Energy Trust New Buildings
Occupant Cx: Learning from Occupants to Improve Building Designs
August 6th, 2015
New Buildings Events

- **Allies for Efficiency Training Series (AFE)**
  - Trainings on high-performance design and construction
  - Takes place 3 times per year
  - Registration priority for New Buildings Trade and Design Allies

- **Building Energy Simulation Forum (BESF)**
  - Advance energy modeling presentations
  - Takes place every other month
Upcoming BESF

- August 19th – Energy and Comfort Modeling for the Net Zero Rocky Mountain Institute Headquarters
- October 21st – Energy Savings for Occupancy-Based Control (OBC) of Variable-Air-Volume (VAV) Systems
- December 16th – Revisiting the OHSU Data Dome

*BESF takes place at the Ecotrust Building at noon*
Training & Education

Commercial Training and Events

Continuing education opportunities for development and design professionals.

Energy Trust offers trainings and resources for trade allies and customers. The Allies for Efficiency, Building Energy Simulation Forum and other training series feature real-world examples and case studies presented by experts from the fields of architecture, engineering, construction and development, as well as specialists in a variety of building types and market sectors.

Attendees may also be eligible for continuing education units, CEUs. Please see event details to learn whether CEUs are offered.

Questions? Contact Us

About Allies for Efficiency

About Building Energy Simulation Forum

Presentations & Resources

Click here to access presentations and resources from past events.

Upcoming Events

Allies for Efficiency
Today’s Agenda

- 2:40pm to 3:40pm: Research Overview
- 3:40pm to 3:50pm: Break
- 3:50pm to 4:50pm: Lessons Learned
- 4:50pm to 5:00pm: Program Wrap-up
- 5:00pm to 6:00pm: Networking Reception
OCCUPANT COMMISSIONING (Cx): LEARNING FROM OCCUPANTS TO IMPROVE BUILDING DESIGNS

JULIA K. DAY, PHD, IDEC, LEED AP, NCIDQ
KANSAS STATE UNIVERSITY
AUGUST 6, 2015

JULIAKDAY@KSU.EDU
ABOUT ME

my life’s work summed up in logos...

BA interior design
minor, construction management
IDL | inland northwest

retail design

CALLISON

MA interior design
teaching
IDL | inland northwest

research
IDL | boise

PHD: architecture, design, education
teaching

KANSAS STATE UNIVERSITY
Energy, Behavior, and the Built Environment Laboratory

Ozzy and Zeppelin
1. **Understand key research** that demonstrates how **occupants play an integral role in building energy use outcomes**

2. **Identify factors** of building occupation that may negatively impact overall building energy use reduction goals

3. Understand the importance of an **integrated design process, post occupancy evaluation, and feedback loops**

4. **Identify and learn techniques for effectively educating occupants** about high performance building strategies to maximize both comfort and energy efficiency
In 2010, commercial & residential buildings comprised nearly 42% of the total energy use in the U.S. ...


**Commercial Energy Use Breakdown**

- Lighting: 26%
- Heating: 14%
- Cooling: 13%
- Water Heat: 7%
- Ventilation: 6%
- Office Equipment: 6%
- Refrigeration: 4%
- Computers: 3%
- Cooking: 2%
- Other: 13%
In 2010, commercial & residential buildings comprised nearly 42% of the total energy use in the U.S. ...


<table>
<thead>
<tr>
<th>Commercial Energy Use</th>
<th>Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting 26%</td>
<td>Opportunities for occupant interaction</td>
</tr>
<tr>
<td>Heating 14%</td>
<td></td>
</tr>
<tr>
<td>Cooling 13%</td>
<td></td>
</tr>
<tr>
<td>Water heat 7%</td>
<td></td>
</tr>
<tr>
<td>Ventilation 6%</td>
<td></td>
</tr>
<tr>
<td>Office equipment 6%</td>
<td></td>
</tr>
<tr>
<td>Refrigeration 4%</td>
<td></td>
</tr>
<tr>
<td>Computers 3%</td>
<td></td>
</tr>
<tr>
<td>Cooking 2%</td>
<td></td>
</tr>
<tr>
<td>Other 13%</td>
<td></td>
</tr>
</tbody>
</table>
The 2030 Challenge

Source: ©2015 2030, Inc. / Architecture 2030. All Rights Reserved.
*Using no fossil fuel GHG-emitting energy to operate.
THE PATH TO NET ZERO ENERGY USE

Adapted from an info-graphic by the Miller Hull Partnership of the Bullitt Center, a Net Zero Energy office building in Seattle, WA.
THE INTEGRATED ENERGY DESIGN

Adaption of Integrated Energy Design diagram
A high-performance building is energy efficient, durable, intentionally optimizes all installed systems, and promotes health and productivity for its occupants.
THE PROBLEM...

