Energy and Behavior Modification:
Students Saving the Day (and Money) in Existing Buildings

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November 5, 2014
America’s Schools Need Improvement

WHERE WE LEARN MATTERS

25% of the US population goes to school everyday.

133,000 K-12 schools

4,300 colleges & universities

America’s Schools Need Improvement

Studies show that a building’s condition can negatively affect achievement scores by over 10%.

Institute of Education Sciences at Department of Ed
Back To School Stats. September 2012

WHERE WE LEARN MATTERS
America’s Schools Need Improvement

Classroom conditions have a direct effect on teacher morale and effectiveness.
Human Centered Design: There’s no Such Thing as Normal
every brain is unique; we each process information in different ways
The 21st century learners and workers have not changed...our awareness of how people work and learn best as individuals has changed.

01 Montgomery Middle School
02 South Tahoe High School
03 Newport Beach Learning Center
04 Old Town Newhall Library
I wonder what it's like to be dyslexic
- Sam Barclay

roughly 10% of people have a language-based learning disability, the most common of which is dyslexia.
...a person with an auditory strength means that individual was able to remember approximately **75%** of what they hear in a 30-to-40 minute lecture without taking notes...

Less than **15%** of the adult population worldwide are auditory learners

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01 Southwest High School
02 Birch Street Elementary School
03 Helix High School, Digital Music Studio

— Susan Rundle, EDL_621 Lecture on Perceptual Elements
Learning style is the way in which each individual learner begins to concentrate on, process, absorb and retain new and difficult material.”

- Drs. Rita and Kenneth Dunn and Susan Rundle, Learning Style Preferences & The Building Excellence Survey 1996-2004
patterns drive our understanding – intelligence is the ability to elicit and to construct useful patterns and links connecting to other information or experience stored in our memory.

-12 Design Principles Based on Brain-based Learning Research
By Jeffery A. Lackney, Ph.D
Giving the big picture (i.e. showing how concepts connect, building on previous knowledge (scaffolding), the overall purpose in the real world) leads to a deeper understanding and retention.

-12 Design Principles Based on Brain-based Learning Research
By Jeffery A. Lackney, Ph.D
HOW ARE WE PREPARING THE NEXT GENERATION FOR THE CONCEPTUAL AGE?

PROJECT-BASED LEARNING (PBL)

**learning / innovation skills**
- critical thinking
- communication
- collaboration
- creativity

**CORE SUBJECTS**
- (the 3 R’s)

**life / career skills**
- grit, resilience
- project management
- social / cross-cultural skills,
- leadership & responsibility

**information, media, technology skills**
- digital and emerging technologies,
- media and information literacy

supported by:
- Standards & Assessments
- Curriculum & instruction
- Professional Development
- Learning Environments

- Partnership for 21st century skills
Context: Where we Learn Matters
“Energy costs are the second largest expenditure in schools”

Behavior Based Conservation is a powerful no cost tool
<table>
<thead>
<tr>
<th>SCHOOL</th>
<th>Annual Reduction in Electricity Usage vs. Baseline Year</th>
<th>Annual Cost Savings vs. Baseline Year</th>
<th>Length of Time Covered by Energy Data</th>
<th>Baseline Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holston MS, Knoxville, TN</td>
<td>-37%</td>
<td>-12%</td>
<td>6 years</td>
<td>Fiscal Year 2007</td>
</tr>
<tr>
<td>Rosa Parks ES, Lexington, KY</td>
<td>-36%</td>
<td>-20%</td>
<td>4 years</td>
<td>Fiscal Year 2009</td>
</tr>
<tr>
<td>Laguna Creek HS, Elk Grove, CA</td>
<td>-30%</td>
<td>-19%</td>
<td>4 years</td>
<td>Fiscal Year 2009</td>
</tr>
<tr>
<td>Henderson HS, West Chester, PA</td>
<td>-30%</td>
<td>-28%</td>
<td>5 years</td>
<td>Calendar Year 2008</td>
</tr>
<tr>
<td>John Jacobs ES, Phoenix, AZ</td>
<td>-20%</td>
<td>-10%</td>
<td>5 years</td>
<td>Mar. 2007 - Feb. 2008</td>
</tr>
</tbody>
</table>
According to the U.S. Energy Information Administration (EIA), the Building Sector consumes nearly half (48.7%) of all energy produced in the United States.

