"I want a classroom ...
where the roof opens up to the sky, like a BMW convertible, so I can see the clouds,
that uses windows with colourful glass which glows in the sunshine,
where there are cool breezes [from outside] and limitless supplies of icecream,
that is quiet [other than the birds] while the teacher reads,
...and...
a classroom I can watch arrive on the back of a truck because I think that is cool!"

[a compilation of responses from Queenskand primary school children, aged 9,y.o, on how to design a relocatable classroom that highlights their interest in biofilic design and passive solutions]

2. Sustainable school environments

Overview

Looking Forward

Inspiration

How might sustainability - from environmental through to social - impact on the design of future relocatable classrooms?

How can the design of prefabricated learning environments best address issues of indoor environment quality?

This Brochure>

"I want a classroom that gives me the freedom to teach appropriately, with different approaches for different children and classes... but it's also important that it's a classroom where the children don't get too distracted by light, noise and temperature."
[a teacher]

Aspirational targets, which are statements about a desired condition, will be set in this brochure in relation to sustainability in future relocatable classrooms

Overview

This brochure outlines aspects of sustainability and how they might impact on the design of future relocatable classrooms. It concentrates on environmental, and to a lesser extent, social sustainability.

The key issues presented are on:

- energy & water;
- materials;
- indoor environment quality;
- construction waste;
- climate change; and
- the ability to teach a green curriculum by using the buildings as 3 dimensional text books.

Irrespective of whether a classroom is a reloactable or a permanent structure it is not sustainable if it does not support teaching and learning.

Green Star Guide

The brochure will link the issues to the requirements set out in Green Star, *which is a voluntary environmental rating system for buildings in Australia.*

Case Studies

International, national and *mini* case studies are presented in this brochure to describe:

- what is happening around Australia currently involving the design and performance of green schools and relocatable classrooms, and
- what is happening internationally as far as producing 'sustainable' relocatable classrooms.

The case studies summarise key best-practice approaches and raise issues that need to be considered in the design of relocatable classrooms of the future.

Methodology

The *international* and *national case studies* were compiled following literature reviews, site visits and interviews with the designers|manufacturers of green schools and relocatable classrooms

The *mini case studies* draw on preliminary results from current research being undertaken over 12 months in 2010/2011, involving the environmental monitoring of 8 Australian prefabricated classrooms across 5 climate zones.

Challenges

Problems found **internationally** in relocatables can be summarised as follows. They tend to:

- use more energy than traditional classrooms;
- have poorly functioning HVAC systems that provide minimal ventilation with outside air;
- have poor acoustics due to loud ventilation systems;
- have chemical off-gassing from pressed wood and other high-emission materials, of greater concern because of rapid occupancy after construction;
- have water entry and mould growth, and;
- are often placed haphazardly on a site with minimal consideration of connectivity to the site and other buildings, often eroding playspace.

Many of these problems are due to light weight construction. This is an important consideration for the future design of sustainable relocatables.

Main Image: National case study: The General Purpose Classroom in Victoria by eme designs (www.emegroup.com.au). For more information on this building refer to page 10.

Inset image: A thermal image of the General Purpose Classroom taken by a student exploring how the building is different from other buildings on the school campus.

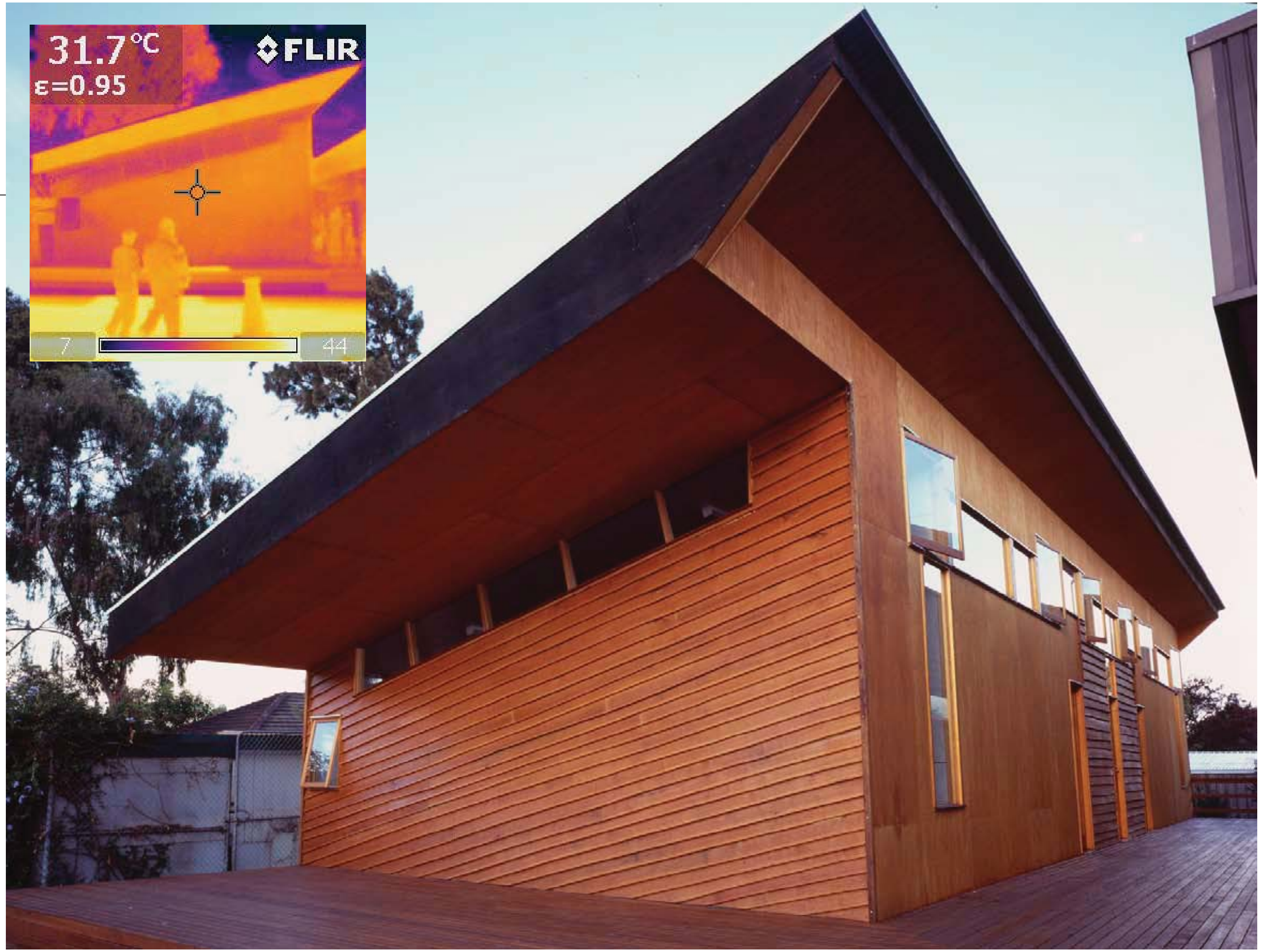
This is not a ‘relocatable’classroom...However this building was designed so that all elements could be screwed together to make disassembly possible if there was a future requirement for the building to be relocated. The building is designed using first principles and *looks* and *feels* different from other buildings on the campus. This motivates the student to ask and want to explore *why*?

