internal and external environmental noise is even more critical. The following information reviews the issues related to noise in the learning environment; however, a lack of empirical evidence exists for students with ASD.

A study conducted by Lercher, Evans, and Meis (2003) of 123 school children concluded that negative developmental effects on cognitive systems of young children were found in noise levels present in typical North American neighborhoods. Studies of high noise levels are well documented and have been shown to affect reading acquisition in children, including letter, number, and word recognition (Shield & Dockrell, 2008). However, even modest noise levels, typical of those found in many residential areas in North America, can cause delays in cognitive development in young children. This study examined the relationship between ambient noise, memory, and attention. The researchers concluded that cognitive development is adversely affected at this moderate noise level.

Interestingly, students with ADHD showed significant improvement in math scores with background music in a study by Abikoff, (1996). Students with and without ADHD were tested in three conditions including silence, speech, and music. In this study, the students without
ADHD performed similarly under all three conditions. Mozart and Vivaldi are thought to be beneficial for learning, so playing classical music in the background could prove to be therapeutic in class (Kranowitz et al., 2001). Music exposure affects spatial-temporal reasoning that is the foundation for math, engineering, and chess skills (Freed & Parsons, 1997). Many students categorized as having learning differences as well as those classified as “gifted and talented” prefer some sound or music in a classroom to screen out random noise distractions (Rayneri et al., 2003).

A simple modification of using an earplug for children with learning disabilities was investigated by Green and Josey (2002). Students with learning disabilities have been shown to perform better when they hear through only one ear instead of both ears simultaneously. In this study, the children with learning disabilities using the earplug showed an average of 39% improvement in recall (Green and Josey, 2002). Students without learning difficulties showed no differences in recall.

Technology may also improve the auditory learning environment. Studies involving Freefield FM amplification systems have shown benefits both to students with hearing losses and to those with normal hearing. McCarty and Rosen (2005) conducted a multi-year study in Orange County Public School District. The results showed that students in audio enhanced classrooms scored 10% higher on achievement tests than those without the systems. Teacher absenteeism was reduced by 25% less in these classrooms. Another study by Nelson and Nelson (1997) of 23 elementary classrooms equipped with Freefield FM amplification systems showed strong teacher satisfaction, an increase in student’s academic achievement, increased ability to understand and follow directions, increased attention to tasks, and a drop in special education enrollment.

**Reducing Noise**

Controlling noise must be addressed during the planning stage of the design process (Clark, 2003). The noise of the mechanical systems must be controlled. The air conditioning units need to be placed at a distance far enough away from classrooms to avoid noise interference. Diffusers, acoustic linings, and silencers all reduce noise but may dictate space planning and ceiling heights. High-density vinyl barriers within the walls can reduce noise from adjoining classrooms. A six inch wall width is needed to be most effective instead of the standard four inch walls. Simply closing a classroom door will also reduce auditory input from the hallway (Stokes, 2003).

The noise-reduction coefficient (NRC) measures the sound absorbing properties of a substance. Hard surfaces should be avoided on walls, floors, and ceilings to reduce noise and reverberation (Manlove et al., 2001). Suspended ceilings, fiberglass, and acoustic ceiling tiles help to control noise. The noise from lighting should also be considered. Fluorescent lights may produce noise levels of 50 db(A) (Manlove et al., 2001). In addition, dimmers may also increase noise levels (Manlove et al., 2001).

Carpeting and wall panels help reduce reverberation (Manlove et al., 2001). Carpeting should have ample padding. The use of glass, stone, and laminated work surfaces should be minimized in classroom furniture. Other ways to reduce noise are to place curtains over the windows and wall-mounted cork bulletin boards on the walls (Manlove, et al., 2001). Headphones may be used for appropriate equipment such as computers or tape players. If the loud speaker of the classroom has static or is very loud, the cover should be removed and lined with foam or newspaper to reduce the “surprise” factor when it comes on (Manlove et al., 2001). A child with auditory sensitivities should be prepared for bells, fire drills, and morning announcements.

Noise interferes with learning for all children and those with learning differences are more sensitive to sound in the environment. Younger students who are developing speech and learning
how to process words are in need of an environment with proper acoustics. Classroom noise also may have an adverse effect on teachers.

**Purpose/Justification for the Study**

Worldwide, the number of children diagnosed with ASD continues to increase. The inclusion of students with ASD into the general education classroom is common practice. In a British study of 10 special needs schools, Ghasson Shabha (2006) explored the effect of environmental sensory stimuli on the behavior of students with ASD. The study was preliminary in nature and surveyed teachers and caregivers about sensory parameters that negatively influence behavior. Echoing, high and low-pitch sound, and background noise level were identified as negatively influencing behavior in Shabha’s study.