If every U.S. family replaced one regular light bulb with a CFL, it would eliminate 90 billion pounds of greenhouse gases, the same as taking 7.5 million cars off the road.

Seventy-six percent (75.7%) of all the electricity produced in the U.S. is used just to operate buildings. Globally, these percentages are even greater.
IF WE HAVE ALL THE FACTS AND CHARTS, WHY CAN’T WE MOVE THE DIAL MORE?

EMOTIONAL MIND vs RATIONAL MIND

The rational mind wants to change something at work; the emotional mind loves comfort of the existing routine

- Switch, Chip Heath and Dan Heath
Case Study:
Davis Magnet Green[ren]ovation
Davis Magnet School
Math, Science, and Technology Magnet School

Located in Costa Mesa, CA
Serving students within Newport-Mesa Unified School District since 2009
About 575 Preschool - 6th grade age students

Students must live within the NMUSD boundaries and are admitted through a computerized lottery system.
MISSION
Provide hands-on, inquiry based learning opportunities for our students in all subject areas with an emphasis on math, science, and technology.
Greenovation

Who
Importance of this study:

Provides alternative ideas and data for schools and districts to consider

Demonstrates financial, environmental, and possible health benefits

Inspiration and real-life application for students in math, science, and technology
1. ADMINISTRATION
2. STUDENT GARDEN
3. FOOD SERVICE
4. MPR
5. ENVIRONMENTAL LAB
6. CLASSROOM BUILDINGS
7. GREEN CLASSROOM 7
8. CONTROL CLASSROOM 8
9. PLAYGROUND
10. PLAY FIELDS
BASELINE MONITORING OF CLASSROOMS 7 AND 8
PROVIDED BY SUN BELT CONTROLS

HVAC ENERGY TOTAL
HVAC COMPRESSOR ENERGY
LIGHTING ENERGY
PLUG LOAD ENERGY
ROOM TEMPERATURE
ROOM RELATIVE HUMIDITY
ROOM CO2
ROOM LIGHT LEVELS (INTERIOR & PERIMETER)
DOOR MONITORING SWITCH
OUTSIDE AIR TEMPERATURE + HUMIDITY

BASELINE | BASELINE CONTROL DATA
Greenovation

**What**

- **Displacement Ventilation:** better air quality, reduces energy demands located in each corner
- **Carpet:** walk-off
- **Linoleum:** durable, healthy
- **Carpet Tiles:** durable with recycled content
- **Ceilings:** improved acoustic performance
- **Casework:** modular to allow for flexible use and storage
- **Insulation:** insulate exterior walls
- **Lighting:** indirect direct with whiteboard lighting and lutron controls system
- **Technology:** integrate technology provided by district
- **Tubular Daylighting:** natural daylight and energy savings
- **Floor Plan:**
  - **Greenovated Classroom #7**
  - **Control Classroom #8**

**Greenovation**
DEMOLITION

PROVIDED BY AMERICAN WRECKING AND MILLER ENVIRONMENTAL

REMOVAL OF ALL SURFACE MOUNTED ELECTRICAL AND DATA LINES

CARPET WAS COVERING OLD ASBESTOS TILES WHICH HAD TO BE REMEDIATED

CONFIRMATION THAT ALL NON WOODEN WALLS HAD ACOUSTICAL OR THERMAL INSULATION

EXISTING POWER AND DATA LINES DISCOVERED

UNFORSEEN ITEMS

DEMOLITION | POINT OF NO RETURN
ADJUST EXISTING CONDITIONS IMPACT DESIGN

FRAMING AND ELECTRICAL
PROVIDED BY GOLDEN STATE FRAMING AND BERG ELECTRIC

WOOD FRAMING TO MATCH EXISTING CONSTRUCTION

SOFFIT RELOCATION

SOLATUBE SIZE, NUMBER AND LOCATION IMPACTED BY STRUCTURAL FRAMING

CEILING ALTERATION DUE TO OPERABLE WINDOWS

ELECTRICAL/DATA PATHWAYS
BETTER TEACHING AND LEARNING ENVIRONMENT
PROVIDED BY ARMSTRONG, SAINT GOBAIN/ CERTAIN TEED, NEVELL GROUP, PERFORMANCE CONTRACTING GROUP, ALERT INSULATION