Inspiration>

“Relocatables can be the greenest of solutions; they are a planned response to a student number spike. It means we can provide usable space quickly that will be used and not stand there empty. They touch the ground lightly, leave a small footprint and can be very efficient.”

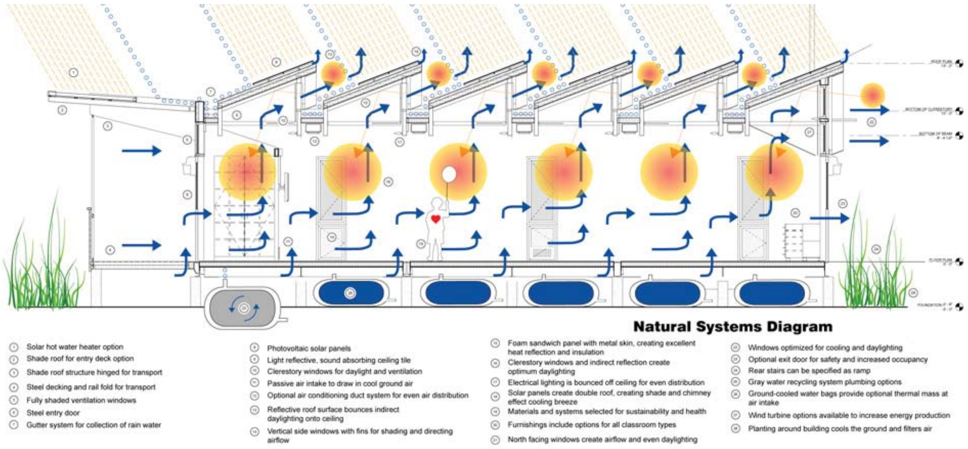
[Ms Leanne Taylor, Director Planning and Infrastructure, Department of Education and Training Northern Territory Government]

To design and build classrooms that motivate student enquiry...
(see page 9 & 10)



1: Energy Neutral Portable classroom, Anderson Anderson Architects (http://andersonanderson.com)

2: Photos from an Eco-cubby workshop (www.eco-cubby.com/) where children aged 8-12 added Solar Photovoltanic Panels and Water tanks to their cardboard cubby house (see completed cubby house on page 11)



Key Issues>

Energy, Water

Green Star: Water

Rain water should be used to flush toilets and be a 5A standard – integrated rainwater collection.

Where possible, integrate with a teaching landscape.

Integrate meters and monitoring if water is being used.

Reduce potable water consumption from heat rejection systems by 50%, 90% or 100%, for example by using a geothermal coupled system to remove heat.

Integrate regionally appropriate low water vegetation – roof, wall, interior (refer to landscaping brochure and image 2 on page 12)

Can you make your building CO^2 positive in operation and water neutral with embodied energy paid back in ten years?

Water

Water efficiency is an important aspect of all new building designs in Australia. In southern parts of Australia it is not uncommon to have water tanks and water efficient fixtures incorporated into the design. In the school context, this creates opportunities for integrated learning where the tanks and the associated plumbing become teaching tools when made visible (see pages 9 & 10).

refer 3

While it is common for relocatable classrooms to have running water, toilets are generally not integrated into the design and these classrooms are often not located in close proximity to toilet blocks.

An international study by Vernon *et al* [2003] into 9-11 year old student attitudes to school toilets found that inadequately located school toilets, along with bullying and lack of cleanliness, led to students not using the facilities and later suffering from dehydration, constipation, urinary tract infections or incontinence.

In a recent workshop, primary students in Queensland voted that the inclusion of a toilet was one of the top 10 things they would change about their current relocatable classroom.

Energy

Energy use in classrooms is mainly for HVAC (heating , ventilation, air cooling) systems, lighting and equipment.

To improve energy efficiency, consider how to design the building to reduce the heating and cooling loads on the HVAC system. This can be done through considering building orientation and external sun shading, wall and ceiling insulation with high R-values, double and triple glazed windows with low emissivity glass, white roofs and thermal breaks.

Building occupant behaviour will also have an impact on energy consumption. For example, in a temperate climate, the National Australian Built Environment Rating System recommends that rooms be heated to between 18-20°C in winter and cooled to between 24-27°C in summer. Every one degree higher in winter will increase energy usage by 15%, while every one degree lower in summer will increase energy usage by 10%.

Energy savings can also be made through maximising daylight, using energy efficient lighting, and ensuring that equipment is not left on standby power.

Solar Energy

Design the classroom so that the building can be placed at the correct orientation on *any site* to enable solar photo voltanic panels to be used on the roof. PV panels can be used to offset energy used by the classroom and, depending on the size of the array, may even generate solar credits for energy used elsewhere by the school.

Green Star: Energy

Aim for zero net production of CO^2, but try to limit energy use within each general purpose classroom.

Green star sets a benchmark of $108kgCO^2/m^2$/p.a., which varies depending on the function and location in Australia.

Green Star also gives credits for:

- the integration of energy monitoring & display energy use,
- putting in place strategies for peak energy demand;
- installing motion and light level sensors; and
- ensuring unoccupied areas have wider temperature ranges or are not air conditioned.

Many of the issues outlined here are not only a problem of relocatable classrooms but all teaching spaces.

They are presented here because they require consideration in the design of all new learning spaces - including relocatables.

Key Issues>

IEQ Introduction

Impact on Learning

There have been several studies undertaken on school effectiveness and the influence of the learning environment on education [Fraser 1986; Sammons *et al* 1996; Walberg 1981]. The research underlines the complexity of effective school environments, emphasising that success is not dependent on one solution or single characteristic.

Studies into Indoor Environment Quality (IEQ) and occupant productivity show that the quality of the indoor environment can impact both positively and negatively on effective learning [Heschong Mahone Group 1999; Wakefield 2002; Cox-Ganser *et al* 2005]. Some of these impacts are touched upon in the following pages. For more detail refer to the studies referenced.

> Can you provide thermal comfort primarily through passive and radiant sources and fresh air at no additional energy input?

Indoor Environment Quality or IEQ

An integral part of the entire building performance is IEQ [Ali *et al* 2009]. IEQ relates to the combined impact of environmental parameters such as indoor air quality (IAQ), thermal comfort, light and acoustics. IAQ is an assessment of dust particle matter (PM), mould, pollen, CO^2 and Volatile Organic Compounds (VOCs) in the air. There is a direct relationship between IEQ and the comfort and productivity of building inhabitants [Ahmed 2010].

IEQ is impacted on by thermal comfort which includes: air temperature, mean radiant temperature, relative humidity, air velocity and rate of air change.