This study examined and built upon Shabha’s (2006) theory on the relationship between the sensory environment and the behavior of students with autism spectrum disorders. Differences in the present study include:

1. A survey instrument was developed using a focus group.
2. The study involved schools in the United States instead of the United Kingdom.
3. Public schools were the focus in this study instead of schools catering to students with special needs.
4. Students with ASD were the subjects for this study. The special needs schools used in Shabha’s study also included children with sight and hearing impairments.
5. A larger sample of over 608 special education teachers was used in the survey.

The objective of this study was to assess the impact of the sensory environment on the behavior of students with ASD. The research questions addressed by this study are:

**Question 1:** Does the design of the auditory environment affect the behavior of students with ASD?

**Question 2:** What auditory design features of the built environment trigger undesirable behavior?

**Question 3:** What auditory design features of the built environment help to decrease undesirable behavior?

Currently, a lack of knowledge exists in understanding the impact of the physical environment on behavior and learning for students with ASD. Educational designers, educators, and parents must understand the way autistic students learn and be aware of the sensory dysfunction experienced by individuals with ASD in order to provide appropriate learning environments. The results from this study will add to the body of knowledge by providing baseline data for educational design.

**Method**

A mixed method approach to inquiry using sequential procedures was utilized for this study. By collecting diverse types of data, research questions are better addressed. The review of literature revealed a lack of research concerning the effects of the sensory environment on individuals with ASD. Therefore, a pilot study (focus group) was utilized for the first phase of this research project. The information gained was used to develop the survey instrument for phase two of the
A focus group interview of individuals with experience in working with children with ASD was conducted to facilitate in answering the research questions of the study. Questions were asked to gather data about the schools, teaching settings, and behavioral reactions. Questions from Dr. Shabha’s questionnaire were adapted for use in the focus group discussion. The instrument contained both open-ended and closed-ended questions. The questions were given to each participant in a hand-out form prior to the discussion. A moderator then led the discussion.

**Participants**

Eleven respondents were included in phase one of the study. The participants of the focus group were diverse in their experience, ages, and included both genders. The group included:

- One behavioral specialist.
- Two special education teachers.
- Two general education teachers with several years of experience working with students with ASD in an inclusive classroom.
- One ASD specialist.
- Two speech therapists with experience working with individuals with ASD.
- One assistive technologist.
- Two directors of the Burkhart Center for Autism Education and Research at Texas Tech University.

**Data Analysis**

Data analysis of this focus group followed the procedures outlined by a systematic analysis process. According to Krueger (1994), systematic analysis has two dimensions. The first includes the way data are gathered and handled. The second incorporates specific processes. Both of these components oblige the researcher to follow a sequential process. The process may vary, but must be purposeful and planned.

For this study, a systematic analysis began with Shabha’s questionnaire (Shabha, 2006). The questions were analyzed by the relationship to the research questions. The data were collected using the researcher’s notes, video tape, and memory. The data were then reviewed for dominant themes that emerged throughout the discussion. The themes were selected according to the verbal and nonverbal responses directed toward the question, the number of participants mentioning an issue, and agreement or disagreement on an issue.

**Survey Method (Questionnaire)**

The survey method (questionnaire) provides a quantifiable description of attitudes, opinions, or trends of a population through a sample (Creswell, 2003). Survey research is commonly used in social science research for descriptive, explanatory, and exploratory purposes (Babbie, 2009). Strengths of surveys include usefulness in describing the characteristics of a large population, flexibility, and ease in administering. Self-administered questionnaires (e.g., SurveyMonkey) have advantages over an interview survey. These include economy, speed, lack of interviewer bias, and anonymity (Babbie, 2009). The questionnaire used in this study was developed from the information gained from the focus group.
**Target Response Group**

Special education teachers in Texas public schools were the participants for this phase of the study. Most special education teachers work with children who have mild to moderate disabilities, although some work with severe cases of autism or mental retardation. Since schools are becoming more inclusive, special education teachers’ roles are changing. No matter the setting, special education teachers design and adapt curriculum and teaching techniques to meet the needs of students with disabilities. They are also involved in the students’ behavioral and social development.

