FUTURE
PROOFING
SCHOOLS

Future **Proofing** **Schools**

The Phase 1 Research Compilation




Alparra Remote Community School, Northern Territory

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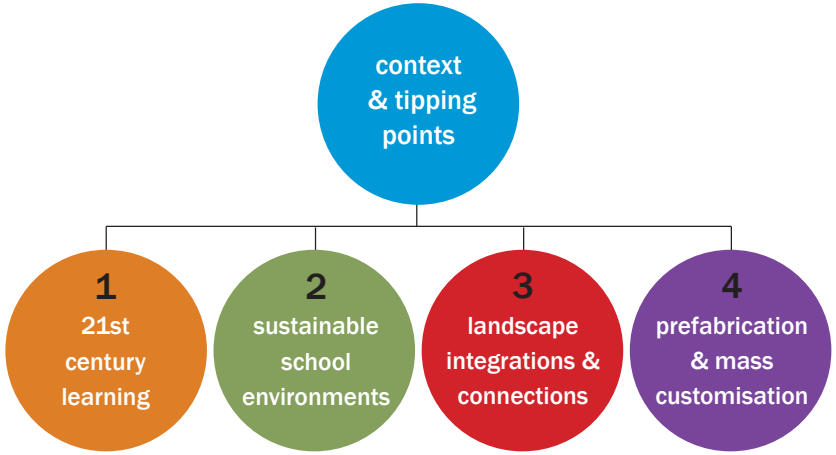
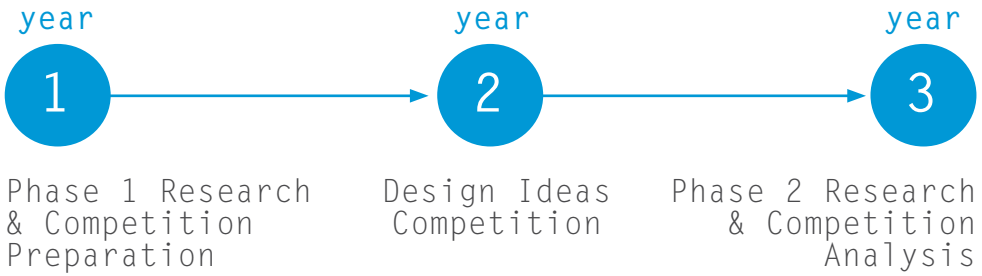
Contents





Future Proofing Schools

The research context

Future Proofing Schools is an Australian Research Council funded research project that is working with six education departments across Australia and other Industry Partners to re-vitalise 'relocatable classrooms' as 21st century learning spaces.

Our research suggests that we have an unprecedented opportunity to benefit from a range of 'tipping points' in sustainable school design, 21st century pedagogies and emergent technologies in manufacturing that will allow us to transform the notion of the relocatable classroom.

An Ideas Competition

A unique research strategy has been the inclusion of a Design Ideas Competition. Occurring midway through the three-year ARC Linkage Project, the competition was proposed as a way to leverage research outcomes by inviting design professionals and students to apply our Phase 1 findings as published in this document.

The competition was structured to encourage future proofed solutions which move beyond current practices into tipping point possibilities within the multiple disciplines of education, sustainability, design and manufacture.

Further information on the Design Ideas Competition can be found at:

www.futureproofingschools.com

This Compilation

The inter-disciplinary research team includes architects, educators, landscape architects, and sustainability specialists. and this Compiliation comprises outcomes from the four major research topics that were explored during year 1 of the research programme.

The four topics were important elements of the the Competition Brief:

- 21st Century Learning
- Sustainable School Environments
- Landscape: Integrations & Connections
- Prefabrication

They highlight trends, best practice and possibilities for innovation; they act as a springboard for design ideas.

Relocatables Today

"There'd be no school here at all if it wasn't for these relocatables…"
[Remote Community School, Northern Territory]

"We've worked really hard to improve their comfort but yes, they do still look quite agricultural…"
[Department of Education]

"Teachers and students are getting used to the innovative spaces of our new permanent buildings. It's really hard to then work in a relocatable…"
[A teacher, anonymous research interview November 2010]

An Overview

Relocatable classrooms have been used for decades within the Australian Government school system – and internationally – to respond rapidly and economically to changing school enrolment levels, to deal with remote community needs, and to cope with disasters such as our recent fires, floods and cyclones. They are an agile and sustainable solution as buildings can be moved and follow demands.

Yet these classrooms have been typified by their utilitarian appearance, poor connection to outdoor spaces, and less than ideal indoor quality – for example problems with glare, acoustics, temperature, or carbon dioxide levels.

While Australia has gained international recognition for the quality of its permanent educational buildings funded through the recent Federal Government's **Building the Education Revolution** [BER], the same attention to design thinking has not yet been applied to relocatable classrooms.

Students spend up to 15,000 hours at school, and relocatable classrooms currently accommodate up to 30% of Australian students in some states.

Why relocatables?

Relocatable classrooms are an important, **planned response** to a number of scenarios:

Disaster response
Relocatable classrooms provide a rapid response to infrastructure provision in the aftermath of events such as fires, floods and cyclones.

Remote communities
Relocatable classrooms create part or entire schools in remote areas where there is a shortage of skilled trade labour. They play an important role in providing education to remote and indigenous communities.

Mining communities
Mining communities swell and contract in response to resource booms, and relocatables allow communities and schools to respond swiftly to these fluctuations.

Changing Demographics
Relocatable classrooms allow for an agile, sustainable and economical response to Australia's rapid population growth and shifting demographics. Buildings can be moved and follow changing demands.

The problem?

Many of the issues with today's relocatables stem from the challenges faced by a generic, mass produced product that is required to perform in a wide variety of contexts.

Yet they are not specifically customised for any of these contexts, and are generally a 'one size fits all' response.

Some of the most common problems relate to:

- Environmental performance
- Indoor air quality
- Lightweight building envelope
- Floor level disconnect from outside
- Placement on school site
- Window size and positioning
- Utilitarian appearance
- Finite space
- Adaptability

How can we better deal with local contexts and transferability?

How might we address these problems by future proofing through design?

Context

Relocatable classrooms require a high degree of transferability:

>from one climate zone to another;

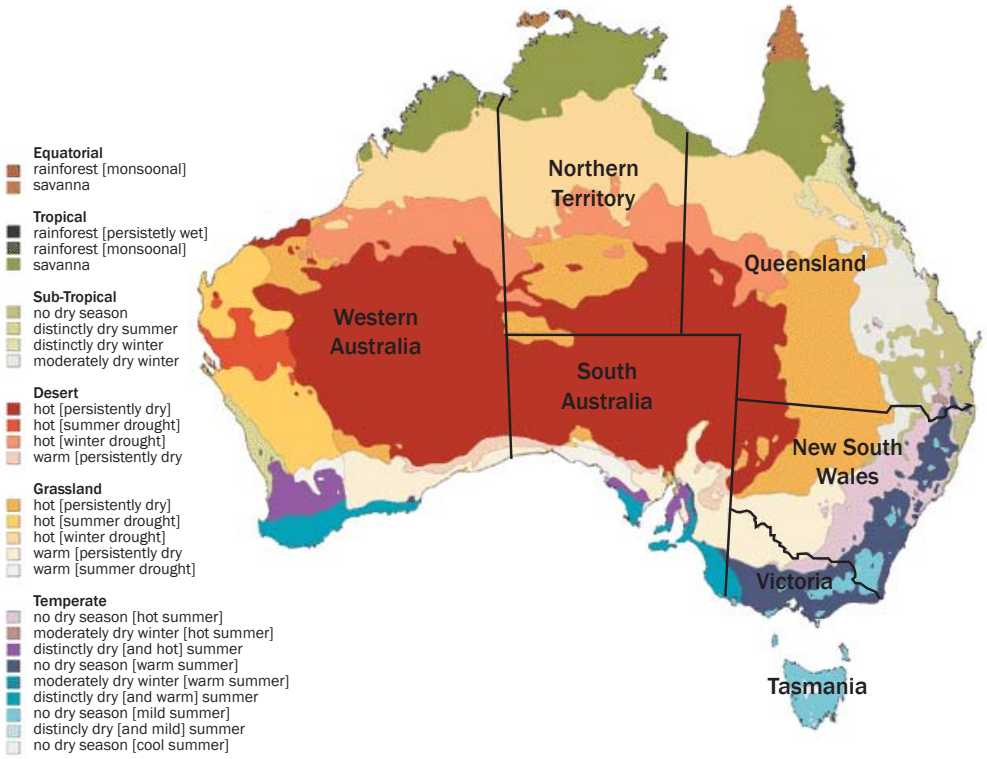
>to a wide variety of physical and cultural contexts; and

>to support a wide range of teaching and learning styles.