CONVENTIONAL OFFICE BUILDING

HIGH PERFORMANCE OFFICE BUILDING
OCCUPANT COMMISSIONING \((C_x)\)
It is necessary to educate occupants on the differences between using a green building versus a conventional building in order to secure the green building’s success. (p. 175)

–STEINBERG, PATCHAN, SCHUNN, & LANDIS (2009)
“interdisciplinary studies is a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline and draws on disciplinary perspectives and integrates their insights to produce a more comprehensive understanding or cognitive advancement.” (Repko, 2008, p. 12)
Many studies link passive design strategies and energy use and/or environmental satisfaction. However, there is a lack of research that successfully links passive design strategies with an occupant's knowledge of building systems, resulting behaviors and the corresponding relationship to environmental satisfaction and a building's energy use.

– DAY & GUNDERSON (2014) P.117
### Method & Sample

<table>
<thead>
<tr>
<th>Phase</th>
<th>Procedure</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qual (I)</td>
<td>Qual data collection, analysis and results</td>
<td>Interviews with experts in the field ($n=3$); coded and compiled database of high performance buildings ($N=8045$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quan (II)</td>
<td>QUAN data collection</td>
<td>Numeric data and open ended responses from survey ($n=118$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>QUAN analysis</td>
<td>Frequencies, descriptive stats, inferential stats including t-tests, chi-square, Pearson r, one and two-way ANOVA results</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>QUAN results</td>
<td>Matrix of results/completed QUAN data analysis; QUAN results for each research question</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>identify results to be further explained &amp; select cases for next phase</td>
<td>Sample identified for QUAL phase; compiled list of potential interview questions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qual (III)</td>
<td>Qual data collection</td>
<td>Text data (transcribed interviews ($n=41$), documents, emails); image data (photographs, building plans + drawings for selected buildings)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>QUAN data analysis and results</td>
<td>Codes and emergent themes; similar and different themes; use results to answer each research question</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>interpretation of QUAN and QUAL results</td>
<td>Compared results, answer research questions &amp; hypothesis, recommendations for further research</td>
</tr>
</tbody>
</table>

**Mixing**

**Methods & Samples**

**Phase:**
- Qual (I)
- Quan (II)
- Qual (III)

**Procedure:**
- Qual data collection, analysis and results
- QUAN data collection
- QUAN analysis
- QUAN results
- Qual data collection
- Qual data analysis and results

**Product:**
- Interviews with experts in the field ($n=3$); coded and compiled database of high performance buildings ($N=8045$)
- Numeric data and open ended responses from survey ($n=118$)
- Frequencies, descriptive stats, inferential stats including t-tests, chi-square, Pearson r, one and two-way ANOVA results
- Matrix of results/completed QUAN data analysis; QUAN results for each research question
- Sample identified for QUAL phase; compiled list of potential interview questions
- Text data (transcribed interviews ($n=41$), documents, emails); image data (photographs, building plans + drawings for selected buildings)
- Codes and emergent themes; similar and different themes; use results to answer each research question
- Compared results, answer research questions & hypothesis, recommendations for further research
METHOD & SAMPLE

qual phase 1

$n = 3$

experts in the field
METHOD & SAMPLE

qual phase I continued

N=8045 “high-performance” building database
METHOD & SAMPLE

QUAN+QUAL data collection

data collected from 56 buildings
METHOD & SAMPLE

QUAN | survey responses

n = 154 (n = 118 after data cleaning)

survey responses from 13 buildings
IN TOTAL, THERE WERE 51 QUESTIONS & FIVE PRIMARY CATEGORIES:

(1) OFFICE ATTRIBUTES,
(2) THE PRESENCE AND TYPE OF TRAINING FOR
   (A) MANUAL BLINDS,
   (B) AUTOMATIC BLINDS,
   (C) NATURAL VENTILATION,
   (D) TEMPERATURE CONTROLS, AND
   (E) ELECTRIC LIGHTING,
(3) SATISFACTION WITH THE OFFICE ENVIRONMENT,
(4) LEARNING STYLES, AND
(5) DEMOGRAPHICS.

BOTH OPEN-ENDED AND CLOSED-ENDED QUESTIONS WERE INCLUDED ON THE SURVEY.

SATISFACTION RESPONSES WERE ASSESSED THROUGH A SEVEN POINT LIKERT SCALE, WHICH RANGED FROM “STRONGLY DISAGREE” (1) TO “STRONGLY AGREE” (7).

A FIVE-POINT SCALE, FROM “NEVER” (0) TO “ALWAYS” (4), WAS USED FOR FREQUENCY RATINGS UNDER THE LEARNING STYLE SECTION. MULTIPLE CHOICE AND YES/NO RESPONSES WERE USED THROUGHOUT THE SURVEY.


QUAL phase II | interviews

n=41 interview responses
HYPOTHESIS

H1: OCCUPANTS WHO RECEIVED TRAINING FOR HIGH PERFORMANCE BUILDING STRATEGIES (SUCH AS BLINDS, NATURAL VENTILATION, THERMAL CONTROLS, OR ELECTRIC LIGHTING), WILL DEMONSTRATE AN INCREASED LEVEL OF REPORTED ENVIRONMENTAL SATISFACTION WHEN COMPARED TO INDIVIDUALS WHO DID NOT RECEIVE ANY KIND OF TRAINING.
**RESEARCH QUESTIONS: TRAINING & LEARNING**

RQ1 Did building occupants receive any training or education surrounding high performance building systems?