All fifty states require licensure of special education teachers. A bachelor’s degree and completion of an approved teacher preparation program are minimum requirements. However, most states require a master’s degree in special education and a professional assessment test. In 2006, approximately 459,000 special education teachers were employed in the U.S. with nearly all working in educational institutions (U.S. Department of Labor). In the state of Texas during the same time period, there were an estimated 32,546 special education teachers (Texas Center for Educational Research, 2006).

For this study, the target response group was special education teachers who had worked with a student with ASD within the previous five years. A total of 608 individuals participated in the study. All of the participants were recruited by the special education director in their respective regions or districts, principals of their schools, or through university professors in special education programs.

**Procedures**

SurveyMonkey was used to administer the survey. SurveyMonkey employs a third-party firm to conduct daily audits of security while using firewall and intrusion prevention technology. Data were kept confidential. All students with ASD were anonymous as the teachers were not asked for names of students. Only teachers were asked to respond to the survey, and they were not identified by name. Instructions were included. The first question on the survey asked the respondents if they had worked with a child with ASD within the past five years. The second question asked if respondent had a teaching certificate. Those who responded negatively to either of the first two questions were excluded from the survey. The answers to the questions remained confidential.

Of the 608 respondents, 94.4% (574) stated they had worked with at least one student with ASD within the previous five years. Thirty-four participants (5.6%) answered negatively to the question. The responses for those who had not worked with a student with ASD in the past five years were omitted from the study. Ninety-five percent (578) of the participants responded positively when asked if they had a teaching certificate. Two respondents answered negatively to both of the first two questions. Therefore, a total of 546 participants remained after the elimination of those without teaching certificates and those who had not worked with a child with ASD in the past five years.

**Data Analysis**

This study was exploratory in nature into the environmental design aspects of auditory features of the inclusive classroom for students with ASD. Simple statistical processes were used to analyze the data using descriptive statistics (e.g., frequency distributions) from the Statistical Package for the Social Sciences (SPSS). Data analysis was designed to address the research questions.
Results

Focus Group

The first key question referred to the main acoustic/auditory triggers in the classroom that cause sensory hypersensitivity and stereotypic behavior in children with ASD. The second question asked about aspects of the auditory learning environment contributing to positive behavior. The participants agreed that auditory triggers were the greatest source of environmental factors leading to stereotypic or self-stimulatory behavior.

The group agreed that fluorescent lighting was a concern. Some students said they could not hear the teacher because of the noise from the lights. Noise coming from air conditioning and streets also causes problems. Too many students (class size) were also mentioned as a source of problems. Some students complained about hearing other students breathing or swallowing. MP3 players were utilized by some of the teachers to provide the students with soft background music to filter out noise. Headphones were used by some participants. None of the participants had used an FM System in their classroom.

Some materials and finishes created problems. Tile floors, concrete walls and metal lockers intensified the noise according to the focus group participants. They also stated that carpet improved behavior for all students. Cafeterias and gymnasiums were mentioned by the participants as the areas causing the greatest problems.

The group cited unexpected noise such as the loud speaker in the classroom or fire drill alarms as creating great discomfort for students. One teacher used a wind chime as an attention getter instead of a bell. The focus group agreed that a low, calm, authoritative voice was necessary.

The participants stated that the optimal classroom would block outside noise while absorbing classroom noise. One participant stated that, at times, a student with ASD may yell out. The teachers feel pressured to try to get the student quiet as soon after an outburst as possible to avoid bothering students in other classrooms throughout the building. Table 1 outlines the focus group participants’ responses concerning auditory triggers and Table 2 outlines the aspects having a positive effect on behavior for students with ASD.

Table 1. Participants’ Responses Concerning Auditory Triggers

<table>
<thead>
<tr>
<th>Trigger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise from lighting, air conditioning, streets</td>
</tr>
<tr>
<td>Noise from other students</td>
</tr>
<tr>
<td>Noise from materials and finishes</td>
</tr>
<tr>
<td>Echoing in cafeterias and gymnasiums</td>
</tr>
<tr>
<td>Unexpected sounds (e.g. fire drill, loud speaker)</td>
</tr>
</tbody>
</table>

Table 2. Participants’ Responses Concerning Auditory Aspects Positively Influencing Behavior

<table>
<thead>
<tr>
<th>Positive aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP3 players</td>
</tr>
<tr>
<td>Headphones</td>
</tr>
<tr>
<td>Carpeted floors</td>
</tr>
<tr>
<td>Wind chime</td>
</tr>
<tr>
<td>Low, calm voice</td>
</tr>
</tbody>
</table>

The summary question asked what the participants thought was the most critical point discussed. The participants unanimously agreed that the built environment has a profound effect on the behavior of students with ASD. Auditory triggers cause more stereotypic or self-
stimulatory behavior in students with ASD. Interestingly, they stated that behavior improved for all students in the classroom when measures were taken to decrease auditory triggers for students with ASD.