Climate Zones

Map adapted from the Australian Bureau of Meteorology

Koppen Climate Classification System



Population Density + Major cities

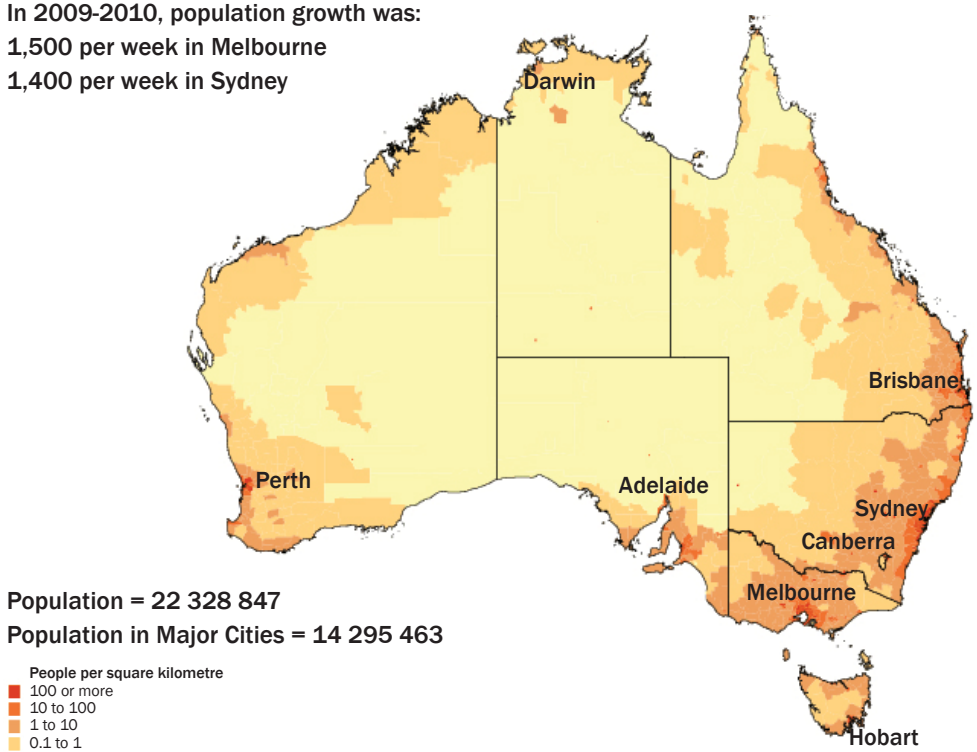
Map and figures from the Australian Bureau of Statistics

Figures from June 2010

In 2009-2010, population growth was:

1,500 per week in Melbourne

1,400 per week in Sydney



Population = 22 328 847

Population in Major Cities = 14 295 463

People per square kilometre
- 100 or more
- 10 to 100
- 1 to 10
- 0.1 to 1
- less than 0.1

Tipping Points

We have an unprecedented opportunity to benefit from 'tipping points' that are set to revolutionise the design and manufacture of relocatable classrooms:

"Relocatables... at their best they can be described as cheap and cheerful – but they aren't always cheap and often aren't too cheerful. It's time to get some proper design thought applied to the problem..."

Professor Alistair Gibb, Loughborough University, research interview November 2010]

a

Traditional Teaching
> teacher centred
> directive
> passive
> chalk + talk

→

21st Century Learning
> student centred
> self-directed
> experiential
> new technologies

b

Sustainable Design
> efficiency
> productivity
> climate change
> learning outcomes

→

Regenerative Design
> neutral to positive
> buildings as 3D textbooks
> biodiversity issues
> students leading action

c

Mass Production
> generic products
> generic client
> generic site
> manufacturer-led

→

Mass Customisation
> customised solutions
> adapted to client
> adapted to site
> design-led

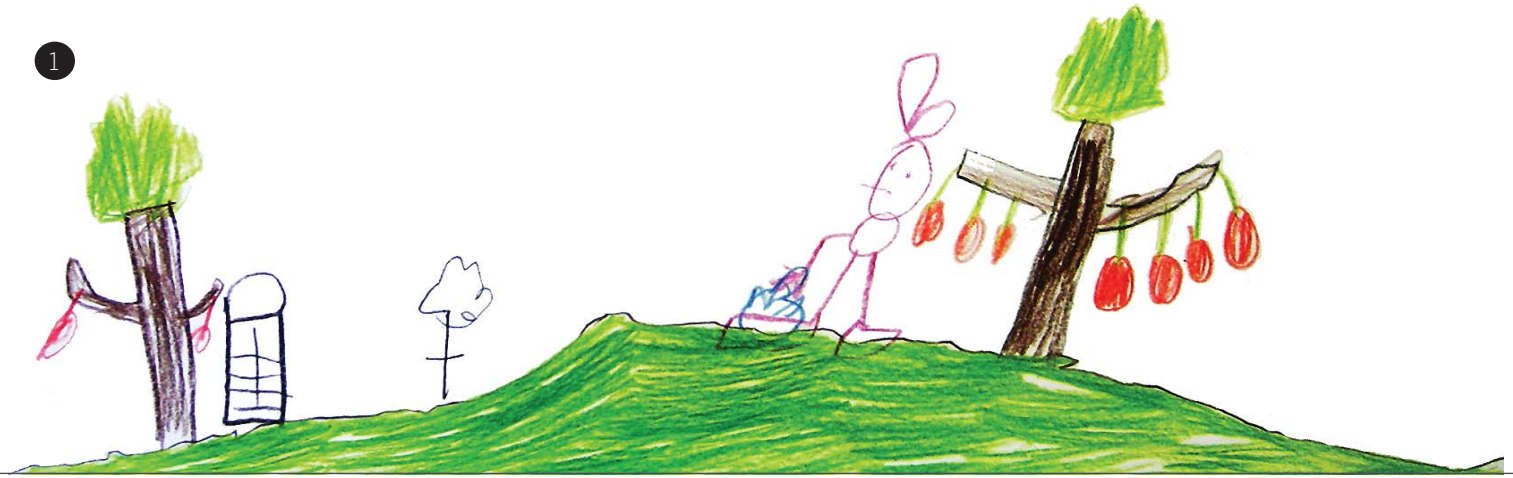
"Today's reality must not limit tomorrow's possibilities"

"You could learn well in it [a colourful, funky, modern classroom], cos the main reason for kids coming to school is cos it's comfy and warm and fun, and most kids don't want to come to school cos they think it's boring."

[Primary School Student, focus group in WA]

1. 21st century learning

Contents >



Introduction >

There are many factors that drive change within education in today's rapidly changing and increasingly complex world. These include the combined effect of government policy, economic imperatives and social trends along with new technology, sustainability issues and changing pedagogies.

Since the late 18th century we have moved from a production-based, through a service-based, to a knowledge-based economy. The implication of this is that businesses now require agility, creativity, ingenuity and collaboration of their workforce. Educational policy around the world is reflecting these new market demands.

Learning spaces that support the development of these skill sets need to be agile, inspiring, supportive of effective teaching and learning and inclusive of the broader community and other cultural and educational organisations.

This brochure outlines the context and key concepts of 21st century learning as they apply to the design of learning spaces and in particular, relocatable learning spaces.

1] Student art, Buranda Primary School, Qld
2] Primary school classroom

Learning >
What is it?

Scientific observation has established that education is not what the teacher gives; education is a natural process spontaneously carried out by the human individual, and is acquired not by listening to words but by experiences upon the environment.

[Maria Montessori 1947]

1] McKinnon Primary School, Victoria
2] Marymede College P-12, Victoria

Learning

Young people learn in various environments and physical locations - in the neighbourhood and in classrooms. They learn when they play, when competing at sport, and through experiencing curriculum materials. Learning experiences are shaped by adults, peers, and access to books, television and the internet. It is also the result of the complex interplay between the child's body, diet, family life, and degree of security.

Today's emphasis on collaborative, interdisciplinary and self-directed, personalised learning reflects a much broader and subtler view of learning than the 'chalk and talk' alternative. As globalisation and societal changes transform the world we live in, the demands placed on learners and our education system are changing to reflect this. At the same time, our understanding of learning itself is changing.

OLD ASSUMPTIONS	NEW ASSUMPTIONS
Learning only happens in classrooms	Learning happens everywhere
Learning happens at fixed times	Learning happens anytime
Learning is an individual activity	Learning is very much influenced by the social environment
What happens in classrooms is fairly much the same from class to class & day to day	Differences in course goals & teaching methods from day to day & course to course require purposeful spaces
A classroom always has a front	The activity determines classroom configuration
Learning demands privacy & removal of distractions eg windows	Openness & stimuli aid learning: windows provide light & a sense of openness
Flexibility can be enhanced by filling rooms with as many chairs as will fit	Movable furniture/equipment is a key factor in adapting spaces to activities & teaching modes
One teacher per class	Collaborative teams & team teaching
Separate single classrooms	Multiple, reconfigurable, linked learning spaces

[Source: Paraphrased from J.Martin 2005]

Research on learning styles, formative assessment, multiple and emotional intelligences, constructivism and so on have combined with the rapid development of technology-enabled, peer-to-peer self-directed learning to facilitate very different approaches to the 20 students in rows model. [Higgins et al. 2005]

Schools today >
Old and new


1


2


3

OPPORTUNITY:

To design innovative relocatable learning spaces that integrate complex and conflicting briefs into finely resolved behavioural settings, which support new modes of learning.

[Clare Newton 2011]

1] Boys School, Victoria, circa 1920
2] McKinnon Primary School, Victoria
3] Wooranna High School, Victoria | Mary Featherston Design

Designing Today's Schools For Tomorrow's World

Many existing schools are still based on the 18th and 19th century factory model. These schools embody the concepts of conformity, formal teacher-centred, explicit teaching and a hierarchy of subjects. From a physical perspective, the traditional classroom was arranged like an egg crate. This historical model has been associated with an emphasis on control of students and on teacher-centred, lecture-format learning. Today, we look beyond this traditional template of learning to a more interactive, collaborative and inquisitive student-centred approach to learning. However, while pedagogical changes are taking place within the classroom, the design of new learning spaces is only now beginning to catch up.

During the past decade, the academic community has seen a strong emphasis on learning rather than teaching, and new learning spaces must allow for interactive, formal and informal, and peer-to-peer learning experiences. The traditional 'lesson' has not been done away with, but is only one of the numerous ways that students will engage in learning. The new learning paradigm necessitates that the entire school be a learning environment rather than a set of rectangular enclaves with a specified number of seats for focussed and approved activities.

Many education departments and school leaders are now promoting new pedagogical practices and require facilities that will enable the new collaborative and experience-based learning approaches to occur.