Research into IEQ is important. Studies reveal that a child spends 15,000 compulsory hours in the school environment during their formative years [Rutter 1979] and of this, 85 to 90% of their time indoors [Johnson *et al* 2010].

Green Star: IAQ

- Dry bulb temperature of 20-24°C and a mean radiant temp of 20-27°C or shading so that there is no radiant load on the glass
- Relative Humidity 40-60%
- Air velocity <0.2 m/s unless occupants have control of air direction
- Double glazing to 90% of glass 100% of N W E and 15% improvement on BCA glazing compliance
- IEQ-1 ventilation rates 95% natural ventilation in accordance to AS1668.2-2001; if mechanical then a 50%/ 100%/ 150% improvement over AS1668.2-1991 (10l/s/p over 16yrs, 12l/s/p under 16yrs) – CO^2 – set point 800ppm/700ppm/640ppm (3,2,and 1 credit)

NOTE: increasing air changes and ventilation rates can have an impact on energy use for heating and cooling.

- Demand Control Ventilation (DCV) using CO^2 sensors is a way to achieve both good IAQ and energy efficiency.

Mould, Dust, Pollen and Asthma

Mould, dust and pollen have an impact on indoor air quality (IAQ) and can affect children with asthma. The impact of these needs to be minimised by appropriate air filtration, education of building users about when to close windows and control of moisture.

There is a direct link between poor air quality and respiratory illness such as asthma. In the US asthma is the cause of an average 4.6 missed days of school per child annually [Wakefield 2002].

These findings are consistent with those of Cox-Ganser and colleagues [2005] who found that between 1994 and 1996, asthma was the cause of 14 million days of school loss or around 3.4 school days per child.

Green Star: Mould

Humidity levels to be less than 60% in space and 80% in ducts

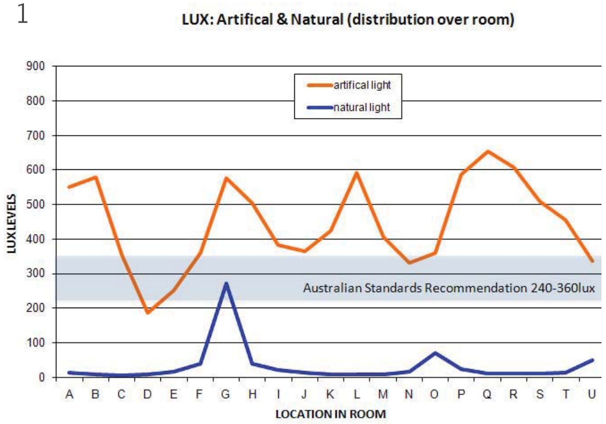
1: Graph mapping average natural and artificial light levels against the levels set out in the Australian Standards

2: Image from a mini case study hightlighting how the teacher has set up the classroom to control daylight levels. The windows are covered with coloured paper and student work.

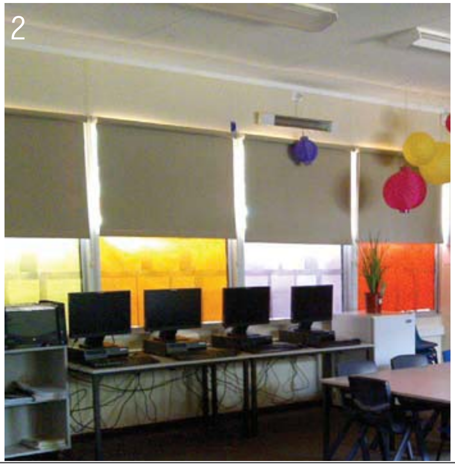
Key Issues>

IEQ: Light

1



2



"...the kids love the daylight but the glare is awful."
[a teacher working in a relocatable, 2011]

"...I use coloured paper to block the sun - it's like stained glass..."
[a teacher working in a relocatable, 2010]

Green Star: Lighting

Daylight – 95% of area has a daylight factor of 2%

Glare – shading which ensures 80% of work surfaces are protected from direct sunlight or where there are blinds and screens.

Lighting – high frequency ballasts and lux levels do not go above 25% of those specified in AS 1680.2.3 1994 table E1 – for a GPC 240 lux. Energy impact of less than 28 kg CO^2eq/year for lighting

Views – 60% of space has views to the outside or an internal atrium

Can you provide diffuse, indirect daylight with artificial light between 240-400lux which can be blocked out when AV equipment is in use?

Light - Natural or Artificial?

There is a significant body of research that identifies the visual environment as one of the most important factors in learning. It effects students' mental attitude, class attendance and performance [Hathaway 1995; Heschong Mahone Group 1999].

However, there is no single approach that can provide universally good lighting. The design of classroom lighting is complex and requires careful integration of artificial and natural lighting systems that consider:

refer 1

- the range of activities or tasks to be undertaken in the classroom and the people who will perform them [Veitch & McColl 1994];
- the site orientation and neighbouring buildings;
- energy efficiency; and
- the integration of new technologies (such as I-Pads, laptops and electronic whiteboards) that have their own built-in light source.

Current Research Australian Case Studies

Data collected on the lux levels of existing Australian relocatable classrooms reveals that the combined levels of artificial and natural light greatly exceed the minimum standards (Graph 1), through a mix of too much daylight or too much artificial light.

In *mini case study 1,* small windows equivalent to 7% of the floor area were found to let in very low levels of natural light. This had been overcompensated for in the artificial lighting design. The 13m x 9m classroom was designed with 36 fluorescent tubes. Over the period the measurements were taken, only 26 of the tubes were in operation. The average lux level across the day was 470lux, with the highest average 655lux. In this space one student commented that the light "hurt" the back of her eyes.

Mini case study 2, with large windows (oriented east/west) equivalent to 40% of the floor area, had an average lux level across the day of 970lux. At one set point in the room the lux level fluctuated from 2750lux (at 8am) to 760lux (at 12pm) to 54lux (at 3pm). Having little to no control of the daylight, the teacher blocked it using blinds, coloured paper and student work.

refer 1

Effective Learning Melatonin & Serotonin

Much of the scientific research on lighting and its effects on people relates to the natural production of melatonin (the hormone that induces sleep) and serotonin (the hormone associated with memory, learning, temperature regulation, mood and behaviour [Kuller & Lindsten 1992]).

Melatonin levels decrease with bright light (both natural and artificial) making people more alert, while serotonin levels increase with daylight but decrease with artificial light, impacting on concentration and attention levels [Ott 1973].

There is inconclusive research on the ability to substitute daylight with full spectrum fluorescent tubes [Tanner 2008; Hughes 1980; Vietch & McColl 2001].

This research may explain why teachers in *mini case study 1* experienced high levels of hyperactivity. The students were alert but unable to concentrate. Teachers in this classroom were responsible for removing fluorescent tubes and explained that sometimes they turned the lights off when they wanted to calm students down.