RQ2 Do occupants understand how to effectively control, change or override the building controls?

RQ3 What are the types of delivery methods for occupant training, and which were most effective?

RQ4 Were trainings delivered one time, continuously, or intermittently?

RQ5 How do individuals best learn a new concept?

RQ6 Is there a difference between an occupant’s reported learning style and the assessment of the effectiveness of the training they received?

RQ7 Is there a difference between the building size and effectiveness of training?
RESEARCH QUESTIONS: ENVIRONMENTAL SATISFACTION

RQ8 In general, what were the most common high performance building complaints and appraisals?

RQ9 Is there a difference between the climate type and thermal satisfaction or visual satisfaction?

RQ10 Are individuals who reported health issues more or less satisfied with their office environment?

RQ11 How did satisfaction appraisals differ among groups?
RESEARCH QUESTIONS: BEHAVIOR

RQ12 Why do occupants interact with the blinds, electric lighting or thermal controls?

RQ13 For what reasons do occupants choose not to interact with high performance building features?

RQ14 How often do occupants interact with, change or override the blinds?
HYPOTHESIS

H1: OCCUPANTS WHO RECEIVED TRAINING FOR HIGH PERFORMANCE BUILDING STRATEGIES (SUCH AS BLINDS, NATURAL VENTILATION, THERMAL CONTROLS, OR ELECTRIC LIGHTING), WILL DEMONSTRATE AN INCREASED LEVEL OF REPORTED ENVIRONMENTAL SATISFACTION WHEN COMPARED TO INDIVIDUALS WHO DID NOT RECEIVE ANY KIND OF TRAINING.
**HYPOTHESIS**

Effectiveness of training and environmental satisfaction were tested using both a Pearson chi-square test and an independent t-test. A significant difference (p < .05) was found between groups for both tests. Therefore, the null hypothesis was rejected. **Occupants who received training for high performance building strategies** (such as blinds, natural ventilation, thermal controls, or electric lighting) **demonstrated an increased level of reported environmental satisfaction** when compared to individuals who did not receive any kind of training.

“I didn’t actually receive any training because I am a part time employee... I guess... but I do think that understanding the big concepts of the building envelope, windows and daylight, how the toilet and the water system works ... understanding all of those things might make people more actively participate and also figure out ways to change the building to suit their needs.”
RESULTS

ENVIRONMENTAL SATISFACTION DESCRIPTIVE STATISTICS

Table 2

<table>
<thead>
<tr>
<th>Training</th>
<th>Total</th>
<th>No training reported, or reported that training was not helpful</th>
<th>Training was helpful</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>27</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Expected Count</td>
<td>22.1</td>
<td>7.9</td>
</tr>
<tr>
<td></td>
<td>% within 'effective training'</td>
<td>31.0%</td>
<td>9.7%</td>
</tr>
<tr>
<td>Mostly satisfied</td>
<td>Count</td>
<td>60</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Expected Count</td>
<td>64.9</td>
<td>23.1</td>
</tr>
<tr>
<td></td>
<td>% within 'effective training'</td>
<td>69.0%</td>
<td>90.3%</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
<td>87</td>
<td>31</td>
</tr>
<tr>
<td>Expected count</td>
<td>87.0</td>
<td>31.0</td>
<td>118.0</td>
</tr>
<tr>
<td>% within 'effective training'</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Chi-square tests
- Value df Asymp. Sig. (2-sided)
  - Pearson chi-square 5.498a 1 .019
  - N of valid cases 118

Symmetric measures
- Value Approx. Sig.
  - Nominal by Nominal Phi .216 .019
  - N of Valid Cases 118

a 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.88.

Fig. 2. Mean values for environmental satisfaction section, in response to: “please rank the following for your office”.

### Table 3
Independent t-test: environmental satisfaction* effectiveness of training.

<table>
<thead>
<tr>
<th>Training</th>
<th>N</th>
<th>Mean</th>
<th>Std. deviation</th>
<th>Std. error mean</th>
<th>d (Cohen's d)</th>
<th>r (effect size)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Satisfaction (all)</td>
<td>87</td>
<td>4.56</td>
<td>1.059</td>
<td>.114</td>
<td>0.87</td>
<td>−0.39</td>
</tr>
<tr>
<td>no training reported, or reported training was not helpful</td>
<td>31</td>
<td>5.38</td>
<td>1.133</td>
<td>.146</td>
<td>−0.72</td>
<td>−0.34</td>
</tr>
<tr>
<td>Environmental Satisfaction (thermal)</td>
<td>87</td>
<td>4.97</td>
<td>1.316</td>
<td>.236</td>
<td>−0.57</td>
<td>−0.27</td>
</tr>
<tr>
<td>no training reported, or reported training was not helpful</td>
<td>31</td>
<td>6.06</td>
<td>.921</td>
<td>.165</td>
<td>−0.77</td>
<td>−0.36</td>
</tr>
<tr>
<td>Environmental Satisfaction (general)</td>
<td>87</td>
<td>5.21</td>
<td>1.459</td>
<td>.156</td>
<td>−0.36</td>
<td></td>
</tr>
<tr>
<td>no training reported, or reported training was not helpful</td>
<td>31</td>
<td>6.15</td>
<td>.939</td>
<td>.169</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Independent samples test**