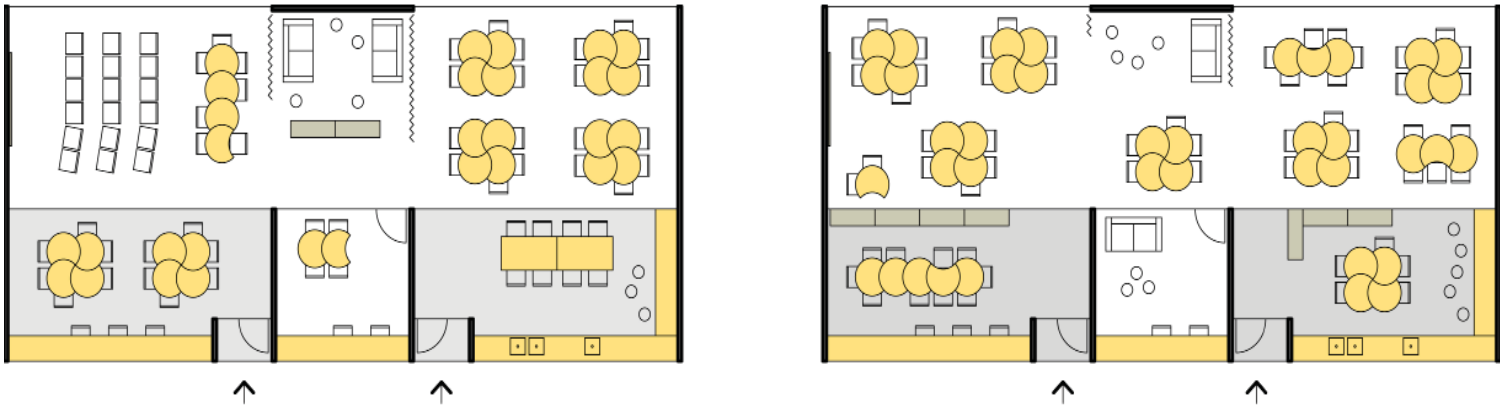
1. In February 2009 the Australian education and design industries began an intense period of activity and discussion when the Federal Government announced the $42b Nation Building - Economic Stimulus Plan. A major component of the plan was a $16.2b Building the Education Revolution (BER) but the media statements focused on the need to create jobs in response to the Global Financial Crisis. Funds needed to be spent (and workers employed) quickly. There was little time for State education departments to work with architects and schools to design spaces suitable for the rapidly changing education environment. Instead, education departments around Australia were required to offer schools a limited choice of Template designs or 'shovel ready' projects which could start on-site within six months of the funding announcement.

Building the Education Revolution [BER][1]

The Federal Government's BER funding focussed on the provision of permanent buildings - many being 'templates'. However, many schools chose to spend their funding on relocatable classrooms as they were in great need of additional learning spaces and could not afford permanent buildings.

There is a vast array of vintages and models of relocatable classrooms currently in use. Older models are gradually being phased out, but this will take time to complete. One issue this raises is that different models and vintages cannot be easily co-located to create multi-unit learning centres or hubs.

There are many variables around the provision of relocatable classrooms across Australia. These include: climate-related issues; site conditions; locations in suburban, rural and remote communities; transportation; and the availability of skilled labour.



Examples of existing double relocatable classroom furniture layouts which accommodate individual, small group and large group activities

Many classrooms feature a speech intelligibility rating of 75% or less. That means listeners with normal hearing can understand only 75% of the words read from a list.

[Mark Waldecker 2006-08]

Basic Needs

Children are ready to learn only when basic needs such as food, water, warmth, toilets and security are met. In addition to these basic needs, other qualities are important in an ideal learning environment. These include natural light, thermal comfort, indoor air quality and non-toxic materials.[2]

A major consideration and concern for both educators and students is acoustics. Many children, notably indigenous children, have both temporary and chronic hearing issues. A child who cannot hear in class will lose interest very quickly.

Good acoustics reduce teacher absenteeism due to vocal fatigue and repeat instruction whilst at the same time, improving attention spans and educational outcomes.

2. See 'Sustainable school environments'

Creativity & The New Learning Models

21st century learning spaces must be agile, able to be easily reconfigured to engage different kinds of learners and teachers, and able to accommodate individual, small group and large group activities.

Current and future economies depend on innovation and creativity, skills that need to be encouraged. For true innovation and creativity to occur, learning spaces should facilitate people working collaboratively across disciplines. Spaces should allow teachers and students to group and regroup and classes to be easily reconfigured (Robinson 2009).

Gardner's theoretical work in the 1980s was important in that it broadened teachers' concepts of students' cognitive abilities to include spatial, linguistic, logical-mathematical, bodily-kinaesthetic, musical, interpersonal, intrapersonal and naturalistic skills. His 'frames of mind' or 'multiple intelligences' helped educators understand that people have preferred ways of learning, and a variety of skills and talents. Traditionally, schools had mainly focussed on fostering mathematical and literary skills.

In 2007 Gardner outlined five cognitive abilities he believed would need to be cultivated, lead to useable knowledge and be sought by leaders in the future. They are useful guidelines for thinking about education in the 21st century:

- **The Disciplinary Mind**: the mastery of major schools of thought, including science, mathematics, and history, and at least one professional craft
- **The Synthesizing Mind**: the ability to integrate ideas from different disciplines or spheres into a coherent whole and to communicate that integration to others
- **The Creating Mind**: the capacity to uncover and clarify new problems, questions and phenomena
- **The Respectful Mind**: awareness of and appreciation for differences among human beings and human groups
- **The Ethical Mind**: fulfilment of one's responsibilities as a worker and as a citizen.

I believe that the school is primarily a social institution... I believe that education, therefore, is a process of living and not a preparation for future living.

[John Dewey 1897]


1


2


3


4

OPPORTUNITY:

To integrate adjustable display space into relocatables. This includes wall space along with hanging ceiling display options. Primary schools require more display space.

OPPORTUNITY:

To design the building as a teaching tool with monitors and technologies visible. Students today take a great interest in sustainability which is now integrated into curricula across Australia.

1] Glamorgan Primary School, Victoria
2] Wiluna Remote Community School, WA
3] Hen, Buranda Primary School, Qld
4] Markers, Currumbine Primary School, WA

3. See 'Landscape integrations & connections'

Creativity and The New Learning Models [cont'd]

Changes in society and the unknown future challenges and technologies facing learners have led to the need for what can be described as anywhere, anytime, ubiquitous learning (Cope & Kalantzis, 1999) and problem solving approaches. Twenty-first century learning theories emphasise the importance of authentic learning and providing students with opportunities and spaces to develop their creative and critical thinking skills (Newton & Fisher, 2009; McGuinness, 1999 & 2010). Learners will need to develop skills to analyse and respond to authentic situations through inquiry, imagination and innovation.

New pedagogies, including problem and inquiry-based learning approaches, require students to plan and organise their learning activities with their peers, to tackle big ideas, become technologically literate and develop cultural awareness.

A learning environment aided by learning technologies and rich in evocative images and objects, triggers active learning by allowing students to engage with what appeals to them. The community, the landscape and faraway places can be brought to the classroom enabling a rich cultural diversity to be explored. The acknowledgement and visual stimulus provided by the display of student work in this digital era is important, and display space is a high priority with educators, particularly those working in primary schools.

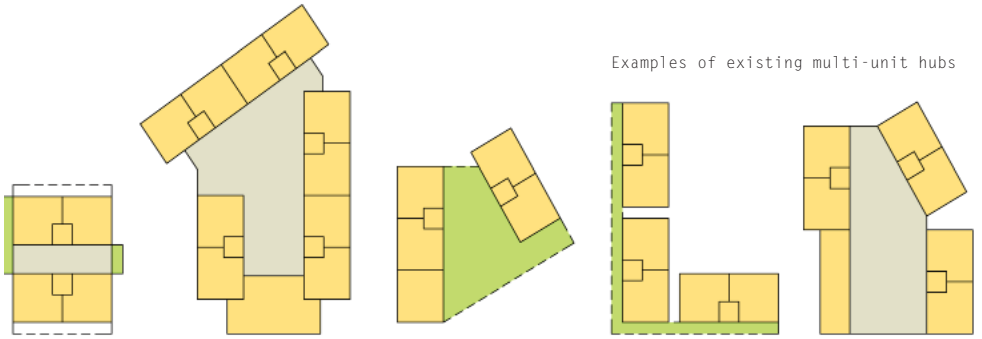
Integration & Connectedness

Today there is a general trend towards integration and 'connectedness' in schools:

- **Of subject areas**: teachers now teach in teams, and subject areas are integrated into project-based activities. Integrated curricula are designed for greater engagement and relevance to the external world. For young people to learn, they must first be engaged and this means putting the 'fun' and challenge back into learning.
- **Within classrooms**: new collaborative, shared, interconnected spaces that allow team teaching are being created with operable walls. Visual connection also provides a sense of connection within a space.
- **On campus**: the boundaries around classrooms are being blurred as learning opportunities on the entire school campus are being discovered. Learning spaces now extend onto decks adjacent to classrooms, and to covered outdoor learning areas, wetlands and kitchen gardens. Fluid movement between indoors and outdoors facilitates the use of these spaces for social, formal and informal learning.
- **With the community**: the boundaries around schools are also becoming blurred and there is much greater interaction with the community both through the involvement of parents and proactive initiatives on the part of teachers. Much of what is important with regard to learning happens outside the school – in the home and community.
- **Into the landscape**: whole school campuses are now being carefully planned to create cohesive, workable environments that meet the needs of current and future cohorts. New buildings, both permanent and temporary, are integrated into the existing school landscape. Relocatables are no longer just 'stuck out the back'.[3]

OPPORTUNITY:

To design relocatables that can be integrated into multiple school landscapes, and different site and climate conditions as they are moved from one location to another.



Examples of existing multi-unit hubs

OPPORTUNITY:

To facilitate the use of deep verandas, covered decks or walkways as extra classroom space, break-out zones, sheltered bag storage and undercover social spaces in harsh weather conditions.

One of the reasons I want to go to the new school is because I heard there was going to be a wetlands with lots of frogs.

[Primary School Student, Regional Victoria]

We require spaces better suited to different types of activities - even within a single period there might be a 10 minute lecture then you might group them or send some to reading nooks. It would be great to have a space where you could divide the time into different types of activities to suit different learning, kids and cohorts.