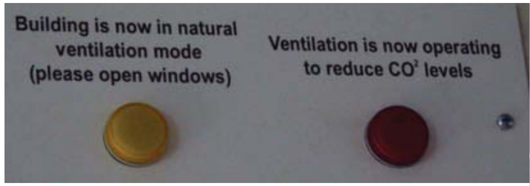
1: Images taken in a classroom by Bendigo Relocatables (www.brb-buildings.com) to inform occupants on how to get the best performance from the building HVAC system.

2. Displacement ventilatiom used by Project Frog (see page 14).

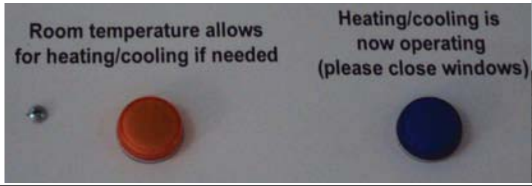
3. Overhead ventilation used by Triumph Modular (www.triumphmodular.com)

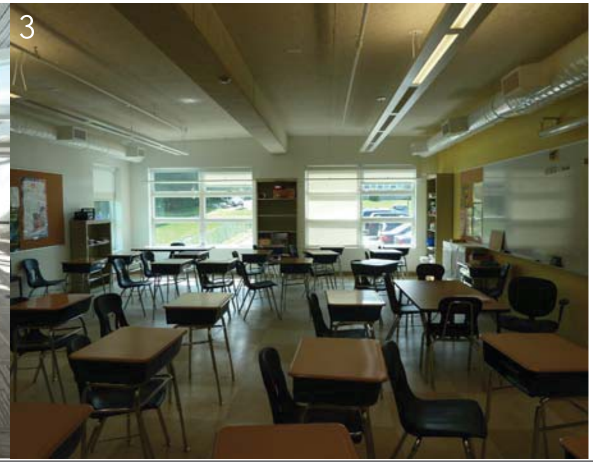
Key Issues>

HVAC systems



Diffent coloured lights are illuminated to communicate the corresponding messages to the building occupants about the HVAC opeartion (Bendigo Relocatables).





Thermal Comfort & IAQ

Research into thermal comfort showed that being comfortable positively impacted on students' performance in terms of attention, comprehension and learning levels [Corgnati *et al* 2007]. This finding is supported by other international research [Seppänen *et al* 2004; Pepler & Warner 1968; Wyon 1970; Wargocki & Wyon 2006 and 2007] which concluded that students were less distracted and less likely to become ill if the classroom environment stayed between the comfort band of 20-27°C.

Research also shows that inadequate ventilation can also lead to a build up of CO^2 levels in the classroom making students feel lethargic impacting on their performance [Daisey 2003; Shorrock 2006].

Reverberation times of no more than 0.4-0.5 seconds; mechanical noise no more than NR40; traffic noise no more than 40dB(A); rain noise no more than 45dB(A)10mm/hr

"Ongoing research and scientific analysis contributes to provide evidence that IAQ [Indoor Air Quality] in schools can cause acute health symptoms,increase absenteeism, and directly and indirectly affect student and teacher performance... experts in the field generally agree that healthy indoor school environments are a necessity if a high standard of education is to be expected."

[GBCA, 2008, Technical Manual Green Star - Education Version 1, Sydney: GBCA, p62]

Acoustics

A holistic approach must be taken to address acoustics. A wide range of internal and external factors such as traffic, plant, lighting, finishes, ventilation system and adjoining rooms impact on background noise and reverberation times [Ecophon 2002].

There is a direct relationship between good acoustics and effective learning [Evans & Maxwell 1997]. Consideration of classroom acoustics is particularly important with changing pedagogical models as they involve more group and project work [Ecophon 2002].

refer 1

Poor classroom acoustics is also attributed to voice disorders and stress amongst teachers [Wakefield 2002, Ecophon 2002].

A reduction in the total area of hard surfaces in a space is key for embedding good acoustics. Careful consideration should also be given to selection of Heating Ventilation and Air Conditing (HVAC) systems. Sound absorbing ceilings and acoustic wall panels also effectively reduce the noise levels experienced in a classroom.

Australian Case Studies

Research into acceptable levels of background noise in classrooms recommends 35dB(A).

Acoustic testing of background noise was carried out in mini case study 3 and the results revealed the sound level to be a 38dB(A). This increased to 43dB(A) with the addition of fans and there was a further increase to a constant 53dB(A) with fans and air-conditioning.

"An increase or decrease by 10dB is perceived as a doubling or halving of the sound level" [Ecophon 2002]

Hathaway [1997] pointed out that an air conditioning unit could be downsized reducing noise if appropriate daylighting (that did not add heat load) was used.

Green Star: Acoustics

If mechanically ventilated and conditioned then 95% of the space must not go over satisfactory ambient internal noise AS/NZS2107:2000.

For a GPC this should be 35 dB(A)with a recommended reverberation time between 0.4-0.5 seconds.

1: 'Eco-Villlages Worldwide' manufactured homes are highly insulated and feature compressed straw panels and decking made from recycled milk bottles (www.ecovill.com.au)

2: Children in an Eco-cubby workshop nominate recycled bricks in their carboard cubby.

3.The waste from two large houses fits into two small skips at Baufritz's factory in Erkheim, Germany (www.baufritz.com)

Key Issues>

Materials, Waste

Materials

refer 4

The materials used is a key consideration for the design and development of relocatable classrooms. There are inherent waste and efficiency opportunities that off-site manufacture presents.

It is important to consider the choice of materials, optimising **re-use** and **recycling** where possible and minimizing embodied energy - but not at the cost of maintainability, strength and longevity.

Examples such as those of Eco Villages Worldwide and Gen 7 highlight innovative use of insulating materials.

Results from monitoring the internal temperatures of *mini case study 4* highlight that current levels of insulation in Australian relocatable classrooms may be inadequate

> Can the design be low in embodied energy (less than 10GJ/m² and be able to be successfully relocated over a life span of 40 years?

Australian Case Studies

In an arid climate on a 43°C summer day, *mini case study 4*, a newly commissioned relocatable classroom orientated north-south with sunshading, R1.5 wall insulation and R1.8 ceiling insulation reached a maximum temperature of 43°C. Meanwhile, an older relocatable classroom on the same site with equal or lower R-values of insulation, orientated east-west with sunshading, reached a maximum temperature of 52°C.

Green Star: VOC

VOC level guidance

- Paint – TVOC walls 14-16 g/L, trim 75 g/L, primer 30, latex 60, one or two pack 140 Other solvent based 200
- Sealants meet TVOC – 50-100 g/L
- Carpets– TVOC 0.5mg/m2 per hour and 4-PC 0.05mg/m2
- Fitouts– TVOC 0.5mg/item/hour
- Formaldehyde – low to no – E0 to super E0
- All materials, refrigerants, insulation materials have a zero ozone depleting potential and green warming potential under 10.