ADDITION OF INSULATION IN ROOF AND PERIMETER WALLS

GYPSUM BOARD REPLACES ¼” PANEL BOARD

SUPERIOR SOUND ABSORBING CEILING TILES AND CARPET

REDUCTION IN SYSTEM NOISE

SOUND REDUCTION IN CLASSROOM NOISE
FINISHES

PROVIDED BY PATCRAFT, ISEC, CIR, SOUTH COAST COATINGS, FORBO, R&T SPECIALTIES, PAN PACIFIC

REPLACEMENT OF CASEWORK

NEW FLOORING – CARPET TILES, WALKOFF MATS AND LINOLEUMN FLOORING, WALL BASE

LOW VOC PAINT FINISHES

TACKABLE WALL SURFACES

REUSE OF EXISTING STAINLESS STEEL SINK
EDUCATION

School as a Teaching Tool
FIRST DAY OF SCHOOL
What are We Learning? (So Far)
Performance Measurement

Green classrooms *should* perform better while using less.

Lighting systems optimized for both **visual comfort** and **energy efficiency**.

HVAC systems optimized for **thermal comfort**, **IAQ**, **acoustics** and **energy efficiency**.

Technology optimized to support **teaching and learning**.
GREEN CLASSROOM LIGHTING
LUTRON, PRUDENTIAL LIGHTING, SOLATUBE, LEDALITE, CMF INC., ALIGHT

NINE 12” TUBULAR SKYLIGHTS WITH ELECTRIC DAMPERS

EXISTING SOUTHERN AND NORTHERN WINDOWS WITH EXTENSIVE OVERHANGS

DIRECT/INDIRECT LIGHTING T8 LAMPS, DIMABLE BALLASTS

OCCUPANCY SENSOR AND DAYLIGHTING DIMMING
2013-2014 Lighting Energy (kWh/month):

Green Classroom: 83
Control Classroom: 98
17% Lighting Energy Savings
GREEN CLASSROOM HVAC SYSTEMS
PACIFIC RIM, BRAGG CRANE AND AAON

HIGH EFFICIENCY VARIABLE SPEED ROOFTOP HEAT PUMP UNIT

DISPLACEMENT VENTILATION
AIR-SIDE ECONOMIZER
DEMAND CONTROLLED VENTILATION
EXISTING OPERABLE WINDOWS

CONDITIONING Thermal Displacement Ventilation
Energy Measurement

2013 – 2014 HVAC Energy (kWh/month):
Green Classroom: 144
Control Classroom: 206
31% HVAC Energy Savings
PLUG LOADS

Technology in the Classroom

OTHER ENERGY SYSTEMS
Provided by District

FOUR STUDENT COMPUTERS
TEACHER LAPTOP
PROJECTOR
SCANNER
CD PLAYER
2013-2014 Plug Energy (kWh/month):
Green Classroom: 101
Control Classroom: 76
35% Higher Plug Energy
Overall Energy Savings ~ 14%

Plug +35%

HVAC -31%

Lights -17%
2013 - 2014 TOTAL ENERGY:
Green Classroom:  327 kWh/mo  ~ $82/month
Control Classroom:  381 kWh/mo ~ $95/month

~14% Energy Savings in Current Conditions
~21% Energy Savings (if plug loads were the same)
~30% Energy Savings with optimized energy management

BEST CASE:
Reduce Classroom Energy Costs from $1200/yr to $800/yr.
Control Classroom: 43 – 45 dBA
Green Classroom: 36 – 39 dBA
Control Classroom: 1 Light Switch