[Educator, Secondary School, Victoria]

Multi-unit Configurations: Hubs & Learning communities

In many cases, such as in remote areas or following a natural disaster, relocatables will be clustered or co-located to create entire schools. In other cases, they will be used to create 'Learning Communities' or hubs for large student cohorts and their teaching team. A Year 9 home centre for 250 students and staff, for example, might comprise five double classroom units an associated covered outdoor learning area, a shared learning space, a withdrawal space, toilets, and a shared resource area.

Learning communities or neighbourhoods should be holistic, democratic and convivial environments comprised of multiple, purposefully designed learning settings. A balance must be attained between purposeful design and flexibility with special facilities such as wet areas, performance space and ICT integrated (Featherston 2010).

Indoor Outdoor Connections[4]

Educators around Australia are asking for better connections between indoor and outdoor spaces. As children learn through their senses, they need to interact with their environment through exploration and experimentation on a physical, social and cultural level.

A primary school in metropolitan Queensland uses a kitchen garden adjacent to classrooms to teach students about food plants and how to grow them, nutrition, the seasons and natural cycles. Students also run a small kitchen garden shop where parents can buy fresh produce and the students apply maths, accounting and commerce.

David Suzuki says that the biggest thing children need today is to reconnect with nature (2009). This is especially important in a world where the vast majority of people live in cities. A growing body of research links mental, physical and spiritual health directly to our association with nature (Louv 2008). Concerns around childhood obesity, nature deficit disorder, awareness of the relationship between wellbeing, the ability to learn and environmental health, underpin the importance of indoor outdoor connections in schools.

OPPORTUNITY:

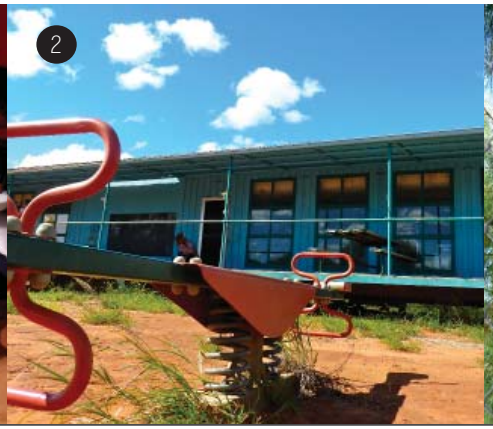
To design relocatables that are readily co-locatable.

...and ease of connection with the exterior so you could easily run activities outside, or inside and outside concurrently. I teach a variety of subjects and I've often run activities outside, but it's a major exercise to get everyone all packed up and moved outside in a traditional space. On a stinking hot day, you may as well be outside because there is a bit of air circulation.

[Educator, Metropolitan Victoria]

4. See 'Landscape integrations & connections'

1] Wiluna Remote Community School, WA
2] Sandover Group, Homeland School, NT
3] Soapy Bore, Homeland School, NT
4] Flags representing the language groups at Arlparra Middle School, NT



Diversity >
Embrace & include

Schools in northern Australia have an indigenous cohort of between 7-100% with an average of 40-60%. The indigenous cohort is the largest growing cohort in NT schools due to increasing lifespan and attendance at school. [Educator, NT]

Diversity & Difference

Australia has a multi-cultural population. Schools can have up to 80 different nationalities and associated language groups on one site. Some Australian states and territories also have a high indigenous population for whom English is a second or third language.

Learning environments must accommodate children from different cultures and language groups, different learning styles and with disabilities. Making a learning environment truly inclusive means designing to accommodate multiple developmental perspectives. These might include environments that are physically accessible, activity-based, sensory rich and developmentally appropriate and adaptable.

Learning spaces must also cater for different age and size cohorts. The size of furniture will alter according to the cohort using the space and this will affect the space available for circulation within a classroom. Older children are also heavier and as they move about, floors in the older relocatables tend to vibrate. This is both disturbing and affects the calibration of the interactive white boards.

Teacher Observations From a Remote Indigenous Middle School and a Metropolitan School

Our school is composed of prefabricated learning spaces recycled from elsewhere. The students all speak two languages along with variably functional English. Most of them have chronic, or acute ear infections, so acoustics are critical. If they can't hear, they get distracted and distract others.

Some students live in prefabricated houses, but many others live in camps with no electricity or running water, which means that homework can be problematic. Teaching in the Middle School has specific issues. We decided to separate the genders to moderate 'avoidance' issues - who can or can't be in the same room with whom according to kinship group. It also helps with shyness in front of the opposite gender at that age.

Indigenous children tend to be more restless than other students; they can't sit still for long periods, especially not in chairs, so we have created a curriculum with lots of movement, activities and mat time. They don't like the air-conditioning and get cold very quickly as their metabolism is different to ours. We've found that they have strengths in art, music, sport and multimedia.

Our indigenous students find interactive multi-media highly engaging and are very creative with it. They are also naturally collaborative and will help each other learn, so we do a lot of group work.

[Educator, Remote Indigenous Middle School & Principal, Metropolitan Primary School, NT]

Personality >
The loose layer


1


2

On delivery, portables will be refurbished but afterwards it's up to us to maintain them. If we do work on them, we make sure that whatever we put in can be removed when they go.

[Educator, growth corridor Victoria]

We can take our laptops outside and everywhere. We can work on the floor or on couches or at tables.

[Secondary student, Metropolitan Victoria]

Furniture & Fittings

Furniture is part of what Mary Featherston calls the 'loose layer' and can create an environment that is at once inviting, stimulating, safe, spacious, interactive, comfortable and healthy (2010). It is the layer that determines the personality and emotional attachment to the environment and affects its functionality. Furniture choice and layout is also critical in the design of purposeful spaces that support different types of learning (Featherston 2010).

Equipping learning spaces with soft floor coverings and domestic features such as kitchens, pantries and cupboards, can help make a school feel like a home. Wet areas are also important for science, art and nutrition/health. In northern Australia, refrigerators in classrooms are essential for school lunches in the heat of summer.

Children and adolescents are restless by nature, and studies have found that fidgeting and rocking on a chair are ways of stimulating brain activity and promoting concentration. Furniture that accommodates sitting needs, while not restricting or suppressing movement is essential. This is particularly relevant to highly active and indigenous children who find both chairs and long periods of inactivity extremely uncomfortable.


3


4

1] Kindergarten Kekec, Lubljana, Slovenia | Architect: Arhitektura Jure Kotnik | Photo: Miray Kambic
2] University of Queensland | Wilson Architects
3] Student art, Currumbine Primary School WA
4] Wooranna Resource Centre, Victoria | Mary Featherston Design

1] College “L’Esplanade”, Begnins, Switzerland
Architect: Pascal de Benoit & Martin Wagner
Architectes SA | Photo: Pascal de Benoit
2] Geelong Grammar School, Victoria | Mary Featherston Design
3] Lilley Centre, Brisbane | Wilson Architects

The future >
Quality & class

Today 8-18 year olds spend on average 6 hours and 15 minutes per day in front of screen media, and only 43 minutes in front of print media. [Roberts, Foehr & Rideout, 2005]

Our staff is currently skilling up to use the new pedagogies in the new BER spaces and we’d like to have that reflected in the portables.

[Educator, Metropolitan Victoria]

OPPORTUNITY:
To integrate technology into learning spaces so that it is seamless and not just an ‘add-on’.

The Classroom of the Future: Technology & Learning

To anticipate what will happen in a building with a lifespan of many decades in this changing academic and technological environment is almost impossible. To discuss how to incorporate as much technological flexibility as possible in its design is a must. The degree of flexibility of the entire internal design of each learning space is critical.

The building technology should be a physical representation of a multi-level learning system that encourages creative thinking, reinforces intellectual and practical skill development, and supports multi-level communal discourse.

Supporting Technology-Rich Learning Spaces

Physical needs have been identified for technology-rich learning spaces that support collaborative, multidisciplinary and project-based teaching and learning. These needs include adequate space, adaptability, appropriate furniture, climate control, networking and electrical service, and adequate display and storage space.

Considerations:

- The needs for comfort and climate control (heating, ventilation and lighting) are heightened with the introduction of technology
- Technology should be thought of as a tool for learning. Therefore the physical environment should be designed to be adaptable for multiple activities
- The technology rich environment for learning is an active and social one. Students work together to assist one another with technical problems
- The physical setting needs to be agile enough to support different kinds of activities of short and long duration, planned and spontaneous, and group and individual.

Learning in the digital age has become an entirely different proposition to learning in the machine age. A child starting kindergarten now may not know how to spell their name, but will probably know how to surf the web. We must now create learning environments as adaptable and fluid as today’s technologically sophisticated learners. And, we must do this without knowing what sort of world these learners will face.

A 21st century classroom must have the capacity to link into learning opportunities beyond its four walls. One of the characteristics of the new technologies is their ability to link people across the globe. Many classes are doing just that. For example, one indigenous class in remote NT is communicating with a class in Mexico.

New technology brings new teaching and learning opportunities, so new learning environments must allow teachers to modify their methods and environments as they embrace the opportunities provided. Today’s reality must not limit tomorrow’s possibilities.

As you grow in size and get a lot of portables, you cannot use the new pedagogies in them and it has an impact on teaching, and kids learning culture as well. It's a major issue for growth corridor schools. Around 50% of our school is made up of portables.

[Principal, Metropolitan Victoria]

All of their curriculum is built around the new pedagogies and the portables don't accommodate them, so for part of the time, they have to put their students into spaces that don't work for their pedagogies.

[Principal, Metropolitan Victoria]

1] Decommissioned relocatables, Victoria

Lingering Perceptions About Relocatable Classrooms

There are still a lot of misconceptions around relocatable classrooms that hark back to our own childhood experiences of these often unsophisticated, utilitarian spaces. Many of these older models have been replaced under the BER scheme; however enough of them are still in use for the associated stigma to persist.