<table>
<thead>
<tr>
<th>Levene's test for equality of variances</th>
<th>F</th>
<th>Sig.</th>
<th>t</th>
<th>df</th>
<th>t-test for equality of means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal variances assumed</td>
<td>4.750</td>
<td>.031</td>
<td>−3.940</td>
<td>116</td>
<td>Sig. (2-tailed)</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>6.135</td>
<td>.015</td>
<td>−2.452</td>
<td>116</td>
<td>Mean difference</td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>10.714</td>
<td>.001</td>
<td>−3.325</td>
<td>116</td>
<td>Std. error difference</td>
</tr>
</tbody>
</table>

Note: *significant difference found.

The table above shows that respondents who received training were significantly more likely to be satisfied with their environment than those who did not receive training (or helpful training) for all environmental satisfaction categories tested (environmental satisfaction as a whole (p < .001), thermal satisfaction (p < .002), visual satisfaction (p < .001), and the remaining satisfaction questions (p < .016).
RESULTS

SURVEYED OCCUPANTS

effective training

MORE SATISFIED

increased productivity $$$
fewer sick days
increased health
thermal/visual comfort

ineffective or no training

LESS SATISFIED

lower productivity
absenteeism
headaches, migraines, etc.
physical discomfort…
RESEARCH QUESTION

WHAT ARE THE DIFFERENT TYPES OF DELIVERY METHODS FOR OCCUPANT TRAINING OF HIGH PERFORMANCE BUILDING FEATURES, AND WHICH METHODS ARE MOST EFFECTIVE?
RESULTS

DID YOU RECEIVE TRAINING FOR ANY OF THE FOLLOWING BUILDING FEATURES?
RESULTS

**What kind of training did you receive (n=118)?**

<table>
<thead>
<tr>
<th>Training Method</th>
<th>Verbally</th>
<th>Meeting</th>
<th>Memo</th>
<th>PP</th>
<th>Formal Training</th>
<th>Informal Training</th>
<th>Email</th>
<th>Workshop</th>
<th>Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic blinds</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Manual blinds</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Natural ventilation</td>
<td>20</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>7</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Thermal controls</td>
<td>15</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Electric lights</td>
<td>25</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

There were 49 participants who reported having some kind of training on one or more of the five building features included on the survey (n=118). Of those, 31 participants rated the training they had received as (4) helpful, or (5) very helpful (63%). The remaining 18 participants (37%) did not think the training they received was helpful or effective in teaching them about the particular building strategy for which they had received training.
RESULTS

"HOW I USE MY PHYSICAL SENSES…”

HOW DID INDIVIDUALS BEST LEARN A NEW CONCEPT?
“…… maybe a combo of an interactive kind of session with some kind of online training that actually teaches you about the systems and their functions and the rationale behind it.”

“……“I do think sometimes it’s easier to have it both verbally and then also written, especially when you can refer back to it as things change.”
RESULTS

IS THERE A DIFFERENCE BETWEEN THE BUILDING SIZE AND EFFECTIVENESS OF TRAINING?

QUAN

Quantitative results (Pearson chi-square statistic) showed that the reported effectiveness of training was significantly different between the two categories of building size [<25k SF and >25k SF] \( (x^2 = 17.504, df = 1, N =118, p \leq .000) \).

OCCUPANTS IN SMALLER BUILDINGS (51.4%) WERE MORE LIKELY TO REPORT EFFECTIVE TRAINING THAN THOSE IN LARGER BUILDINGS (14.8%).

QUAL

All of the interviewed individuals who were interviewed from smaller buildings had received some type of training, although, the level of effectiveness cannot necessarily be interpreted from the responses. However, none of the individuals interviewed in buildings over 25,000 SF reported any training. Two individuals, who were interviewed from a larger building, knew about systems only because they had helped design the building.
SO... ARE THERE WAYS TO USE DESIGN AS A TOOL TO EDUCATE OCCUPANTS ABOUT THEIR BUILDINGS?
The learning process is reflective, enhanced through re-representation, and builds upon existing knowledge and experience.

Mezirow (2000) defines learning as “the process of using a prior interpretation to construe a new or a revised interpretation of the meaning of one’s experience in order to guide future action” (p. 5).

The learning process is similar to the design process as it is enhanced through “re-representation” (Schön, 1983).