Green Star: Materials

- Use of post-consumer recycled to be 20% or greater;
- Reuse of materials - 2% or greater;
- Minimise Portland cement use; substitute with industrial waste such as flyash; use recycled aggregate;
- Steel should be 50% post consumer recycled steel or be reused;
- Minimise PVC usage;
- Timber should be FSC certified, post consumer recycled or reused.
- Design for ease of disassembly;
- Plan dematerialisation, for example minimise need for painting, ductwork, piping;
- Use durable flooring that is low maintenance, modular, low emission and low impact;
- Joinery and furniture to be low emission, durable, low maintenance, modular and low impact;
- Integrate space for recycled materials and waste materials for recycling.

Waste

There are two vital aspects associated with waste.

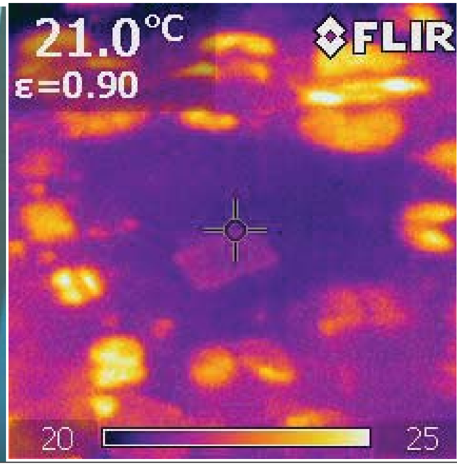
The first is in the design and construction of the classroom itself and choice of materials. (Information on 'emerging' materials is available on page 12.)

Using recycled and reclaimed materials shows an understanding of the value of materials. There is also value in ensuring that benefits in using prefabrication are part of the information that is passed on to the schools and teachers for them to use in their teaching. The German prefabricated timber house manufacturer **Baufritz** limits the waste of two large houses to two small skips (photo 3). **Baufritz has** developed an insulation product that *uses the wood shavings from their own manufacturing processes*.

The second important aspect associated with waste is ensuring that there is sufficient room in the classroom for the collection and storage of recyclables, compostables and materials for reuse.

1 & 2: While exploring heat transfer using the thermal camera, students make a “bum flower” and take a photo of the results

3: Students use environmental monitoring equipment to explore their classroom



3D textbooks>
Hands on learning

Informing Our future ‘Green Ambassadors’

There is a significant opportunity in school design to integrate possibilities for teachers to use the classroom as a teaching tool, to demonstrate environmental responsibility and teach about light, temperature, acoustics, good passive design, materials, etc [Nair & Fielding 1997]

Yet the opportunity for students goes *beyond simply observing* a building’s performance through its integrated monitoring equipment. A most exciting opportunity is to create a *knowing eye* in the students. This means developing a deeper understanding of how a building works, its impact and what they can do optimise its performance, through real *hands-on* experiences [Taylor 2008].

Can the classroom be designed so that the students occupying it can easily access information on temperature, wind, rain, sun, energy usage etc?

Green Star: Buildings as Teachers

Include actual built attributes that demonstrate an environmental benefit relevant to the Green Star- educational credit. For example:

- Easily interpreted electricity meters displayed in classrooms or functional areas showing the impact of electricity use, weather, or time of day on building energy use, or renewable energy source with live data on energy generated and CO^2 reduced
- Equipment providing alternative heating such as solar thermal or geothermal with display of how it works and energy saved
- Clear pipes showing collected rainwater
- Display water consumption, water collection - water saved and other benefits – e.g. costs
- Building elements – e.g. cut-away of wall showing building assembly; framing; linings; thickness of the insulation, etc. Gen 7 clasrooms do this successfully. Refer to page 15 for a photograph.

Green Star: Buildings as Teachers...*continued*

- Include landscaping *within* or *adjacent* to a school boundary. Ensure students manage a natural habitat such as a wetland. This must include a display that shows the building occupants the biodiversity and environmental benefits of the habitat.

NOTE: Signage that informs occupants of what the built attribute is achieveing is an important form of educational material but is not regarded by Green Star as a being an initiative in itself.

Input From the School

refer 1

Designing a building to use as a 3D textbook should involve input from teachers and students. This input will not only assist teachers in understanding what these design initiaves mean in terms of curriculum and teaching opportunities, They will also have their own innovative ideas about what they would like. Consider how you can package some of the documentation about the building together for the teachers. For example teachers could use floor plans to teach about scale and visual literacy.

“…the new building has resulted in lots of questions from students: *why straw bale? why the air lock? why..?* There is clear learning about sustainability happening by the fact that the *building exists* and most importantly it is leading to curiosity”

[a teacher, Thornbury High School 2009]

Green Star: Lifestyle

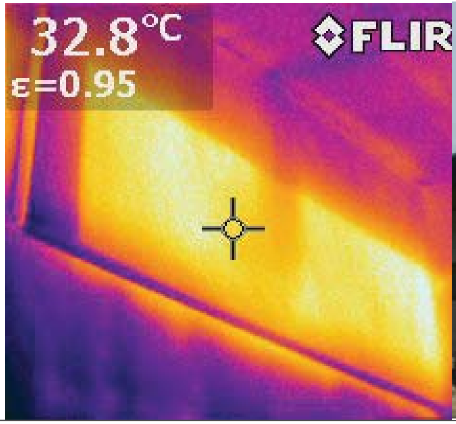
- Energy and health – encourage activity – visible, logical stairways, connection to effective outdoor spaces etc
- Cycling – one or two spaces per 5 students over grade 4 level. Ensure bike storage is safe and weather protected

1: A thermal image taken by a student at Thorbury High School

2: The Environmental Sustainability Centre at Woodleigh School

3: Students at Woodleigh School assist during the building's construction

3D textbooks> Green Schools



"...Students can look up and see the louvres, and understand the cross ventilation strategies. They can see and touch the eco-timber. You can talk concepts all you like but they remain abstract until the students can actually experience them."
[a teacher, Thornbury High School 2009]

Can the design and placement of the building involve student consultation? Is there an educational tool that can be developed to help them understand their building?

Thornbury High School

The provision of a new recording studio and general purpose classroom at Thornbury High School created a wonderful educational opportunity. The classroom was designed as a *'viable alternative to the standard relocatable'* as it could be assembled and disassembled for future relocation (eme designs see builing pictured on page 3).

It was designed using passive solar principles, use locally sourced, sustainable materials was constructed without any metal framing, and was designed to operate comfortably in a temperate climate without heating or cooling.

Students had the opportunity to use quite sophisticated monitoring equipment such as thermal imaging cameras to examine and test the performance of the building. Photo 1 (above). This highlighted to students why closing the blinds avoided heat gain and assisted in keeping the building cool.

The equipment also captured the imagination of the drama teacher. This led to a series of innovative drama performances. This process was fun yet the learning was real and memorable.

Woodleigh School

The school's decision to invest in a new Environmental Sustainability Centre. provided more than just a new building. It provided a series of *hands on* educational opportunities that saw the students involved in its design and construction.