Green Classroom: 3 Light Controls
**Thermal Comfort**

*Outside Air*
- Daytime: 90’s
- Overnight: 70

*Green Classroom*
- Daytime: 72 - 76

*Control Classroom*
- Daytime: 74 - 77
More Ventilation = Fewer Absences

http://newscenter.lbl.gov/2013/06/05/more-fresh-air-in-classrooms-means-fewer-absences/
Elevated CO2 Impairs Thinking

QUALITY | Ventilation
Green Classroom
ZONE CO2
9/17/2014
Max CO2 ~ 1600
~ 2 hrs > 1200

Control Classroom
ZONE CO2
9/17/2014
Max CO2 > 2000
~ 4 hrs > 1200

QUALITY | Ventilation
INDOOR ENVIRONMENTAL QUALITY

ACOUSTICS
AIR QUALITY
THERMAL COMFORT
VISUAL COMFORT
TECHNOLOGY

QUALITY | The Bigger Picture
This report was prepared for the USGBC OC Committee

A Technical and Psychological Assessment of Energy Usage in the Classroom at the Davis Magnet School

Authors:
Nora Davis, Doctoral Student, University of California, Irvine, nedavis@uci.edu
Thomas Pine Ph.D., Associate, Cadmus Group, tom.pine@gmail.com

Paid for by a grant from the Walt Disney Corporation and Cadmus Group
The purpose of this project was to also investigate the on-the-ground experiences of the occupants in a particular green school – the perceptions and behaviors of the teachers and students in the classroom.
Key Constructs

Person-Environment Congruence
+ or -

Energy behavior
efficiency and curtailment

Spillover, Rebound, Moral License
Methods

Quasi-experimental

Quantitative
- student environmental knowledge survey

Qualitative
- interviews with teachers and classroom – observations
Results

Health

Energy Awareness

HVAC & Temperature - Occupant

Lighting Occupant

Plug Load Occupant
## Health

<table>
<thead>
<tr>
<th>Classroom</th>
<th>Absence</th>
<th>#Students</th>
<th>Illness</th>
<th>Sequential</th>
<th>Nurse Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>114</td>
<td>63</td>
<td>93</td>
<td>12</td>
<td>39</td>
</tr>
<tr>
<td>Retrofit Green</td>
<td>127</td>
<td>59</td>
<td>88</td>
<td>15</td>
<td>33</td>
</tr>
</tbody>
</table>
### Table 3: Comparing classrooms: by home, school or general

<table>
<thead>
<tr>
<th>Category</th>
<th>Average - Green</th>
<th>Average - Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy – General at School</td>
<td>2.02</td>
<td>1.32</td>
</tr>
<tr>
<td>Energy- HVAC Mention, Use &amp; Efficiency in General</td>
<td>1.99</td>
<td>1.46</td>
</tr>
<tr>
<td>Energy - Computers Use Energy &amp; Turn Off Saves at School</td>
<td>2.13</td>
<td>1.29</td>
</tr>
<tr>
<td>Energy - HVAC Mention, Use &amp; Efficiency at School</td>
<td>2.11</td>
<td>1.43</td>
</tr>
<tr>
<td>Energy - Lighting at School (mention, energy use, daylight, automatic dimming)</td>
<td>1.92</td>
<td>1.29</td>
</tr>
<tr>
<td>Purchasing general at School</td>
<td>2.0</td>
<td>1.35</td>
</tr>
</tbody>
</table>

### Table 1: Overall

<table>
<thead>
<tr>
<th>Category</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy General</td>
<td>2.17</td>
</tr>
<tr>
<td>Purchasing</td>
<td>2.05</td>
</tr>
<tr>
<td>Water</td>
<td>1.99</td>
</tr>
<tr>
<td>Energy Computers</td>
<td>1.98</td>
</tr>
<tr>
<td>Energy HVAC</td>
<td>1.87</td>
</tr>
<tr>
<td>Energy Lighting</td>
<td>1.78</td>
</tr>
<tr>
<td>Transportation</td>
<td>1.39</td>
</tr>
<tr>
<td>Food</td>
<td>1.37</td>
</tr>
<tr>
<td>Air quality</td>
<td>1.34</td>
</tr>
</tbody>
</table>