In design, re-representational structures, such as sketching, are integral to the design process. Learning can also be enhanced in a similar manner.
LITERATURE REVIEW
THE DESIGN PROCESS & THE LEARNING PROCESS

http://www.designsojourn.com/category/design-process/
**LITERATURE REVIEW**

**MODELS AND THEORIES OF ADULT LEARNING**

<table>
<thead>
<tr>
<th>Models and Theories of Adult Learning</th>
<th>Identify why training/learning is needed (how will it benefit them)</th>
<th>Focus on real world issues that involve solving an actual problem</th>
<th>Allow the learner to challenge ideas and make decisions</th>
<th>Training should relate and build upon past experiences</th>
<th>Respect individual differences, cultural backgrounds, etc</th>
<th>Learning should be action oriented so that adults can be actively engaged</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Theory and Creator</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Andragogy (Knowles, 1980)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Thiagi’s laws of learning (Zemke, 2002)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Three dimensions of learning model (Illeris, 2002)</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-directed learning (Knowles, 1975)</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adult basic education principles (Imel, 1998)</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Model of the learning process (Jarvis, 2006)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Note: Table modified and adapted from Bryan, Kreuter and Brownson, 2009, p.558*
To truly maximize energy savings, occupants should understand specific strategies and corresponding behaviours as they relate to the building they inhabit (Cole & Brown, 2009; Janda, 2011).

Delivering a singular training session does not ensure that occupants will actually learn. However, targeted training sessions can be paired with experiences and interactions within the designed environment to elevate the learning process.

Learning can take place in multiple ways within the built environment (Orr, 1993).

Learning can be enhanced through interactive behaviours and experiences as “...knowledge is continuously derived from and tested out in the experiences of the learner” (Kolb, 1984, p. 27).

“...education about building performance needs to go beyond energy meters and monitors. If the goal [is] to prepare people to accept more responsibility for their role in the built environment, education should be much more comprehensive, integrated, hands-on, and iterative. (Janda, 2011, p. 19)"
There are a few exemplar buildings that have successfully integrated both function (energy efficiency and building systems) and form (building design and aesthetics) in a way that peaks occupants’ interests surrounding the natural elements and high-performance strategies within the building.
CASE STUDIES
GENZYME CENTER: CAMBRIDGE, MA.

The unique aesthetics and designed elements in the space motivate occupants to learn about energy-saving features in the building. For instance, there are large mirrors on the roof (heliostats) that move around throughout the day to reflect the sun onto fixed mirrors and then into the atrium.
The water feature is six stories high and serves to humidify and dehumidify incoming air before it is distributed to other interior spaces. “During warmer, moist weather, water running down the water feature is cooled...[and] moisture in the air is absorbed into the water feature.... In the winter, the process is reversed” (KPMB Architects, 2009).
CASE STUDIES
MANITOBA HYDRO
PLACE: WINNIPEG, MANITOBA.

Atrium water feature

Water vapor  Summer time  Winter time
Water flows down ribbons
Chilled water dehumidifies air
Warm water humidifies air

http://manitobahydroplace.com_Integrated-Elements/Water-Features/
Although the examples above illustrate the use of design elements as learning moments, they are somewhat lacking in terms of active engagement. There are several buildings that have truly aimed to integrate the building design as an educational tool.
CASE STUDIES
MANASSAS PARK
ELEMENTARY SCHOOL: MANASSAS PARK, VA

...green lights signal it’s time to open the windows. A gage on a cistern shows the rain water level. A bioretention area doubles as an outdoor classroom. Even the pipes of the HVAC system are painted red and blue to mimic illustrations of veins and arteries in human bodies. (Knox & Davis, 2010, p.37)

STUDENTS AS ACTIVE PARTICIPANTS IN CONSERVATION

Natural ventilation in the classrooms is encouraged by a ‘green light’ system. When the green light comes on, students know that windows may be opened in order to substitute natural ventilation for mechanical conditioning. Compressors in the heat pumps turn off, and natural convection currents circulate fresh air through the room. When the light turns off, students are quick to remind the teacher that any open windows need to be shut tightly once again.

http://www.vmdo.com/docs/Manassas_Park_case_study_1.pdf
PRINCIPLES OF ADULT LEARNING | APPLIED

case study: NREL RSF
PRINCIPLES OF ADULT LEARNING | APPLIED

case study : NREL RSF

PRINCIPLE 1: IDENTIFY WHY TRAINING/LEARNING IS NEEDED.

PRINCIPLE 2: FOCUS ON REAL WORLD ISSUES.

PRINCIPLE 3: ALLOW THE LEARNER TO MAKE DECISIONS.

PRINCIPLE 4: RELATE TRAINING TO EXPERIENCE.

PRINCIPLE 5: RESPECT INDIVIDUAL DIFFERENCES.

PRINCIPLE 6: LEARNING SHOULD BE ACTION ORIENTED.

• Occupants were informed about the aggressive energy goals prior to moving in to the building.