In my early years of teaching in country Victoria, it was regularly five degrees first period in a portable, so we'd run up the side road and back again just to warm up otherwise you couldn't do anything. [Educator, Rural Victoria]

We can't deny the stigma that is attached to portables. We need to work towards systems that mean that portables don't look like portables, be it through form, materials or rooflines – design in general. [Infrastructure Manager, Victoria]

As a teacher, if you're timetabled into a portable, then you sigh and wish that you were going to be somewhere else. They're perceived as second rate. [Educator, Metropolitan Victoria]

Portables are an accepted part of the school landscape but they are seen as second rate. The kids know this and are less respectful of the space. [Educator, Rural Victoria]

OPPORTUNITY:

To dispel those lingering perceptions with quality, functional and inspirational relocatable learning spaces.

If they're going to continue to be an integral part of the system, then they should be designed to suit the new pedagogies like the new permanent buildings.

[Principal, Metropolitan Queensland]

Visually they're not great to look at and they're not great spaces to teach in because they tend to be smaller spaces than a standard classroom, so you've got the kids crammed in.

[Educator, Metropolitan Northern Territory]

1] El Porvenir Kindergarten, Bogota | Architect & Photographer: Mazzanti Arquitectos
2] & 4] College “L’Esplanade”, Begnins, Switzerland | Architect: Pascal de Benoit & Martin Wagner Architectes SA | Photo: Pascal de Benoit
3] Kita Taka-Tuka-Land Kindergarten, Berlin, Germany | Architect: Susanne Hofmann Architects/Baupiloten | Photo: Jan Bitter

Blue sky >
What we’d like

Perceptions [cont’d]

Fortunately the situation has changed for the better. New models have been better received with reservation:

People like them on the whole. Acoustically they’re good and they’re comfortable to teach in. They have air-conditioning, heating, good display walls and interactive white boards. The spaces are a good size and they’re wired for ICT. They can be arranged for new or old pedagogies. The acoustics affect the [internal] configuration. How portables are connected can be badly done.

[Educator, Metropolitan Victoria]

The new relocatables have a smart roof system, double glazing, automatic lights with a timer, louvre panels, night purging systems and aircon and heating programmed to go on only outside the 19-27 degree band - a whole range of initiatives that try to reduce the reliance on air-conditioning.

[Infrastructure Manager, Victoria]

The negative feedback you’re getting from educators suggests they’re probably talking about the older styles, and if I had enough money I would remove and replace them.

[Infrastructure Manager, Victoria]

What Educators & Students Want: Research Themes

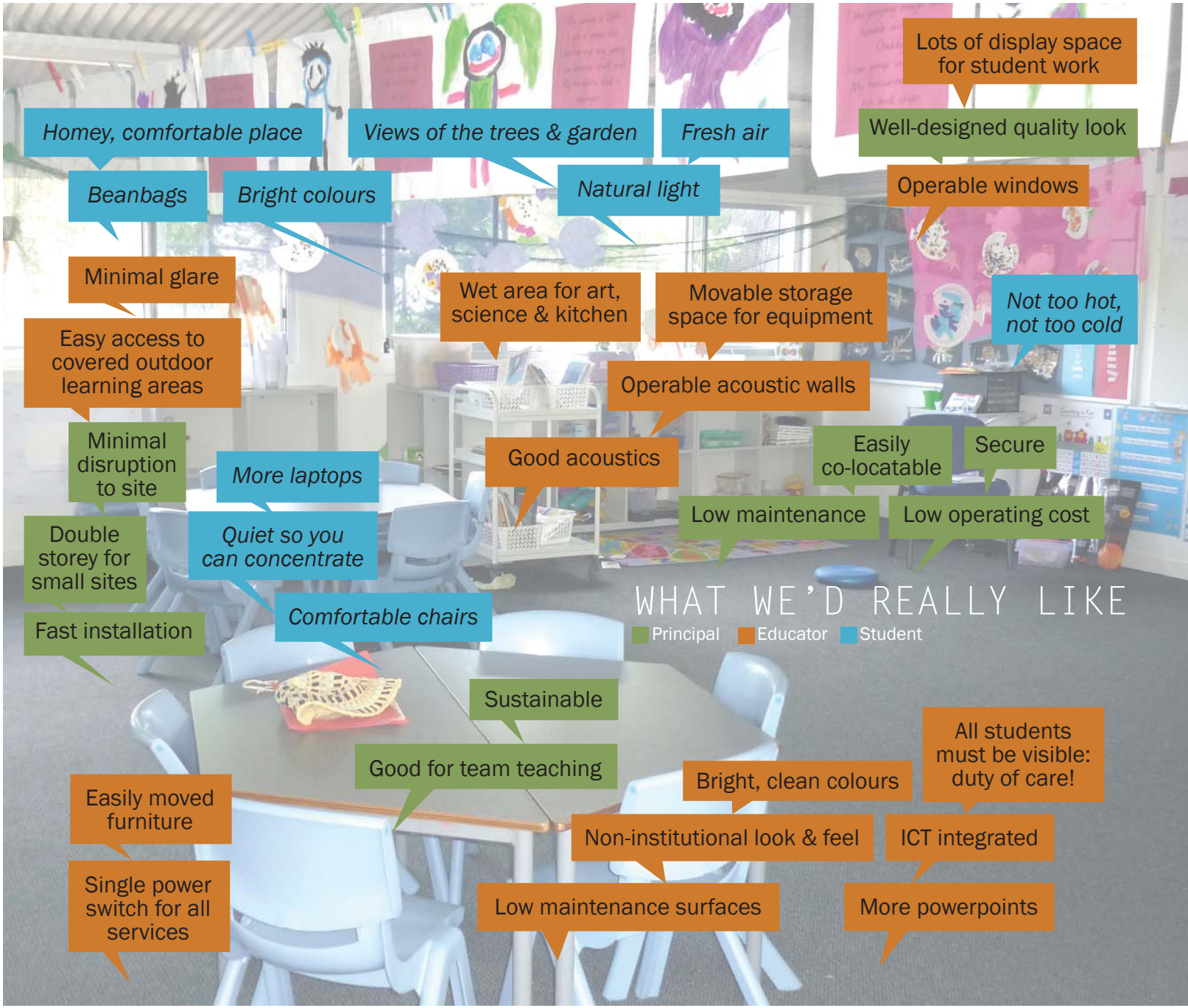
When surveyed about priorities, educators around Australia chose good acoustics as the overall top priority out of 40 variables. Other high priorities were thermal comfort, natural light, glare control, air quality and internal display and storage space.

The following diagram summarises key themes from research conducted in both primary and secondary schools in five states and territories around Australia. A mix of metropolitan, regional and remote schools were surveyed.

CURRENT SHORTCOMINGS*

- Poor acoustics
- Different models, shapes & sizes
- Not easy to co-locate relocatables into learning communities or hubs
- Thermal discomfort: too hot or cold
- Not enough space to easily rearrange furniture for group & individual work & still circulate easily
- Not enough display space
- Not enough storage space
- Limited or no bag storage
- Floors vibrate
- Little or no easy access to outdoors
- Glare affects projectors and interactive white boards
- Not easy to reconfigure internal layouts
- Fixed front of classroom
- Variable integration of ICT
- Access to powerpoints is limiting
- Not enough powerpoints
- Rectangular or awkward shapes reduce adaptability
- Many have no wet areas
- Security - easier to break into & often hidden at the back of the school
- Institutional feel to classrooms
- Poor ventilation and stuffiness
- Covered walkways or verandas too narrow for weather protection and ease of circulation
- Operable walls are not acoustically sound & often not easy to use

* These comments apply to a vast array of vintages and models in very different situations around Australia



A typical day

1] Class, Wiluna Remote Community School, WA
2] McKinnon Primary School, Victoria
3] Covered walkway/deck, Greenslopes Primary School, Qld
4] Student art, Currumbine Primary School, WA
5] Gymnasium Wall, Wiluna, WA
6] Mural, Larrakeyah Primary School, NT

A Typical Secondary Class From a Teacher's Perspective Might run Like This...*

It's the last class for the day. As the previous class spilled noisily out into the corridor, I walked into the classroom and started loading up my data. On winter days like today, the rooms can get stuffy by the end of the day, and this one was very stuffy and chilly due to lack of insulation. I teach geography and climate change and we talk about opening windows or turning off lights and the kids try to do that, but they can't because the windows have all been screwed shut for security reasons.

My students were starting to drift in, so it was noisy and I'd just realised that a previous teacher had changed all the settings on the data projector. It took me another five minutes to readjust them by which time the full class had arrived and were milling around restlessly complaining about the stuffy room. The class had been set up in lecture mode and I was going to start with a group activity, so I asked the students to reorganise the furniture to suit groups of five. Fortunately the furniture is light and easy to move around. While they were doing this, I wheeled the storage cupboard and interactive white board out of the way. Sometimes managing the environment (physical and technological) can become a dominant issue at the start of a class and it takes up valuable time.

We finally managed to get comfortable and I started the class. I'd planned an activity that had a component of outdoor work, but that was impossible with the rainy weather and lack of outdoor covered space, so I switched to Plan B. And of course we had issues with a number of computers being down - meaning that I had to assign the 'computer work' as homework instead of doing it collaboratively in class. It can get frustrating having to redesign lessons at the drop of a hat due to conditions in the classroom. I like to move around during my classes, so I was annoyed at having been scheduled in an old relocatable classroom which is smaller and doesn't have enough space to move comfortably amongst the groups of desks and students. They must have been designed with primary school aged students in mind. Many of my Year 9s are quite 'big boys'. Just as we settled into a quiet period of reflection on a particular issue, the class next door started a video with the volume quite high. The walls between the double classrooms are not acoustically insulated so it was very disturbing.

At the end of the class and day, the students raced out of the door. I was the last teacher in the Year 9 Home Centre that day, so I dutifully went around to all six classrooms, the planning room and staff room to make sure that the heating, equipment and lights had been switched off. Oh for a single power switch!