The school ran the project as a series of 8-week sessions that the students could elect to participate in. During these session they collaborated with the designers whose approach during the briefing and concept stage was to let the students think big and then explain the consequence of their requests in terms of materials, waste, energy, cleaning, acoustics, etc.

During construction the students worked with the builder (in a safe, controlled and supervised environment) to build the stumps, platform and straw bale walls.

It seemed that engaging the students in the design and physical labour helped to create a lived or actual understanding of what was going on. This translated into the students having a great respect and understanding of the building.

International Examples

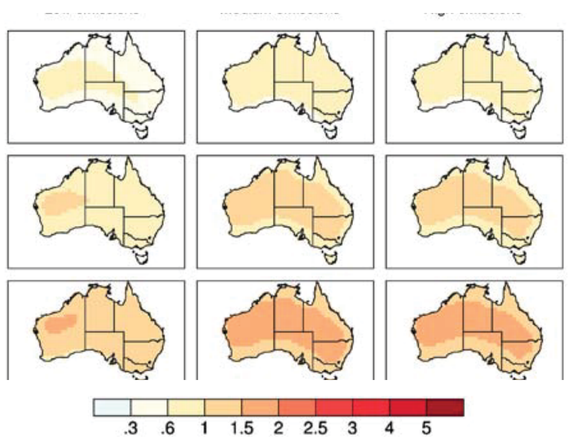
American Modular Solutions (page 15) makes its Gen 7 display classroom available as a venue for workshops on sustainability. One example was the Environmental Stewards workshop where 40 grade 6 students learned how to implement a recycling program at their school. The value of conducting this workshop in the Gen 7 classroom was that students could see first hand how blue denim jeans were recycled for wall and ceiling insulation, providing them with inspiration for innovative approaches.

Project Frog (page 14) contains a monitoring system and dashboard that tracks the buildings energy use, energy generation and environmental quality, both in and outdoors. This is used as an educational tool by students, staff and the community.

"providing a ladder of learning...and a more sustainable society for all"
[Christy Rocca, Director of the Chrissy Fields Centre by Project Frog]

1: A finished Eco-cubby built out of cardboard by children aged 8-12 highlights their emerging understanding of what sustainability is. Students will be active participants in the green classrooms of tomorrow. (www.eco-cubby.com/)
2. Interactive tool on Climate Change
3. St Leonards School, Victoria FMSA Architects (www.fmsa.com.au/)

Big Issues>
Design for change



Green today
- Climate Change
- Efficiency
- Productivity
- Learning Outcomes

Green tomorrow
- Water & Biodiversity
- Neutral to Positive Contribution
- 3D Textbook
- Students as *active participants* and green ambassadors

Introduction

Given the aspirational today/tomorrow scenario (left), the following text elaborates on what this means, and why this shift is occuring.

Water and Biodiversity

Today, central to sustainability are the ideas of climate change and the focus on energy efficiency.

In the future the issues of water scarcity and the protection of genetic diversity through a focus on biodiversity and local specificity will be central. With this will come a focus on producing a world citizen, a student who will actively participate in their own learning and sustainability.

Climate Change

Climate change is a significant issue for designers to consider. Typical weather, temperature, wind, rain and humidity profiles will change but the extent and frequency is still unclear. The central issue for designers is to consider how to make designs robust.

Recent experience in the floods in Queensland showed that the school infrastructure that was the least affected was the relocatable classroom. Generally their elevation about the ground level by around 600mm meant that they were less affected and less undermined by the flood waters.

Summary of predicted changes in the 5 climate zones is shown in image 2 above. Use this tool to look at specific implication for the region for which you are designing[1].

1: Interactive tool published by the Federal Government based on the research published in CSIRO (2007) Climate Change in Australia, Technical Report 2007 http://www.climatechangeinaustralia.gov.au, Accessed 1 May 2011

Neutral to Positive

Future buildings will no longer be asked to look at how efficient they can be, but how they can contribute actively and positively, create more energy, clear the air, collect water, support local biodiversity and support social and ecological regeneration. Main theorists working in this area are William (Bill) Reed, John Lyle, Stephen Moore, Ceridwen Owen in regenerative design and development and Janis Birkeland in positive development.

Another interesting area is that of biophilic design, which is the medical and psychological evidence-based design approach to the integration of biological references to design. From the importance of natural light to views out of windows, colour selection and references to nature, this body of work provides 70 design strategies. In particular, this work links various aspects of the environment to physical and mental health – from photos and pot plants to wilderness.

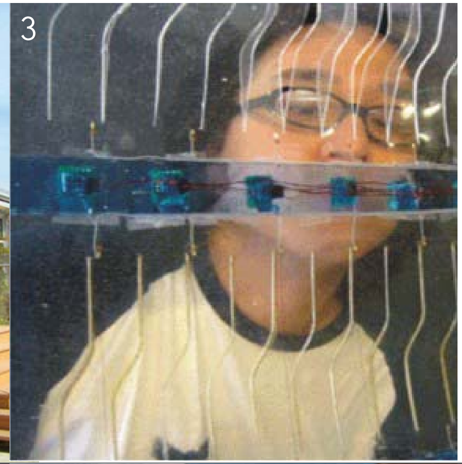
1: Translucent concrete (www.litracon.hu/)

2: Team Montreal Biowall, US Department of Energy Solar Decathlon Challenge 2007 (solardecathlondev.nrel.gov/past/2007/team_montreal.cfm)

3: CO2 Living glass, Soo-in Yang and David Benjamin (inhabitat.com/carbon-dioxide-sensing-living-glass/)

Future Concepts>

New products



Introduction

This summary is not intended to form an extensive list, but rather to motivate readers to research what is ‘out there’ and consider working with a new material or an old material in an innovative way.

Solar Air Heaters

These provide heating in winter passively. To function they need the sun to shine, so looking at solar hours is an important consideration to take into account when specifying this product[1].

Smartbreeze

This is a solar powered ventilation system that can help with passive heating or cooling. These systems have been introduced into the Department of Education and Early Childhood Development’s most recent relocatable classrooms[2].

Solatube Lights

High-performance daylighting systems that use advanced optics to significantly improve the way daylight is harnessed[3].

1 www.resourcesmart.vic.gov.au/
2 www.smartbreeze.com.au/
3 http://www.solatube.com.au/

CO^2 Living Glass

This is a prototype of a glass that senses when there is too much CO^2 and expels it so that you do not need to mechanically ventilate[4].

Paperstone

Made from 100% post-consumer recycled paper and proprietary PetroFree™ resins, PaperStone® is a sustainable solid surface material[5]. Rainstone is the external cladding material.

Cross Laminated Timber

This timber structural panel product[6] - also known as CLT - has been used in Europe for the past 20 years. More recently it has been used on prefabricated building projects in London such as the 9 storey high *Stadthaus Tower Murray Grove* by Waugh Thistleton and the *Kingsdale School Sports and Music Hall* by dRMM Architects. It is used mainly for wall, ceiling and roof construction.