• Goals and strategies were communicated to occupants in a variety of ways through employee newsletters, posts on the internal RSF web page, a brown bag lunch series, workstation prototype tours, an open house, YouTube videos, E-training, and blog polls.

• As an energy research laboratory, NREL considered training for energy efficiency very important for sustainability at a global and organizational level — energy budgets were enforced.

• Occupants were well informed about the energy objectives of the company, and leaders at NREL and the Department of Energy (DOE) enforced these objectives.

(Carlisle et al., 2011; Press et al., 2011).
• Each employee has access to an interactive computer program that allows him or her to report general concerns surrounding their environment (i.e. too cold, too hot, too bright, etc.).

• This provides valuable data to the building operators regarding occupant comfort so building systems can be altered if necessary, and it also allows employees to play an active role in thermal and visual comfort decisions.
Before occupying the new building, employees were informed of behavioral and operational changes that were to take place in the new building.

In some instances, it was explicitly stated that behaviors would have to change to accommodate the aggressive energy goals in the new facility — employees were taught how and why some of their past experiences and interactions in other buildings were no longer applicable to the new building.
One way NREL was able to respect and respond to individual differences was through the implementation of “ask.rsf@nrel.gov.”

Employees were able to express concerns before and after move-in to the facility. Many employees were worried about issues surrounding privacy, noise, lights and health issues. The website allowed employees to ask a question and receive immediate feedback.

(Carlisle et al., 2011; Press et al., 2011).
Design elements, such as red and green lights, daylighting systems, and operable windows, work in tandem with building technologies to create a feedback loop and signal system to occupants. When the outside air temperature is conducive to energy savings, a green light signals to occupants that they may open the windows for natural ventilation.

Technology has been integrated within the design to encourage interaction, support occupant feedback, and to further occupants’ understanding of the building systems.

(Carlisle et al., 2011; Press et al., 2011).
ACHIEVING NET-ZERO THROUGH INTEGRATED LEARNING & DESIGN
BREAK
PART B: LESSONS LEARNED (AND DESIGN MISSTEPS) FOR THE A&E COMMUNITY

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AUGUST 6, 2015

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RESEARCH QUESTION

FOR WHAT REASONS DO OCCUPANTS CHOOSE NOT TO INTERACT WITH HIGH PERFORMANCE BUILDING FEATURES?
FOR WHAT REASONS DO OCCUPANTS CHOOSE NOT TO INTERACT WITH HIGH PERFORMANCE BUILDING FEATURES?

• **Social / cultural concerns** (occupants did not want to affect others) and/or the culture in the office was not conducive to changing thermal or visual conditions.

"...normally in my own house I would certainly go ahead and do it [change the blinds]. But here, I’ll change my own position so it doesn’t affect 20 other people usually ….If the sun is only in my eyes, you know, no big deal."
RESULTS

FOR WHAT REASONS DO OCCUPANTS CHOOSE NOT TO INTERACT WITH HIGH PERFORMANCE BUILDING FEATURES?

- “Not my dime” / thermal comfort (in reference to why they do not care about saving energy)

“... it feels like if you had some individual control [of the thermostat] you actually would end up with energy saved, because I’ve had my window open wasting heat a number of times ... I had a father who taught me not to waste energy in the seventies, but the number of times that I have wasted energy here... it’s because it’s not my dime, right? I do what I want because I’m uncomfortable.”
FOR WHAT REASONS DO OCCUPANTS CHOOSE NOT TO INTERACT WITH HIGH PERFORMANCE BUILDING FEATURES?

- Occupants did not understand how to effectively control the building features.

“I have a problem remembering which way to tilt the blinds so they maximize daylight and reduce glare and heat gain so having a reference for blind positions at the controls or access to a building operation manual would be useful.”

http://www.getreligion.org/getreligion/2012/02/someones-confused-about-santorum
RESULTS

FOR WHAT REASONS DO OCCUPANTS CHOOSE NOT TO INTERACT WITH HIGH PERFORMANCE BUILDING FEATURES?

• Lack of control or perceived control (or asked not to touch it by someone)

**Example of weather station and automated light system (lack of control) — need for an integrated design process.**
RESULTS

FOR WHAT REASONS DO OCCUPANTS CHOOSE NOT TO INTERACT WITH HIGH PERFORMANCE BUILDING FEATURES?

They had disabled the control or building feature...
SO, WHY CAN’T WE JUST MAKE BUILDINGS COMPLETELY AUTOMATED SO THAT PEOPLE DON’T HAVE TO CONTROL ANYTHING?
PEOPLE WANT CONTROL!