**Questionnaire**

The questionnaire addressed (1) sensory triggers in the classroom causing sensory hypersensitivity and stereotypic behavior in children and (2) sensory aspects that positively influence behavior. Teachers were allowed to select as many answers as they deemed appropriate.

**School Information**

The participants represented the twenty educational regions in Texas. The participants’ schools spanned a range of ages from 0 – 60+ years. The greatest numbers reported that their schools were in the 21-40 year range (24.7%), 0-10 years range (24.2%), and 41-60 years range (20.6%). Libraries were present in 99.3% of the school buildings. Other areas available in the majority of the schools included parking area (98.7%), sports/gymnasium (93.9%) and dining area or cafeteria (92.5%).

An open-ended question was asked concerning most common auxiliary areas (other than classrooms) creating sensory problems. The dining room/cafeteria/kitchen was the most frequent response selected by 367 (72.2%) of the teachers. The second most common area was the gym, according to 308 (60.6%) of the teachers. Outdoor play areas were the third most common response with 123 (24.2%) of the teachers. Restrooms, hallways, and music rooms were also mentioned although they were not choices on the original list of school spaces.

The main sign of sensory processing problems observed by the teachers was putting hands over the ears (77.4%). Other common responses were stereotypic and self-stimulatory behavior such as hand-flapping, rocking and sniffing or licking objects.

Teachers were also asked about the main sound triggers in the classroom. Sudden unexpected sounds were selected by 70.8 % of the teachers as a sensory trigger that negatively impacted behavior. Higher pitch sounds such as sirens were considered a primary auditory trigger by 63.5% of the respondents. Background noise levels from group activity (51.1%) and background noise from adjacent rooms and corridors (38.6%) were selected as acoustic/auditory triggers as well. Table 3 outlines the responses over the main sound triggers in the classroom. Responses to the open-ended segment of the questions included bells, fire alarms, noise from crowds, noise from other students, music, ceiling fans, and toilets flushing.
Table 3. The Main Sound Triggers in Classrooms

<table>
<thead>
<tr>
<th>Sound Trigger</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudden unexpected sound (e.g., banging, cracking)</td>
<td>369</td>
<td>70.8</td>
</tr>
<tr>
<td>Higher pitch sound (e.g., drilling sound, siren)</td>
<td>331</td>
<td>63.5</td>
</tr>
<tr>
<td>Higher background noise levels from group activity (e.g., discussion, practical session, etc.)</td>
<td>266</td>
<td>51.1</td>
</tr>
<tr>
<td>Background noise from adjacent rooms, corridors</td>
<td>201</td>
<td>38.6</td>
</tr>
<tr>
<td>Unduly harsh and lengthy echoes caused by hard floors and ceilings, and large areas of windows without curtains</td>
<td>105</td>
<td>20.2</td>
</tr>
<tr>
<td>Noise from fluorescent light</td>
<td>90</td>
<td>17.3</td>
</tr>
<tr>
<td>Noise from heating and air conditioning</td>
<td>82</td>
<td>17.3</td>
</tr>
<tr>
<td>Low pitch sounds (e.g., main road traffic, air conditioning</td>
<td>64</td>
<td>12.3</td>
</tr>
<tr>
<td>Plumbing noise</td>
<td>51</td>
<td>9.8</td>
</tr>
</tbody>
</table>

An open-ended question concerning sources of sound that create a calming effect on the children resulted in 292 responses. The most common responses were music (classical, instrumental, soft, fun kid music, computer music, student’s individual preference, oldies, and lullabies), nature sounds, and a calm voice.

**Discussion of Findings**

This study was exploratory in nature with the purpose of assessing the impact of auditory stimuli on the behavior of students with ASD. The lack of information concerning students with ASD and the built environment was the driving force behind this study. The research questions were directed toward identifying (1) whether the design of the auditory environment affects the behavior of students with ASD, (2) auditory triggers in the learning environment for students with ASD, and (3) auditory design features of the built environment that decrease undesirable behavior. Although this study focused on students with ASD, respondents of both the focus and survey groups acknowledged that designing for the most sensitive students promotes learning for all students.

A focus group and a questionnaire were the instruments used to achieve this objective. Due to the lack of empirical evidence regarding the focus of this study, a pilot study (focus group) was used to investigate the various aspects and themes associated with the subject matter. These aspects and themes were then incorporated into the questionnaire in order to gain information about the views of a larger sample of special education teachers.