4 www.nbmcw.com/articles/glass/639-living-glass-design-and-health-in-synergy.html
5 www.paperstoneproducts.com/rainstone.php
6 http://www.structuremag.org/article.aspx?articleID=947

PCM Plasterboard

Phase change materials (PCMs) can store much larger amounts of thermal energy per unit mass than conventional building materials. PCM Plasterboard is an exciting example.[7] This allows designers to think about the use of thermal mass (PCM acts like it) and night purge in light weight buildings.

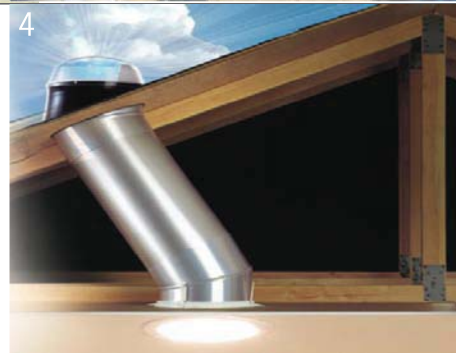
Translucent Concrete

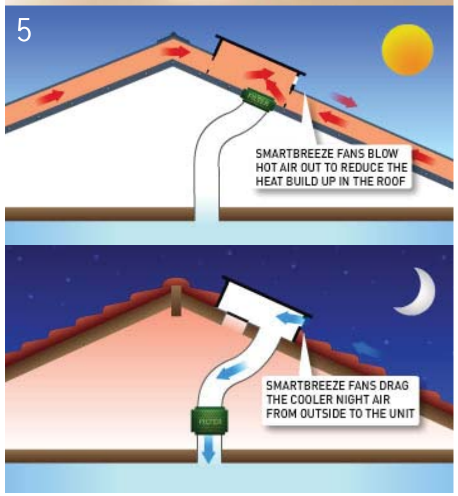
Provides thermal mass while allowing light and connection to external conditions[8].

Bio Walls

Biowalls (living walls, vertical gardens, green facades and green walls) are exterior walls that are covered with living vegetation and used to insulate the building and improve air quality[9].

7 Kendrick, C and Walliman, N, 2007, Removing Unwanted Heat in Lightweight Buildings Using PCMs in Building Components: Simulation Modelling for PCM Plasterboard, Architectural Science Review, Volume 50.3, pp 265-273
8 www.litracon.hu/
9 www.mtnhighinspections.com/biowall_inspection.html





4. Solatube (www.solatube.com.au)
5. Smartbreeze system (www.smartbreeze.com.au)

INTERNATIONAL EXAMPLES:
1: Hunters Point Community Centre, California
Project Frog (www.projectfrog.com)

2: Gen 7 Classrooms, California
American Modular Systems (www.gen7schools.com)

3: Harvard Childcare Centre, Massachusetts
Triumph Modular & Anderson Anderson
(www.triumphmodular.com)

Future Concepts>

New Relocatables

1

2

3

Aspirational Specifications

- Ensure you design in accordance with Class 3 building section F1 of the BCA;
- Appropriate target internal temperature and humidity ranges for different climate zones (*see Victorian specification for example*);
- Provide climate specific vapour barriers for exterior wall construction;
- Ensure adequate continuous outdoor air intake and that this is not located near sources of potential dust, pollen, mould and pollutant problems;
- Ensure that at least one supply air outlet and return air inlet are located in each enclosed area;
- If required, locate HVAC and air handling units as far as possible from teaching areas to reduce noise;
- Provide efficient HVAC air filters for reduction of: airborne dust, pollens and micro-organisms from re-circulated and outdoor air streams;
- Ensure easy access to HVAC ducts for inspection and cleaning;
- Locate classroom away from locations where: (a) vehicles idle, (b) water accumulates after rains, or (c) there are other major sources of air pollution.
- Provide user-controlled ventilation such as operable windows. Include insect screens and operable shading where appropriate (*see Victorian specification for example*).
- Consider covered entries with an exterior entry mat.
- Low VOC emitting building materials to be used throughout (*see Victorian specification for example*);
- Specify complete documentation of operation and maintenance requirements.
- If possible think about effective ways of linking multiple classrooms
- Ensure that energy use and temperature can be monitored and displayed
- For general classrooms provide Lux levels of 320 (AS 1680), with a maximum power density of 8W/m2 and Lumens per Watt of 40 (BCA2010)
- Special-use classrooms - chemistry, biology, fine arts, etc - to have local exhaust ventilation and appropriate ventilation rates.

Relocatables, Victoria: Current Best Practice

Insulation: walls R2 and ceilings R4, floor R1.5 weather protected: Inorganic insulation materials must be biosoluble with an ozone depleting potential (ODP) of zero;

Glazing: U-Value 3.7W/m2, SHGC 0.51; TVLT 0.57 – Argon double glazed with 4mm energy advantage outer skin and thermally improved frame;

Ventilation – Smart breeze solar powered ventilation system set to 21°C

Temperature: Internal range from 19°C to 26°C; cooling when room and outside above 27°C and and heating when room and outside below 19°C; managed by a reverse-cycle air-conditioning system with a cooling capacity of 7kW and heating of 8kW, piping insulated with material with an ODP of zero.

Carpet: VOC – 0.5mg/m2 per hr: 4-PC 0.05 mg/m2 per hour; TVOC 50 g/L

Rainwater: able to be collected via 100mm HDPE pipe

Paint: low VOC (depending on type below 75 g/L)

Acoustics - Reverberation times no more than 0.7 seconds at 500Hz; mechanical noise no more than NR40; traffic noise no more than 40dB(A); rain noise no more than 45dB(A) at 10mm/hr; average noise over 8 hrs period not to exceed 85dB(A) – with no peak greater than 140 dB(C)

Monitoring: Innotech Maxim III, temperature range set at 19-26°C and CO2 controlled if above 600ppm

Sensors: Light and fan sensors off after 15 mins of no movement; perimeter lights only on if below 350 lux and turn off when over 500 lux

1: Hunter Point roof overhang

2: Hunter Point interior with clearstory windows and high ceilings

3: Hunter point roof with 7.2kW solar PV

For more information visit http://www.projectfrog.com/

Case Study 1>

Project Frog

Overview

Project Frog is a design, supply, sales and marketing team based in California that was founded on the notion that there is a better and healthier alternative to traditional portable classrooms.

FROG stands for Flexible Response to Ongoing Growth.

Project Frog utilses a kit-of-parts approach to design and construction, as described in the prefabrication brochure.

Project Frog has four pre-approvals with the Division of State Architect in California, enabling permits for new buildings using the Frog kit to be quickly and efficiently obtained. The Frog at Crissy Field will apply for LEED Platinum and the Frog at Hunter's Point will apply for LEED Gold.

Life Cycle Assessment

A life cycle assessment shows that over a 50-year building lifetime, a net zero energy Frog causes approximately 87% less fossil fuel use, 85% less climate change, 82% less air pollution, and 73% less water pollution than a comparable average building with average energy use.