### Table 5: School Mentions

<table>
<thead>
<tr>
<th>Category</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy at School</td>
<td>1.87</td>
</tr>
<tr>
<td>Purchasing at School</td>
<td>1.85</td>
</tr>
<tr>
<td>Water at School</td>
<td>1.74</td>
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<tr>
<td>Transit at School</td>
<td>1.31</td>
</tr>
<tr>
<td>Food at School</td>
<td>1.26</td>
</tr>
<tr>
<td>Food in General</td>
<td>1.38</td>
</tr>
<tr>
<td>Transit at School</td>
<td>1.31</td>
</tr>
<tr>
<td>Food at School</td>
<td>1.26</td>
</tr>
</tbody>
</table>
HVAC, Temperature & Lighting

*Control and congruence*

- Technology Learning Curve
- Temperature
- Projector & Lighting – Glare, No Lights
1. Inconsistent policy implementation
2. Instructional Style
3. Rebound, moral license
-Curricular Integration
  Plug load teacher & student education;
  Integrate with current technology standards
  being developed by grade level

-Consistent IT policies

-Intervention energy feedback experiment or
  competition with computers
Monthly Energy Report Card for the School

Shows total energy use

Allows students to compare energy use to earlier months

Compares the use to the previous month and to the other classroom

Presents history of total energy use

Classroom Involvement | Involve students and teachers
Social Impact

How does a school impact its students?
By providing a space within which such comparisons can be made, the Davis Magnet School project is unparalleled in its ability to deliver technical as well as environmental psychological insights.

RESEARCH

Investigate behavioral impacts
Case Study:
CURRICULUM INTEGRATION
WHAT IS PEAK?

A STANDARDS BASED EDUCATION PROGRAM

DESIGNED TO EMPOWER ELEMENTARY AND MIDDLE SCHOOL STUDENTS

TEACHES STUDENTS TO SAVE ENERGY AND TAKE ACTION TO CREATE A MORE SUSTAINABLE WORLD
A DYNAMIC CURRICULUM

CORRELATED TO CA ACADEMIC CONTENT STANDARDS (GRADES 3-7)

COMMON CORE ALIGNED

STEM INCLUSIONS

HANDS-ON SCIENCE LABS

ACTION-BASED LEARNING
BENEFITS FOR TEACHERS

FREE SUPPLIES AND ACTIVITIES

TEACHER ORIENTATION AND TRAININGS

MATERIALS AND ONLINE RESOURCES

ON-GOING SUPPORT
BENEFITS FOR STUDENTS

EDUCATIONAL ASSEMBLIES

SPECIAL VISITS FROM PEAK’S SUPERHERO, BULBMAN

CONTESTS AND PRIZES
BENEFITS FOR STUDENTS

2010 GOVERNOR’S ECONOMIC AND ENVIRONMENTAL LEADERSHIP AWARD

BEST CHILDREN’S ENVIRONMENTAL EDUCATION PROGRAM
What's the connection to Davis Magnet?

PEAK teaches the science and background of energy,
How we harness (focused on electrical generation) and use it to our benefit and also why it's important to conserve energy
PEAK combines the science base, with an environmental message to create real behavior change - and give students actual actions they can take to make a difference
What's the connection to Davis Magnet?

Holistic approach
It's important to blend this knowledge with the efforts at Davis Magnet so that students understand WHY it's important to save energy - and even though tools are in place to use less (in the form of retrofits), it's important that their habits become more efficient as well and that students understand conservation as a holistic idea. PEAK also discusses renewable and the development of new/related technology, but if the behavior towards energy conservation remains stagnant, energy will still be wasted even with retrofits and new technology.
What's the connection to Davis Magnet?

PEAK's Involvement

PEAK was asked by Tim Harrison to present the program to NMUSD Science Specialists, and to Davis Magnet teachers late last year. As a result Davis Magnet 3rd-7th grade students will now have full PEAK program access through Pam Brusic, Science Specialist at Davis Magnet (trained in January). PEAK is working to coordinate similar holistic approach efforts with other partner schools.
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