Defining Intelligent School Buildings

Symposium: A Roadmap to Zero Carbon School Buildings

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IBPSA-England
CIBSE Schools Group

9th February 2009
New primary schools – the next wave of education spend - are being financed through local authorities, but if they are to remain outside the Building Schools for the Future Programme, local councils need to prove next year that not only can they offer better value for money than PFI, but they are more design friendly than their private sector equivalent and have a real-not feigned- interest in the longer term.

Baillieu A., New year new uncertainties, Building Design, 2008, Dec19,
Over 25% of the UK population is involved in the education system:

- There are currently over 1.25 million adults involved in the education of over 15 million pupils/students.
- Approximately 70% or 875,000 of these adults are employed as full-time or part-time teachers or teacher assistants.
Concentrate any group of people in a confined workspace and:

- Sickness rates rise
- Stress levels increase
- Performance standards fall

This has been demonstrated repeatedly in workplace studies

- Few environments are as densely populated as a typical classroom; and no-one is asking what the educational consequences of that may be.

John Jukes & CHIDDINGFOLD TECHNOLOGIES
Causes

- Environmental
- Social
- Organisational

All such sources of stress combine to challenge health and well-being and adversely affect the learning process.
Intelligent Schools:

- Reduce sickness
- Enhance concentration
- Improve results in schools, colleges and universities

John Jukes & CHIDDINGFOLD TECHNOLOGIES
How important is to you to live in a well-designed house?

– Vey important. I can’t operate unless I have a calm and organised environment. I think beauty enhances your life. Good design creates a better quality of living and can affect your mood.

How involved were you in the project

– If there is a great relationship between a designer and client you can get great results. But projects can go wrong if clients aren’t clear about the brief.

Which is your favourite room?

– My top-floor studio. It’s where I work when I am at home. It’s a calm space with masses of natural light and a fantastic view across London. Its design helps me to be very organised.

Sir John Sorrell, Chairman of the London Design Festival, Chairman of the Commission for Architecture and the Built Environment (CABE)

Financial Times, 2008, September 13/14 p.3
Defining Quality

- Excellence
- Value
- Conformance to the brief and to the specification or
- The realisation of consumer expectations
- Performing beyond expectations
The Meaning of High Value

- The construction of high-quality systems
- The minimisation of whole-life cost
- The optimal performance of the services
Design Drivers

- Quality of life
- Demographic changes
- Work and Lifestyle changes
- Sustainability
- Health
- Innovation
# Achieving Maslow’s Hierarchy of Needs in the Workplace

<table>
<thead>
<tr>
<th>Need</th>
<th>Achieved by</th>
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<tbody>
<tr>
<td>Physiological</td>
<td>Good working conditions, attractive salary, subsidised housing, free catering</td>
</tr>
<tr>
<td>Safety</td>
<td>Private health care, pension, safe working conditions, job security.</td>
</tr>
<tr>
<td>Social</td>
<td>Good relationships, team spirit, company sports, office parties, informal activities, open communication.</td>
</tr>
<tr>
<td>Esteem</td>
<td>Regular positive feedback, prestige job titles, write-up in company news sheets, promotion and reward.</td>
</tr>
<tr>
<td>Self-actualisation</td>
<td>Challenging job, discretion over work activity, promotion on opportunities, encouraging creativity, autonomy and responsibility</td>
</tr>
</tbody>
</table>

Source: (CIBSE 1999, Huczynski 1991)
Poor Environmental Conditions can Rapidly Fatigue Pupils/Teachers

- Aural/acoustic quality
- Visual illumination quality
- Thermal quality
- Air quality
- Building amenities
- Functional ergonomics

Source: Public Works Canada Study (1985)
Employees with interior plants in their offices tend to consider themselves happier or more content when compared to employees without plants in their offices. Additionally, the group of employees that did not have either plants or windows were “dissatisfied” with their quality of life.