* Compiled from interviews with three teachers in a learning hub composed entirely of older style relocatables in metropolitan Victoria

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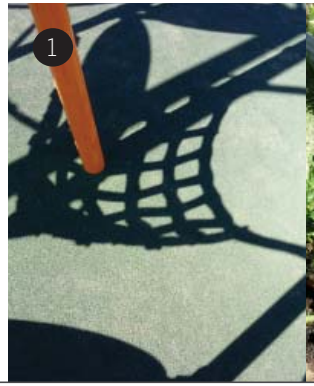
Further reading



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1] Play equipment, Wiluna Remote Community School, WA
2] Kitchen garden beds, Comet Bay Primary School, WA
3] Bite-tables, Marymede College, Victoria
4] Classroom, Buranda Primary School, Qld

Alparra Remote Community School, Northern Territory

"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

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 permament 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:

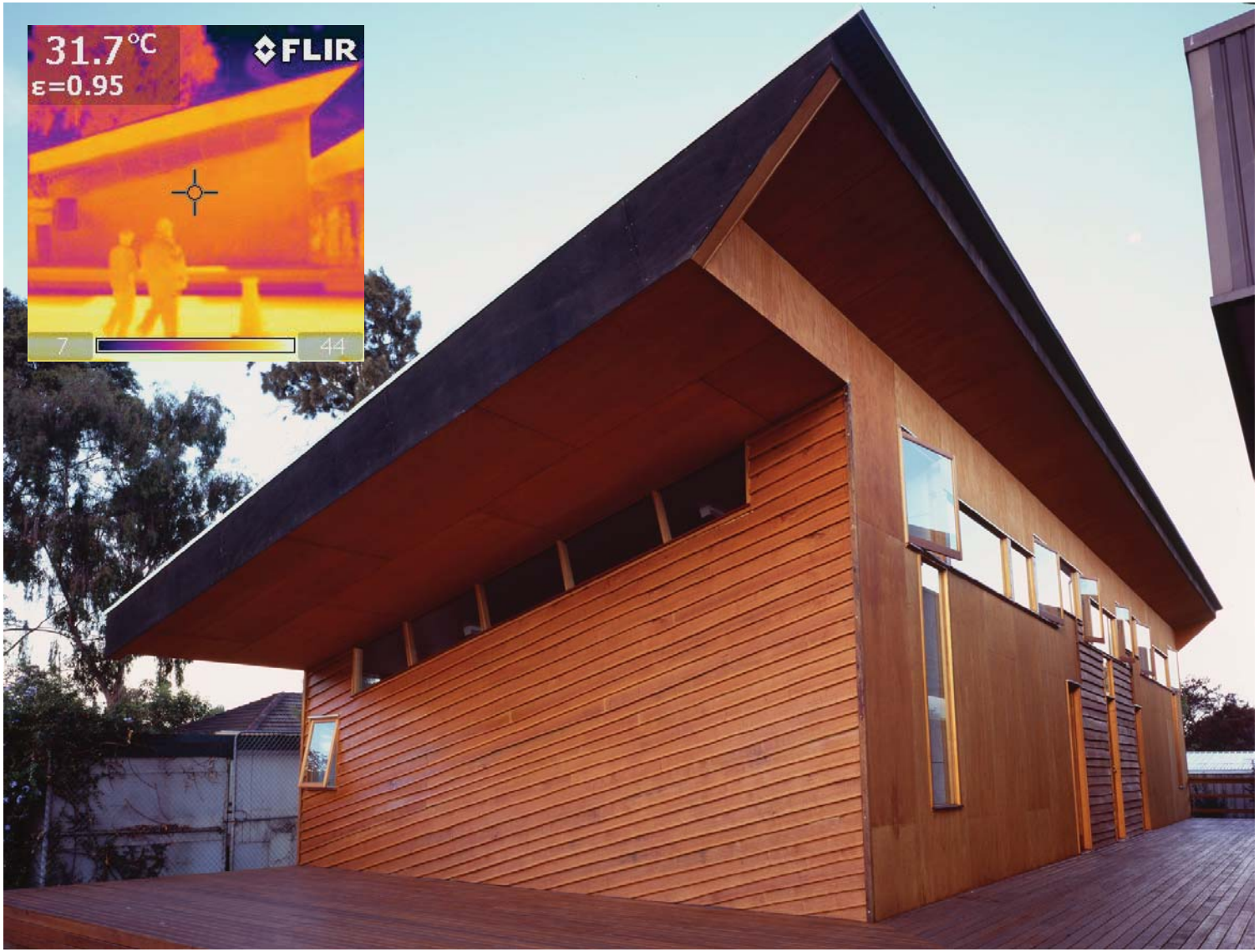
- use more energy than traditional classrooms;
- have poorly functioning HVAC systems that provide minimal ventilation with outside air;
- have poor acoustics due to loud ventilation systems;
- have chemical off-gassing from pressed wood and other high-emission materials, of greater concern because of 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 design (www.emedesign.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*?



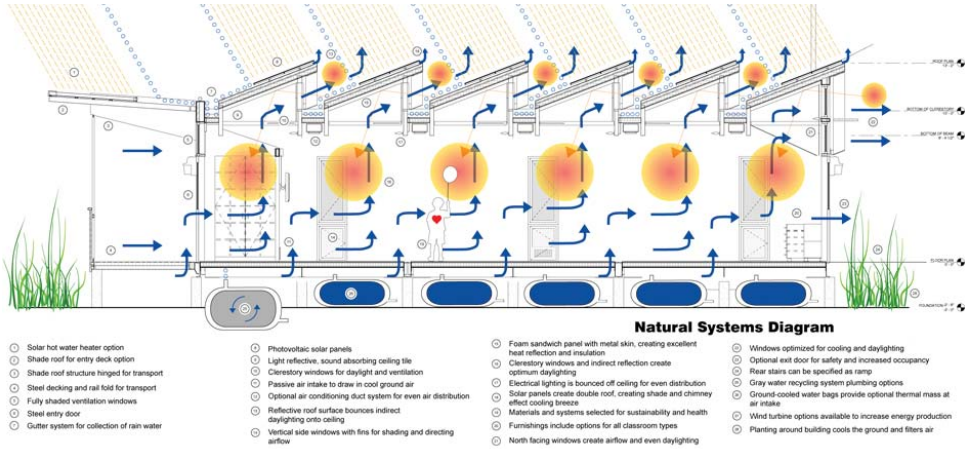
Inspiration>

"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.

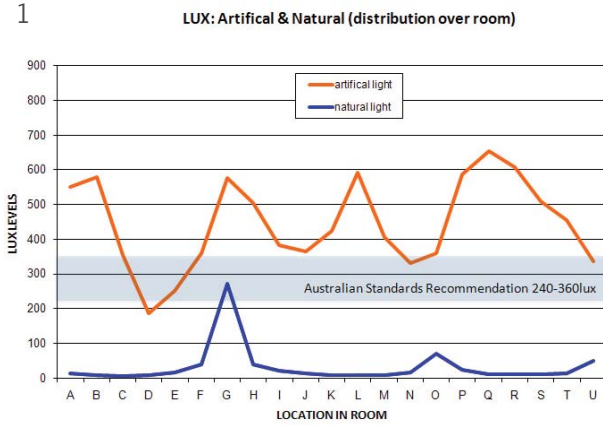
Green Star: Mould

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.

1



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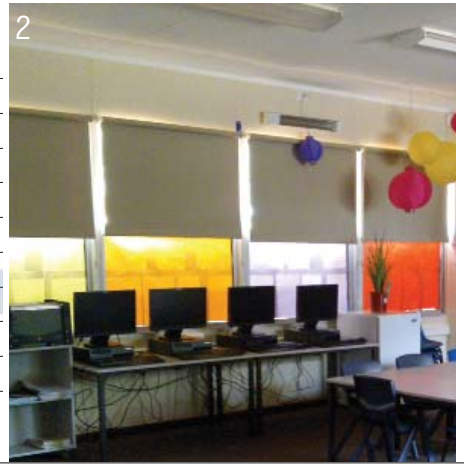


Key Issues>

IEQ: Light

"...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?

refer 1

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:

- 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.

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]).

refer 1

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].

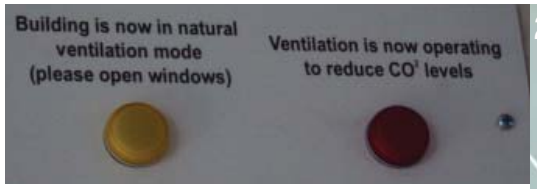
This research may explain why teachers in *mini case study 1* experienced high levels of hyperactivity. The students were alert but unable to concentrate. Teachers in this classroom were responsible for removing fluorescent tubes and explained that sometimes they turned the lights off when they wanted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

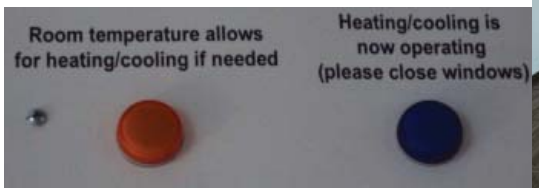
1: Images taken in a classroom by Bendigo Relocatables (www.brb-buildings.com) to inform occupants on how to get the best performance from the building HVAC system.

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

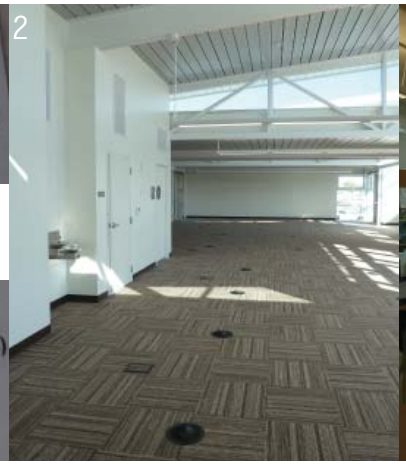
3. Overhead ventilation used by Triumph Modular (www.triumphmodular.com)

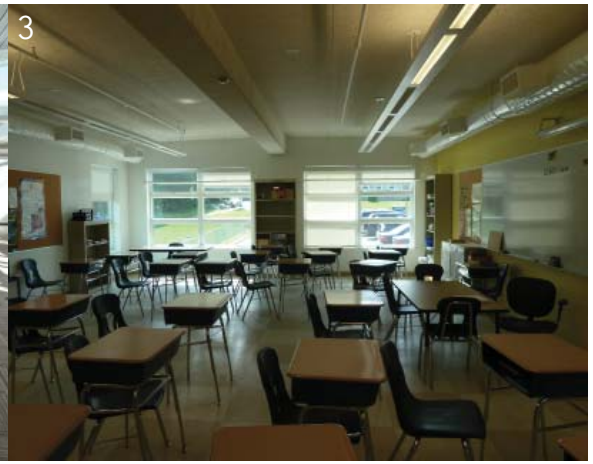
Key Issues>
HVAC systems





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/m^2 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.