Design Refinement

One of Project Frog's points of difference is the ongoing research and refinement that goes into the design and supply of Frog buildings. One of Project Frog's aims is to continue to ungrade the product without driving up the price.

The move from Frog 2.1 (Crissy Field) to Frog 2.2 (Hunter's Point) saw energy efficiency increase by 22% while the cost decrease by over 20%.

Some of these changes include:

- deeper roof overhangs to address glare (from 2ft to 3.5ft),
- higher ceilings to esentutate the sense of space (from 8.3ft to 9.3ft at the lowest point), and
- removing columns for flexibility, reduced the amount of steel by 20%

The next version of buildings will include film insulated glass that will reduce the u-value of the glass from 0.26 to 0.17 and the heat gain coefficient from 0.27 to 0.2.

Acoustics

Project Frog has an ongoing relationship with its product manufactures as this creates opportuities to be innovative. Frog 2.2 features Epic acoustical ceiling panels.

This solution provides an aesthetically pleasing design - with significant noise reduction. The panels also offer exceptional light reflectance, reducing the number of light fixtures needed and cutting down on energy use and eye strain. The result is a healthier, brighter and quieter learning environment.

The panels are also structural which makes for a simpler building assembly. Further information on the acoustic treatment can be found at www.usg.com.

Materials & Waste

Frog Buildings use materials with recycled, renewable and re-used content. A Frog generates one fifth of the waste of a conventional construction site and of this waste, 80% is deverted away from landfill.

Thermal Comfort

Frogs use an underfloor heating and cooling air distribution system with air vents built into the floor tiles than can be repositioned, giving flexibility. The walls have a thermally broken stud with an R19 insulation value. The ceiling insulation is R30. (Australian equvalients R3.3 & R5.2)

Energy Efficiency

The combined lighting, heating and cooling requirements of Frog V2.2 is 57% less than the 2008 Californian Energy Code. To minimise solar gain and maximise energy efficiency a cool roof membrane is used to reflect heat. A 7.2kW Solar PV array is used on the roof at Hunter's Point to generate electricity.

Window Design

Project Frog is designed with large areas of glazing and clerestory windows to let in indirect light. The manually operable windows are position to enable natural cross ventilation.

Water

The rooftop rainwater catchment system at Crissy Fields offsets 86% of water needed to flush toilets.

1: Gen 7 Classroom, California
Wall section showing range of materials

2: Gen 7 Classroom, California
Building Section (www.gen7schools.com)

For more information visit
http://www.gen7schools.com/

Case Study 2>
Gen 7

Overview

American Modular Systems (AMS) is the company behind the creation of Gen 7, a modular classroom that combines the cleanest materials and latest technology to promote sustainable practices and effective learning in schools, while remaining an affordable and low maintenance solution.

The Gen 7 classroom is the result of $200,000 investment and 2.5years of research and development by AMS.

The building design has been developed with pre-approval by the Department of State Architect and has pre-certificated by LEED (Leadership in Energy Efficient Design) and CHPS (Collaborative for High Performance Schools), giving clients full confidence in the 'green credentials' of the product, while shortening the length of the approvals process.

The Gen 7 has been modelled across all 16 climate zones in California and the thermal design exceeds the 2008 California Energy Code by more than 26%, equating to $100,000/year in direct savings for schools through lower maintenance and running costs. With a 6kW Solar PV array on the roof overhang the classroom is grid-neutral.

Scalability

The base product is a single storey rectangular classroom comprised of 10x32ft or 12x40ft module.The overall classroom size can be adjusted by the number of modules that are connected together. A standard classroom in the USA is 960ft. There is also a range of customised options. These include a range of automated systems, exterior finishes and 6kW photo voltanic array (attached to window overhang). AMS have a 2 storey product in development.

Delivery & Community

Because Gen 7 is manufactured off site and delivered to the site more than 90% complete, the project can be completed in 90days. This minimises site disturbances such as noise and dust (which can impact on the IEQ of neighbouring buildings) and lowers demands for energy and water at the project location. Off site manufacture also allows AMS to eliminate material waste by recycling it in the factory and reduces transport emissions by ordering in bulk. A high percentage of fly-ash is used in the 6inch concrete slab, providing both thermal mass and rigidity without adding extreme weight that would challenge transport.

Lighting

The classroom uses 90% natural daylight which translates to an 80% saving in energy. This is achieved using tubular skylights (with adjustable light damper), large low E double glazed windows and energy efficient dimming lights that are programmed to respond to external conditions. The occupant can override the sensor and choose to activate 50% or 100% of the lighting, where 50% controls one lamp per fixture (not 50% of the whole room). The large expanses of glazing are well controlled by generous overhangs and automatically controlled blinds. The standard option has glazing to 700mm above floor level, and there are options for the glazing to come down to the ground, so younger students can see out. An AV switch automatically prepares the room for use of overhead projection.

Materials

The chosen materials are low maintenance, either contained recycled material or recyclable and have no or low VOCs. The project achieved 100% recycled mineral-board sheeting for roof and wall backing, 80% recycled content in the steel and 100% recycled denim for insulation.

Insulation

The building has R32 wall insulation and R40 ceiling insulation (approx R5.6 and R7 equivalents in Australia). The innovative use of recycled denim for insulation has an engaging aspect of the building for the students occupying it.

Acoustics

The classroom achieves a constant 35dB(A). The roof is angled with a suspended ceiling (layered with acoustic treatment) that is pulled away from the wall edge, to improve acoustics. At the lowest point, the ceiling is suspended 8ft 6inches and is 10ft at the highest point. ER3 carpet tiles absorb noise.

Thermal Comfort

The Thermal Displacement Ventilation (TDV) system used in the Gen 7 provides 100% fresh filtered air to the students at a low velocity. A CO_2 sensor communicates when oxygen levels are low. Sensors on the doors and windows switch the TDV from mechanical to natural ventilation mode when doors and/or windows have been open for 15minutes. The system saves 35% in energy and is extremely quiet, having no detectable impact on acoustics.

1-6: A compilation of responses from Queenskand primary school children, aged 9,y.o, on how they would design a classrrom, what makes them comfortable inside their classroom and what they would change about their current classroom.

1
I feel comfortable in a classroom when it is raining outside and the pitter-patter makes me feel calm.

2
I feel comfortable in the classroom when.......
I sit on my chair.
When I talk to my friends.
When It's QUIET

3
I feel comfortable in class room when I'm doing work and seeing friends at School.

4
I think we can change my classroom with a toilet.

5
We should have diso lights.

6
I don't feel comfortable in the class room because it's boring and to hot.

References>

Further reading

"Though educational researchers have in the past theorised that views out of windows cause unnecessary distractions for children in the classroom, recent research by educational psychologists stresses the importance of a stimulating visual environmental to the learning process. Views to nature are believed to improve attention span... improve learning results ... and reduce eye strain."
[GBCA, 2008, Technical Manual Green Star - Education Version 1, Sydney: GBCA, p144]

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