Michael W. Neff ScienceDaily, (May 19, 2008) @ American Society for Horticultural Science
Properties of Intelligent Buildings

- Aesthetics
- Healthy and Sustainable
- Convenience
- Whole life value
- Buildability
- Flexibility
- Adaptability
Intelligent Buildings

The key criteria for achieving good, intelligent buildings are:

- Stakeholder objectives and needs
- Social and environmental needs
- The recognition of available resources

Clements-Croome, DJ, Wu, S John G, 2006, High Quality Building Services, Latimer Trend & Co
The Forms of Building Intelligence

- Building - Connectivity
- Spatiality
- Self-recognition
- Kinaesthetic
- Logic

Mervi Himanen 2003
**IB Concepts**

<table>
<thead>
<tr>
<th>Concept</th>
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<tbody>
<tr>
<td>Central control</td>
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<tr>
<td>Personal Control</td>
</tr>
<tr>
<td>Intelligent space management</td>
</tr>
<tr>
<td>Passive Intelligence</td>
</tr>
<tr>
<td>Organisational Intelligence</td>
</tr>
<tr>
<td>Occupant Intelligence</td>
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</tbody>
</table>

Raymond JC, Bornik Z., Reconciling human and automated intelligence in the provision of occupant comfort
Intelligent Buildings Start with a Good Brief Comprising:

- Clearly articulated *project vision*
- A recognition of the *design and procurement realities*
- Clarity about *whole-life appraisal*

Clements-Croome, DJ, Wu, S John G, 2006, High Quality Building Services, Latimer Trend & Co
# Green Building Concepts

<table>
<thead>
<tr>
<th>Efficient building operation</th>
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<tbody>
<tr>
<td>Provision of feedback on building performance; responsive systems</td>
</tr>
<tr>
<td>Flexible, adaptive design</td>
</tr>
<tr>
<td>Passive environmental control</td>
</tr>
<tr>
<td>Multiple use buildings &amp; spaces; effective operational management support</td>
</tr>
<tr>
<td>Personal control over ventilation, thermal comfort, natural light, noise and privacy</td>
</tr>
</tbody>
</table>

Raymond JC, Bornik Z., Reconciling human and automated intelligence in the provision of occupant comfort
Lessons from Nature
Lessons from Vernacular Architecture
Passive Environmental Control
Active Environmental Control
Smart Facades

- Facade is an interactive inside-outside interface
- Reactive materials and surfaces
- Embedded technology can control inputs/outputs
- Low CO$_2$ emission
- Opportunities for nanomaterials
- Lessons from Nature
- Develop new CPD modules for architects, engineers and construction professionals on facade design
Greening and Photovoltaics at Unterensingen School

Unterensingen Primary and Secondary School, Germany
# Design Quality Indicators

<table>
<thead>
<tr>
<th>Quality Indicator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Build Quality</td>
<td>Engineering performance; durability; integration of systems; construction.</td>
</tr>
<tr>
<td>Functionality</td>
<td>Design of spaces for working in; use; access.</td>
</tr>
<tr>
<td>Impact</td>
<td>Effect of building on environs; does building create a sense of place? Form and materials; internal environment; innovation.</td>
</tr>
</tbody>
</table>
University of Reading Project

Design Quality in Schools

Paula Cardellino, Jennifer Whyte, Derek Clements-Croome
The Key Steps for Optimal Performance

- Selecting the *integrated team* (including specialist M & E and FM contractors)
- Preparing the *strategic brief* and *performance criteria*
- Analysing the *brief*
- *Selecting* the systems
- *Specifying the performance* of the chosen systems
- Arranging the *warranty*
- *Selecting* the manufacturers and contractors
- Performing and identifying *pre-occupancy commissioning*
- Identifying *facilities management procedures*,
- *Post-occupancy evaluation*
Assessing the Quality of WLBM

- Design Quality Indicator (DQI)
- Integrated Logistic Support (ILS)
- Building Quality Assessment (BQA)
- Building Research Establishment Environmental Assessment Method (BREEAM)
- Post Occupancy Evaluation (POE)
Objectives of POE

- To identify the behaviour patterns associated with the use of the building.
- To establish a relationship between the behaviour patterns and the consumption of energy/water.
- To develop an intelligent sensor system.
Post-Occupancy Evaluation (POE)

The essential parameters monitored in post-occupancy are:

- The efficiency and effectiveness of building use
- The performance of each building system
- User satisfaction
- The functioning of systems
- The utilisation of services
- The physiological state of the occupants using sensors
INTEGRATION

The 4 C’s help to achieve the 4 Es:

Communication
Consultation
Cooperation
Coordination

Effectiveness
Efficiency
Efficacy
Economy
The Integration of Building Systems

At a strategic level integration requires the interactive consideration of

People
Processes
Products (systems)

Clements-Croome, DJ, Wu, S John G, 2006, High Quality Building Services, Latimer Trend & Co
Areas of Concern for Integration include:

- *good briefing*
- *coordinating information* across the whole building process
- *standardising* processes and products (rather than allow the proliferation of proprietary systems)
- *interoperability* of systems
- *documentary evidence* on integrated processes
- Have the *proven and tested processes* been adapted and used on similar projects?
- *auditing and monitoring processes*
- Have firms organised *mandatory work processes* as part of their working patterns?