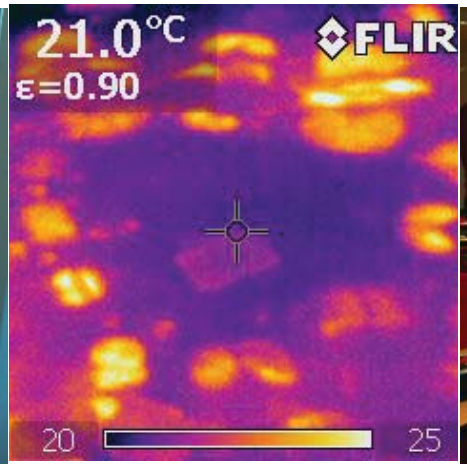
The first is in the design and construction of the classroom itself and choice of materials. (Information on ‘emerging’ materials is available on page 12.)

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]

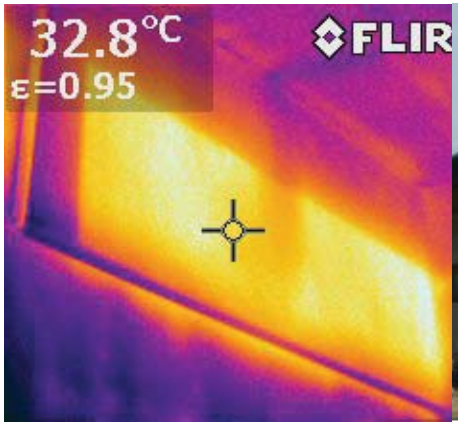
Green Star: Lifestyle

- 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 design 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.

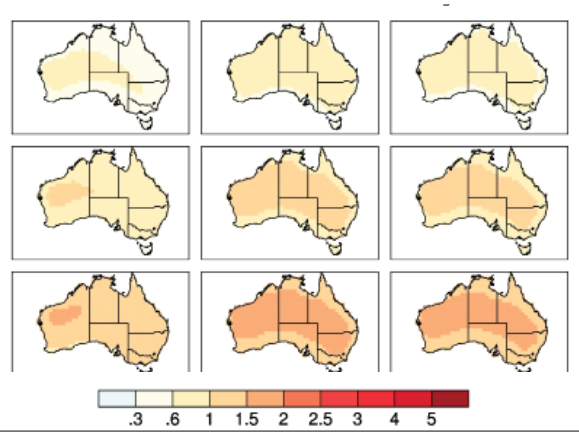
Project Frog (page 14) contains a monitoring system and dashboard that tracks the buildings energy use, energy generation and environmental quality, both in and outdoors. This is used as an educational tool by students, staff and the community.

"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.

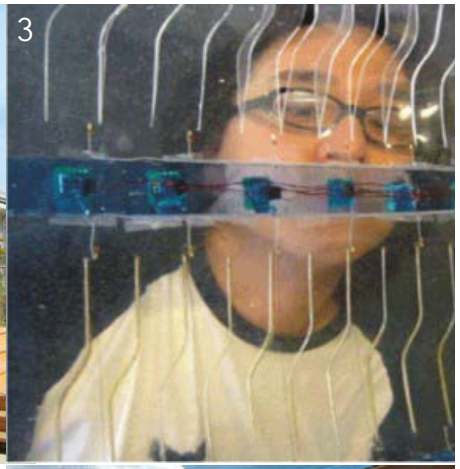
Another interesting area is that of biophilic design, which is the medical and psychological evidence-based design approach to the integration of biological references to design. From the importance of natural light to views out of windows, colour selection and references to nature, this body of work 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.

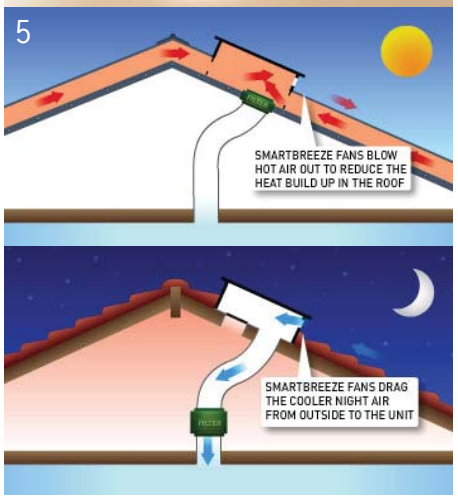
Translucent Concrete

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

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.

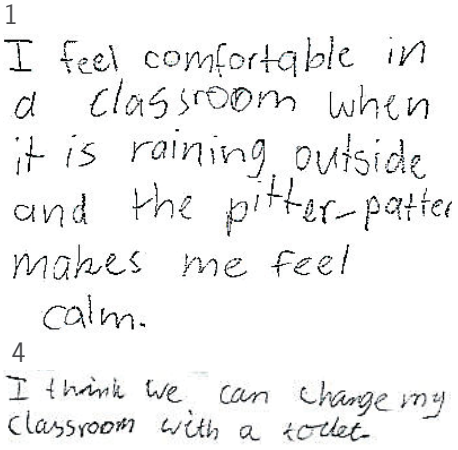
Acoustics

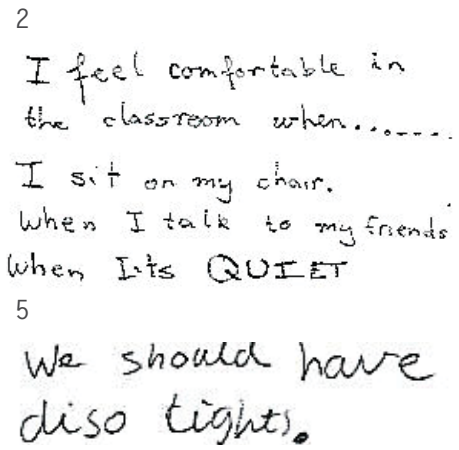
The classroom achieves a constant 35dB(A). The roof is angled with a suspended ceiling (layered with acoustic treatment) that is pulled away from the wall edge, to improve acoustics. At the lowest point, the ceiling is suspended 8ft 6inches and is 10ft at the highest point. ER3 carpet tiles absorb noise.

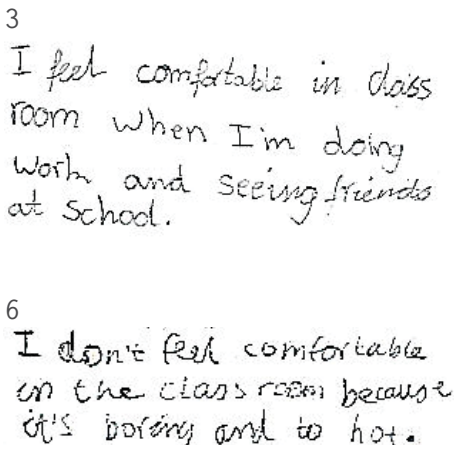
Thermal Comfort

The Thermal Displacement Ventilation (TDV) system used in the Gen 7 provides 100% fresh filtered air to the students at a low velocity. A CO2 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.







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"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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3. Landscape: integrations & connections

What happens when relocatables join or start a school's built environment?

How can we position one or more relocatables in relation to each other and to the rest of the school to maximise variety, play, education and delightful spaces?

This brochure presents an overview for competition entrants to guide their ideas in relation to:

- how relocatable buildings need to be integrated into school landscapes
- the types of spaces that might be created between relocatables and existing or permanent buildings
- the importance of visual and physical connections between indoors and outdoors, and
- the important role of landscape in learning and teaching.

In new learning environments using relocatables, knowledge from education and play about the role of external school environments needs to be considered.

Fundamentally, newer knowledge places landscape as a vital element of school life and learning.

The landscape of the school>

"The campus landscape should not be considered just an aesthetic amenity, but as important as the school buildings themselves."

[Matsuoka, 2010: 281]

What do we remember of our schooldays?

Much of our memory is of the school grounds —

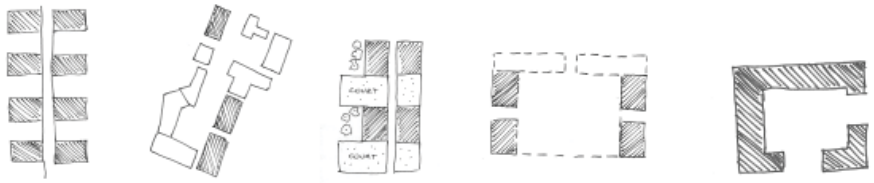
the yard, the playground, the oval, the external spaces, and what we might have been able to see out the windows of our classrooms.

Cover Images (clockwise from left):
Wiluna Remote Community School, Western Australia; Currambine Primary School, Western Australia; Primary School, Queensland.

Images this page:
1. Astrid Lindgren School, Beilefeld, Germany
Architect and Photographer: Monika Marasz

2. Europaschule Harmonie School, Eitorf, Germany
Architect: Guido Casper
Photo: Montag Stiftung Urbane Räume, Bonn (www.lernraeume-aktuell.de)

Facilitating making spaces in deliberate ways



Placing relocatables within school landscapes>

We ask: What sort of spaces might be made with your 21st century relocatable?

Where Placed? How Placed?

Aerial overviews of schools in Australia, and visits to schools, reveal that relocatables in Australia are often placed in exisiting schools in such a way that they have poor integration into the wider landscape of the school.[1] Many have difficult or complex connnections to other buildings (including toilets) or landscape attributes, and resultant loss of play spaces.

Flat ground is often consumed, with the loss of playgrounds — such as hopscotch and other loved social or solitary games — as well as garden beds.