The results from both the focus group and survey group stated that auditory sensitivities were the prevalent sign of sensory processing dysfunction. Likewise, placing the hands over the ears was the most common response to sensory processing difficulties based on the survey responses (77.4%) indicating problems with noise. Even the soft sounds of children whispering may be distracting to children who are oversensitive to sound (Myles et. al., 2000).

Higher pitch sounds (e.g., drilling sound, siren) and sudden unexpected sounds (e.g., banging, cracking) were the main auditory triggers according to the survey participants for this study. The third most frequent response, “background noise levels from group activity (e.g.,
discussion, practical sessions, etc.),” was reported as a problem by more than half of the respondents. Background noise from adjacent rooms and corridors was selected by almost 39% of respondents.

Additionally, noise from flickering fluorescent lights was found to be a problem for 17.7% in this study. Noise levels of up to 50 db(A) have been recorded from fluorescent lighting (Manlove et al., 2001). Only 9.7% selected plumbing noise as a main acoustic/auditory trigger. However, the open-ended responses from the survey group revealed that some students with ASD display sensory processing problems due to toilets flushing. Proximity to toilets may provide further explanation.

According to the focus group and open-ended responses of the survey group, cafeterias, gymnasiums, and hallways were difficult areas for students with ASD. The flushing of toilets and noise from machinery (e.g. lawn mowers, vacuum cleaners) are problematic according to the responses to the open-ended questions by the survey group.

Various types of music were cited by the vast majority of respondents in the survey as a way to alleviate stereotypic or self-stimulatory behavior. Classical music, nature sounds, lullabies, and familiar children’s music were reported as having a beneficial effect on the students. Preparing students for unexpected noise by supplying earplugs or insulating loud speakers may also reduce unwanted behavior due to auditory sensitivities. Students should be prepared for alarms or fire drills according to responses to the open-ended portion of the survey.

Reducing noise should be a consideration during planning of educational spaces. Mechanical systems should be located away from classrooms. The addition of acoustic linings or barriers within walls and ceilings will help keep unwanted noise out of the learning spaces (Clark, 2003). Even modest noise levels (typical of North American neighborhoods) can affect the development of the cognitive systems of children (Lercher et al., 2003).

Hard surfaces should be avoided as much as possible to help control noise. Carpeting, wall panels, and acoustical ceilings may reduce noise and reverberation. Audio enhanced classrooms and noise cancellation technology can improve the auditory learning environment (McCarty & Rosen, 2005; Nelson & Nelson 1997).

This exploratory study presents a line of inquiry that is virtually untapped in the field of educational design. This study serves to identify the features of the built environment having an adverse effect on the behavior of students with ASD, but further investigation is needed. New information was gained; however the scope was limited to special education teachers in Texas. Studies that encompass a greater geographical area would provide greater insight to the design of education environments due to differences in educational spaces and classroom design by region. Another limitation of the study is that the data was collected from individuals working with ASD instead of from the students. Phase two of this study will involve the direct observation of individuals with ASD.

The sources of sensory triggers must be identified before they can be reduced or eliminated. The main benefactors of this study are students with autism spectrum disorders. Others assisted from the result of this study include designers, teachers, school administrators, parents, psychologists, caregivers, and building manufacturers. Building manufacturers may use this information to aid in understanding the need to develop finishes and materials to reduce noise and improve lighting and other visual aspects of the learning environment. Table 4 lists recommendations for the design of the auditory learning environment for students with ASD.
<table>
<thead>
<tr>
<th>Design Feature</th>
<th>Description/recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Music</td>
<td>Soft music, classical, instrument, familiar music, computer music, music therapy, children’s music, white noise</td>
</tr>
<tr>
<td>Nature sounds</td>
<td>Music or other sources with the sound of the ocean, rain, or birds Water feature such as a fountain</td>
</tr>
<tr>
<td>Spatial</td>
<td>Provide an attached quiet room or space Reduce large open areas</td>
</tr>
<tr>
<td>Technology</td>
<td>Headphones: Use with music or computer Headphones: Use to block out sounds Video screens and equipment Reduce volume level on sound systems</td>
</tr>
<tr>
<td>Building materials</td>
<td>Reduce hard surface finishes where possible Use wall and ceiling insulating materials to keep background noise out of the classroom and keep interior noise within the classroom</td>
</tr>
</tbody>
</table>
REFERENCES


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