Clements-Croome, DJ, Wu, S John G, 2006, High Quality Building Services, Latimer Trend & Co
The 3 Facets of Building Performance

Physical:
- Space
- Condition
- Appearance
- Fabric efficiency
- Services efficiency

Functional:
- Usefulness
- Flexibility
- Comfort
- Image
- Convenience

Financial:
- Capital costs
- Operating costs
- Depreciation
- Investment value
- Beneficial value
- Appreciation
Performance requirements in the context of the project life cycle

Buildings and constructed assets – Service-life planning, BS ISO 15656-5:2008
Well-being Needs

- Social milieu
- Freedom for solitary or group working
- Opportunities to develop self-expression
- An interesting visual scene
- Acceptable acoustic conditions.
- Contrast and random changes for the senses to react to
- Opportunities to exercise or switch over from work to other stimulating activities
An individual has to *want* to do the task and then has to be *capable* of doing it; last but not least resources and amenities have to be available so that the task *can* be done.
Space Impacts on People -1

- Communications
- Social interaction
- Flexibility
- Hierarchical and non-hierarchical organisational structures
- Work productivity
- Effectiveness of ventilation (natural or mechanical) and air quality
Space Impacts on People -2

- Sound distribution
- Privacy
- Crowding
- Individual Control
- Storage
- Ergonomic Factors
# Environmental Conditions for Learning (Productivity)

<table>
<thead>
<tr>
<th>Needs:</th>
<th>Means:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Concentration and Clear Head</td>
<td>High O\textsubscript{2} in Blood</td>
</tr>
<tr>
<td>Good Health</td>
<td>Clean Fresh Air, 40-60% rh, 20-22 °C</td>
</tr>
<tr>
<td>High Motivation</td>
<td>No Negative Stress</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Factors:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Daylight</td>
<td></td>
</tr>
<tr>
<td>View</td>
<td></td>
</tr>
<tr>
<td>Noise</td>
<td></td>
</tr>
<tr>
<td>Social Ambience</td>
<td></td>
</tr>
<tr>
<td>Job Satisfaction</td>
<td></td>
</tr>
<tr>
<td>Space and layout</td>
<td></td>
</tr>
</tbody>
</table>
Bichât (1811)

- Proved by experiments, that when venous or dark-coloured blood is injected into the vessels of the brain through the carotid artery, the functions of the brain are immediately disturbed...
... the effect of the venous blood circulating through the brain to be similar action of a narcotic poison; and this takes place when air is impure, and does not perfectly oxygenate the blood. When the lungs receive impure air, imperfectly oxygenated blood is circulated through the brain, producing a cessation of the functions of that organ, ...
Tredgold

Are we from noisome damps of pest-house free? And drink our souls the sweet ethereal air?

*Thomson*
## Symptoms and Illnesses Related to the Quality of Indoor Air

<table>
<thead>
<tr>
<th>Location</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>EYES</td>
<td>Dryness, itching/stinging, tearing, redness.</td>
</tr>
<tr>
<td>UPPER RESPIRATORY TRACT</td>
<td>(nose and throat) Dryness, itching/stinging, nasal congestion, nasal drip, sneezing, nose bleed, throat pain.</td>
</tr>
<tr>
<td>LUNGS</td>
<td>Chest tightness, drowning sensation, wheezing, dry cough, bronchitis.</td>
</tr>
<tr>
<td>SKIN</td>
<td>Redness, dryness, general and localized itchiness.</td>
</tr>
<tr>
<td>GENERAL</td>
<td>Headache, weakness, drowsiness/lethargy, difficulty concentrating, irritability, anxiety, nausea, dizziness.</td>
</tr>
</tbody>
</table>

### MOST COMMON ILLNESSES:

- **HYPERSENSITIVITY**
  - Hypersensitivity pneumonitis, humidifier fever, asthma, rhinitis, dermatitis.