“...the windows are annoying because it's all automated... so you can’t control it.”
SO WHAT CAN DESIGNERS AND OWNERS DO TO HELP REDUCE OVERALL BUILDING ENERGY USE & TO ENSURE THE BUILDING — AND THE OCCUPANTS — ARE REALLY PERFORMING AT THE DESIRED LEVEL???
1. THROUGH AN INTEGRATED DESIGN APPROACH

2. REMOVE BARRIERS

3. EDUCATE OCCUPANTS

4. IMPLEMENT EFFECTIVE BEHAVIORAL CHANGE APPROACHES...
INTEGRATED DESIGN PROCESS + FEEDBACK LOOP

Integrated Design Process and Feedback Loop: pre- and post-design identified as critical areas for intervention

(Theodorson, 2014)
<table>
<thead>
<tr>
<th>DESIGN PHASE</th>
<th>DESIGN ACTIVITY</th>
<th>Interiors + Human Centered ENERGY DETERMINANTS</th>
<th>Interiors + Human Centered DAYLIGHTING DETERMINANTS</th>
</tr>
</thead>
</table>
| PRE-DESIGN   | Eco-design charrette | • initiate team building, inclusive of occupant  
• establish importance of occupant in energy profile  
• influence leadership toward eco-design perspectives  
• discussion of automation vs. autonomy  
• set measurable energy goals, considering human-behavioral inputs | • present research on human benefits related to daylighting and resulting economic benefit  
• consider socio-cultural influences relative to the provision of daylight and views  
• rank daylight and views in preferred building attributes  
• establish ‘daylight priority’  
• set daylighting performance goals relative to user inputs |
|               | Programming      | • align occupancy patterns with energy requirements  
• align spatial organization with climate resources  
• review comfort criteria in consideration of personal adaptation  
• passive buildings = active occupant | • align building schedules with daylight resource  
• prioritize daylight resource for areas of critical visual tasks and prolonged human occupation  
• set luminous environment requirements  
• consider concept of autonomy vs automation relative to daylight harvesting |
|              | Form and siting  | • align human functions with climate and microclimate resources | • consider qualities of daylight source relative to building / spatial orientation  
• provide “bright spaces” for circadian entrainment  
• maximize view |
| DESIGN       | Space planning, fittings and finishes | • consideration of systemic inhabitant-architecture interactions relative to energy conservation strategies. | • shape interior space to modify and distribute natural light source, ie: interior light shelves, ceiling surfaces  
• select surface finishes to benefit daylight distribution  
• interior arrangements (furniture, computers, projection surfaces, etc) consistent with daylight controls and qualities  
• consider color of daylight relative to material color selections |
|              | Interior Systems | • consider human-technology interfaces  
• provide multiple adaptive controls for thermal and luminous comfort provisioning | • review programming requirements and human interface in developing daylight controls |
| OCCUPANCY    | Commissioning    | • consider human-technology interfaces  
• provide multiple adaptive controls for thermal and luminous comfort provisioning  
• fine-tune behaviors | • occupant education  
• commission daylight harvesting systems (electric lighting) and daylight controls (blinds) |
|              | Post occupancy evaluations | • verify performance with occupancy  
• increase understanding of inhabitant-architecture interactions | • collect data on user preferences, behaviors, controls  
• develop human-factors daylighting argument |

Interiors and Human-Centered Energy Determinants throughout design process
(Theodorson, 2014)
EDUCATE OCCUPANTS

Based on the literature review, the results from this study, and a few case examples, a successful occupant education program should:

(1) incorporate multiple types of delivery methods to support differing learning styles,
(2) provide opportunities for experiential learning through an interactive approach within the building context,
(3) encourage learning through techniques that facilitate motivation, reinforcement, retention, and transference of knowledge such as feedback, goal setting and competition, and
(4) explain the rationale behind the need for training and how it will benefit the occupants. Occupants need to understand the building owners have aggressive energy reduction goals and their actions directly affect the energy use of the building and their personal comfort.
Social Influences. Social influence is when a person's actions are prompted by the actions of another person in a social group. In the case of energy, a user may use less energy because they see their peer is using less energy (Jain et al., 2013). Therefore, it is likely behaviors in high performance buildings may also be influenced by social cues or norms within a given building. People's behaviors often echo what they perceive as the norm (Goodwin, 2013). Thus, it is important for companies to create an environment in which employees are encouraged to interact with the building with the goal of energy saving. The next section briefly mentions strategies used for encouraging and motivating energy efficient behaviors.

Encouraging Behavioral Change for Energy Efficiency. There are a few ways in which energy efficient behaviors can be encouraged including removing barriers, providing feedback and/or incentives, goal setting, and competitions ("Behavior-based energy efficiency programs discussed at the NW Efficiency Exchange," 2013). The following table was compiled by Goodwin (2013) and posted to conduitnw.org (an energy efficiency community for the Northwest) as part of a document geared toward recommendations for behavioral change in the residential energy sector.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Why It Works</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normative influence</td>
<td>It is a consistent finding that people tend to align their behavior with the perceived norm.</td>
</tr>
<tr>
<td>Goal-setting/Pledges</td>
<td>Commitment is a powerful motivator -- especially when it's public.</td>
</tr>
<tr>
<td>Consistency Cues</td>
<td>Relates to goal-setting above; people tend to have a drive to be consistent with their internalized value system, stated commitments, or past behavior. Prompts that remind people of their commitments, or point out ways in which they could better align with them, can drive behavior change.</td>
</tr>
<tr>
<td>Competition</td>
<td>Competition can increase performance on familiar tasks, especially when a person is competing with those who are relevant or of similar ability. In the case of energy efficiency, competing with friends, similar households, and coworkers is likely to be more effective at inducing behavior change than competing with leaders in sustainability.</td>
</tr>
<tr>
<td>Remove Barriers</td>
<td>Behavior change often comes down to identifying and removing barriers to more desirable ways of acting. In the case of energy efficiency, providing individualized tips on how to save energy or shift load may help drive energy savings.</td>
</tr>
<tr>
<td>Provide Direct Feedback</td>
<td>Often, people persist in less desirable behaviors merely because they aren't aware of how much they do them, how impactful they are, or how easy it would be to change. Giving people access to their real-time energy use information can make wasteful behaviors more salient. In the case of energy efficiency, providing individualized, hour-by-hour reports through live feedback (computers, energy kiosk, etc.) can make people aware of opportunities throughout the day where they can save energy without sacrificing comfort.</td>
</tr>
<tr>
<td>Provide Indirect Feedback</td>
<td>Providing indirect feedback (via billing statements) can help people save energy by inducing them to &quot;compete&quot; with their own past performance and set goals.</td>
</tr>
</tbody>
</table>

KILOWATT CRACKDOWN

Kilowatt Crackdown is the energy-saving competition that helps every building win.

Portland Metro

Boise Metro

HTTP://WWW.KILOWATT-CRACKDOWN.COM/
GOAL SETTING

Dashboard

- Charge HR
  - Connected

- 25,088 steps
  - Target: 10,000

- 53 bpm resting

- 20.3 km
  - Target: 8.05

- 3,893 calories burned
  - Target: 2,779

- 57 floors
  - Target: 10

- 121 very active minutes
  - Target: 30

- 3,057 calories
  - Date: February 15, 2015
PROVIDE FEEDBACK (TO OCCUPANTS)
PROVIDE FEEDBACK (TO DESIGNERS) | POE

**Air Quality**
- VOC = Volatile Organic Compound
- PM10 = Particulate Matter
- Mould = Microbial organisms
- CO2 = Carbon dioxide

**Light**
- Control = Light controllability
- Daylight = Access to daylight
- VI = Vertical Illumination
- HI = Horizontal Illumination

**Thermal Comfort**
- RH = Relative Humidity
- Ta = Ambient Temperature
- Var = Air Velocity
- Tr = Radiant Temperature

**Acoustics**
- Reverb = Reverberation times
- SNR = Signal to Noise Ratio
- Mech = Mechanical noise
- Background = Background noise

retrieved from msd.unimelb.edu.au
PROVIDE FEEDBACK (TO OWNERS)
### Tools for Designers...Coming Soon

#### DOE Tool Selection

<table>
<thead>
<tr>
<th>Energy Asset Score</th>
<th>Input Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>components</td>
<td>rip code, state</td>
</tr>
<tr>
<td></td>
<td>address, city</td>
</tr>
<tr>
<td></td>
<td>year, comp, floor, area, notes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOE Buildings Performance Database</th>
</tr>
</thead>
<tbody>
<tr>
<td>components</td>
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<td></td>
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</tbody>
</table>

#### Building Context

- **Building Information**
- **Building Classification**
  - Shading by Building’s Surrounding

#### Internal Loads

- **Occupancy**
  - Number of Occupants
    - Metabolic Rate
    - Occupant Clothing
    - Radiant Fraction

Red tiles indicate mandatory inputs required for the simulation.

Blue tiles indicate available but not mandatory inputs.
TOOLS FOR DESIGNERS

DAYLIGHT PATTERN GUIDE

HTTP://PATTERNGUIDE.ADVANCEDBUILDINGS.NET/
EXISTING PROGRAMS / INITIATIVES - OWNERS

PORTFOLIO MANAGER

HTTPS://PORTFOLIOMANAGER.ENERGYSTAR.GOV/
EXISTING PROGRAMS / INITIATIVES - OWNERS

BUILDING METRIC LABELING

HTTP://WWW.IDLBOISE.COM/BML
SO, TO RECAP ..

HOW CAN WE ENCOURAGE ENERGY EFFICIENT OCCUPANT BEHAVIORS IN HIGH-PERFORMANCE BUILDINGS?
1. THROUGH AN INTEGRATED DESIGN APPROACH

2. REMOVE BARRIERS

3. EDUCATE OCCUPANTS

4. IMPLEMENT EFFECTIVE BEHAVIORAL CHANGE APPROACHES...
CONCLUSIONS

Ultimately, better occupant education initiatives may lead to increased environmental satisfaction for occupants and unrealized energy and cost savings in high-performance buildings.

ABBREVIATED REFERENCE LIST


THANK YOU!!
DISCUSSION & QUESTIONS

Q&A

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