- **INFECTIONS**
  - Legionellosis (Legionnaire’s disease), Pontiac fever, tuberculosis, common cold, flu.
  - Of unknown chemical or physical origins, including cancer.
Asthma in UK

- 2.6 million “severe symptoms” sufferers
- 1,400 people died from asthma in 2004.
- 6 times as many children’s asthma attacks than 25 years ago
- 3 children in every UK classroom have asthma on average
Air Quality

Temperature
- MRT
- Air
- Gradient

Moisture
- Dryness
- Condensation
- Relative Humidity

Contaminants
- Odours
- CO₂
- Gases
- Dust
- Bacteria
- VOC’s
- Allergens

Air Movement
- Change (eg freshness)
- Distribution of Heat, Moisture and Ions
Air Quality

- Content of Air (particles, VOC’s, CO₂, ions)
- Temperature
- Relative Humidity (40-60%)
- Movement of Air
- Freshness
Sources of Pollutants

- Human activities
- Various materials and products including HVAC systems
- Combustion processes
- Microbiological organisms such as mould and dust mites
- Outdoor air pollution
- Ground under the building
- Allergens from home to school.
Effects of Poor Air Quality

- Physiological (respiratory, asthma, allergies)
- Less efficient oxygenation of blood
- Decrease pH of blood
- Decreased concentration, less productivity
- Stuffiness
- Building Sickness Symptoms
Many schools have a problem supplying their classrooms with enough fresh air. Yet at least eight out of ten schools have an indoor environment with much too high a level of CO₂. Research has shown that this has adverse effects on the health and performance of pupils. The problem is often raised, but then little is written about solutions.

School Ventilation Newspaper, Ned Air, Netherlands, 2008
Average, Maximum and Minimum $\text{CO}_2$ Concentrations in 11 Dutch Primary Schools

Source: Dijken et al, 2005) in Boerstra et al, Rehva Workshops Clima 2005
Health Symptoms Reported by Pupils

Van Dijken, Van Bronswick Sundell, 2006, Indoor environment and pupils health in primary schools, Building Research & Information.
Mean CO2 concentrations (±SD) according to the experimental conditions during the computerized performance tests in 16 classrooms at 8 schools.

* For Schools 1-3 no recirculation was made; the low ventilation condition was obtained by leaving the windows in closed position.

Mean CO$_2$ concentrations (±SD) during the computerized performance tests in 16 classrooms at 8 schools; 3-4 Groups of pupils were tested in each school.

Research at University of Reading

Effect of Ventilation Relative Performance

**Research at University of Reading**

**Ventilation Rate vs. Relative Performance**

![Graph showing ventilation rate vs. relative performance](image)

10 classes

Clements-Croome DJ, Bako-Biro Z at al., 2008, Ventilation Rates in Schools Report
Performance of School Work as a Function of Outdoor Air Supply Rate

- Summer experiment
- Winter experiment

$R^2 = 0.90$, $P = 0.052$

Boerstra et al, Rehva Workshops Clima 2005
Recommendations

Whole-life performance is based on quality and whole-life costs. Tools needed are:

- *the design quality indicator* when planning the design process to ensure that the mission and its value are understood and shared by all members of the integrated design team;

- *integrated logic support analysis* for the whole-life process

- *building quality assessment* to ensure that the quality has been achieved

Clements-Croome, DJ, Wu, S John G, 2006, High Quality Building Services, Latimer Trend & Co
Recommendations

- Test the sustainability using the **Building Research Establishment Environmental Assessment Method**

- *good communication* between all stakeholders

- Select *quality supply team* for design, construction and operation

- *Effective feedback* in use

- Use *Whole Life Value* concept
Whole Life Cost Ratio

Design : Operation : Business

1 : 10 : 200

Value = Cost x Quality

1. Design
   - acquisition
   - construction

2. Operations
   - commissioning
   - maintenance

3. Learning:
   Teachers/Pupils
   - health & safety
   - productivity
   - sustainability

*Source: BRE

University of Reading
Recommendations for Schools

- Design for fresh air supply rates of 8 l/s per pupil
- Equip classrooms with a monitoring device for: CO₂ temperature & relative humidity
- Take intermediate actions for additional ventilation if CO₂ concentration exceeds 1000ppm
- Keep temperatures within comfortable range between 20-22 °C (winter) and 22-24 °C (summer)
- Avoid moisture build up in classroom and keep humidity levels below 60% during winter time.
- Create daily window opening routines for the school
  - Monitoring before children arrive
  - During breaks
  - After school hours during cleaning, vacuum
- Use odourless cleaning agents
- Remember that dirty carpets can pollute the indoor environment.
In an increasingly complex world we need to seek clarity in briefs and specifications and aim for simple solutions that satisfy the needs of people, organisations and society.

Clements-Croome, DJ, Wu, S John G, 2006, High Quality Building Services, Latimer Trend & Co