The position of electricity services often dictates the placement of relocatables to the detriment of opportunities for best spatial placement in relation to existing school buildings and other new relocatables.

How can your design create delightful spaces between buildings?

1. See '21st Century Learning'.

Where is the Floor Level?

The way a relocatable meets the ground can be critical to how well the building integrates with the school landscape, and how temporary the building appears.

Coping with Slope

A building at ground level has opportunities to integrate with its surroundings, and provide easy flows between inside and outside.

Existing relocatable classrooms in Australia are generally raised above ground level (minimum 300mm) to enable straightforward on-site mounting and subsequent removal. Visually, this can create a clumsy connection with the landscape, highlighting the temporary nature of the building.

Decks, terraces and sheltered verandahs can be used to create a progression of spaces between indoors and different outdoor spaces, and to visually integrate a building into the school landscape.

How can your design accommodate different slopes?

Multi-storey/Stacked

In inner-urban high density areas a vertical arrangement of classrooms can be an appropriate design solution to minimise loss of play space when new relocatables are simply added into 'vacant' spaces or flat spaces in the school grounds.

On sloping sites, stacked classrooms might create interesting connections to different ground levels. For example, use of multiple storeys might create opportunities for classrooms to open onto the rooftop space of the classroom below.

Stacked or elevated relocatables might also be able to provide shelter from sun and rain, and playspaces.

Can relocatables cope with flood by being raised?

Images above:
Collège "L'Esplanade", Begnins, Switzerland
Architect: Pascal de Benoit & Martin Wagner Architectes SA
Photos: C.Cuendet, Clarens/Lignum Vaud (left) & Pascal de Benoit (right)

diversity
unstructured
shade and shelter
structured
social spaces
transparency
big spaces
microclimate
interstitial spaces
sense of enclosure
play
different age needs
messy spaces
outdoor learning
intimate spaces

Creating informal and formal spaces between relocatable classrooms>

The placement of buildings within a school ground can promote a diversity of outdoor spaces and hence opportunities for various outdoor experiences.

It is important to provide both open and dynamic outdoor environments, as well as enclosed and intimate spaces (Tovey, 16). Herrington (1997) describes the importance of 'embracing' landscapes – landscapes can be carefully designed to provide seclusion in more enclosed and intimate spaces, providing the security and stability that can be lacking in open environments.

The arrangement of buildings on a site, both in relation to each other and in relation to their surrounds and the broader landscape is critical in achieving quality, and diverse outdoor spaces.

The arrangement of buildings, combined with the façade design, the internal use of buildings and the connections between inside and outside, will influence the comfort and use of the adjoining outdoor spaces.

Can your design include landscape elements that could be provided to schools as a part of the relocatable building?[2]

1. Jardín infantil El Porvenir, Bogotá, Columbia
Architect: Mazzanti Arquitectos
Photo: Rodrigo Davila

2. Gesamtschule in der Höh, Volketswil, Switzerland
Architect: Gafner + Horisberger Architekten GmbH Landscape Architect: Guido Hager
Photo: Gesamtschule in der Höh

3. The Country School, California, USA
Architect: Office of Mobile Design
Photo: Dave Lauridsen

4. Geschwister-Scholl School, Lünen, Germany
Architect: Hans Scharoun
Photo: Montag Stiftung Urbane Räume, Bonn (www.lernraeume-aktuell.de)

2. See 'Prefabrication'.

Why are spaces outside important?

Because being outside for a child assists:

- imagination
- social wellbeing
- fitness
- inquiry
- environmental literacy
- spatial awareness
- mathematical understandings
- wonder
- stillness
- different learning styles
- learning about nature specifically
- attention spans inside
- combatting obesity
- restoration from mental fatigue
- fun!

Creating outside spaces>


1


2


3


4

1. Glamorgan Primary School, Toorak, Victoria
Architect: Mary Featherston Design

2 & 3. The Country School, California, USA
Architect: Office of Mobile Design
Photo: Dave Lauridsen

4. Comet Bay Primary School, Western Australia

5. Currambine Primary School, Western Australia

Surface Reflectivity

Material	Level of reflected UV radiation
Lawn grass summer/winter	2% - 5%
Grasslands	0.8% - 1.6%
Soil, clay/humus	4% - 6%
Asphalt roadway, new (black, old (grey)	4.1% - 8.9%
Concrete footpath	8.2%- 12%
House paint, white	22%

Source: Cancer Council Victoria, 2010

Light and Shade

Australia has the highest levels of skin cancer in the world, with high levels of ultra-violet (UV) radiation during school months, even outside of summer. Schools require shade structures, and most children in Australian primary schools (aged approximately 5-12) are required to wear hats outside. External, but undercover, areas for eating lunch are essential.

How Much Rain?

Yes it rains in Australia! Good connections are required between buildings.

Noise and Acoustics

The experience of the outdoor space from an acoustic perspective is critical for a comfortable environment for students. Noisier outdoor play spaces in childcare centres with primarily hard surfaces, little vegetation or soft materials, and close to traffic noise, create stress in children and teachers (Herrington et al., 2007).

How will your design and materials function acoustically, and how does placement of relocatable classrooms affect noise levels between and within your relocatables?

Services and Their Impact on Outdoor Spaces

The aim for prefabricated learning environments is for them to be comfortable without the need for substantial heating and cooling systems.[3] However, the huge variation in climate and site conditions means that, in some cases, this may be unavoidable.

How can these and other services be integrated into the design to minimise intrusion into outdoor areas, in terms of space, sound, appearance, temperature and air quality?


5

3 See 'Sustainable School Environments'.

"Schools are overdesigned; they leave no active role for the learner."
[Jilk, 2005: 32]

Messy, unstructured and flexible spaces outside>


2


3


1

What is This All About?

Often when educators speak about outdoor school spaces they are talking about the school grounds in terms of 'educational' spaces or 'learning spaces', and how the teacher can take learning into the outdoors.Thinking about messy and unstructured spaces in schools is not about formal educational spaces but about the very opposite, unstructured learning.[4]

There need to be opportunities for not doing anything specific at all. How might you be able to frame relocatables for unstructured spaces?

The outdoors is more expansive, can provide for freer movement, noise and mess, providing for a very different play experience to that possible indoors (Tovey, 2007).

Flexible Space

The world of education is placing increased emphasis on the need to create generous, flexible spaces and a 'loose-fit' architectural form that can be adapted over time as the needs of the school community change (Koralek and Mitchell, 2005).

Berlin schools have embraced untidiness and created exciting and uncontrolled play landscapes

1, 2 & 3: Grounds for Learning/Learning Through Landscapes (www.ltl.org.uk/scotland)

Children outside

There has been a considerable movement in the last twenty years to acknowledge the benefits to children of being outside, whether in schools or not. The concept of the benefits of engagement with nature go beyond any ideas of 'outdoor learning' or using external spaces as extensions of the classroom.

In his book *"Last Child in the Woods"*, Richard Louv (2008) articulated the disconnection between young people and the outdoors, and outlined links between a lack of exposure to nature and childhood obesity, attention disorders and depression. Louv's book has influenced national policy in the US and spurred international debate.

An outdoor space changes constantly as it is inhabited by its users. It should be a place that children play *with*, rather than *in*, and should not contain equipment for children to play *on* (Herrington, 1997; Tovey, 2007).

4. See '21st Century Learning'

1. Mason Pilot Elementary, Massachusetts, USA
Boston Schoolyard Initiative (www.schoolyards.org)
Landscape Architect: Klopfer Martin Design Group

2. Geschwister-Scholl School, Lünen, Germany
Architect: Hans Scharoun
Photo: Montag Stiftung Urbane Räume, Bonn (www.lernraeume-aktuell.de)

2. Meriden State College, Queensland, Australia

3. Kita Taka-Tuka-Land Kindergarten, Berlin, Germany
Architect: Susanne Hofmann Architects/Baupiloten (www.baupiloten.com)
Photo: Jan Bitter


1


2


3

Moving in and out>

Getting In and Out

Consideration needs to be given to movement between the indoors and the outdoors:

- Might doors be transparent and of generous width and open directly onto usable open space areas?
- Are structures that connect indoor and outdoor space generous? Do they enable free movement?
- How might your design accommodate the addition of overhead structures such as verandahs, pergolas, shade structures, breezeways, or underfoot structures including stairs, ramps, decks and terraces?
- What might the relationships between internal and external use of space be like? How can you provide useful outdoor space with a direct connection to indoor space?

Thinking About the Floor Level

Existing relocatable classrooms are generally raised off the ground, and connected to the ground level by stairs and ramps. These structures can create bottlenecks and restrict access.

The design of connecting structures, and the surrounding landscape design and vegetation are important in creating physical connections with landscape.

Children Learning and Playing Out

The ability for teachers to make good use of outdoor environments for structured and unstructured learning can be strongly influenced by the ability to move freely between indoor and outdoor space. Outdoor space can become an extension of the classroom.

How can your design encourage movement and flexible learning, and for the school to be more delightful for both children and their teachers?


4

Plasticity means that your relocatable can change shape in response to site, whether it be to slope or the spatial possibilities within the school.

Consider tailoring for:

- Shade
- Shelter
- Solar Access
- Surfaces and Colours
- Flood
- Fire
- Cyclone

Is plasticity for climate possible in relocatable design?>
What are the essential drivers of adaptation for relocatables?>

There is a great diversity of climatic conditions across the Australian continent, yet relocatables are required to fit most of them. This Ideas Competition is asking you to consider the many climatic conditions found in Australia and how your design ideas might be plastic enough to accommodate different climatic conditions.

The supply of relocatables is controlled within the States and Territories of Australia by the respective Education Departments. They need to send relocatable classrooms where needed, and require assistance in re-imagining these classrooms.

In thinking about a new type of relocatable, is plasticity for climate possible?

A kit of parts approach that includes various options for the school to choose might be a catalyst in terms of both a starting point as well as creating ideas for the outdoor landscape.

Shade and Shelter

Providing shade in schools is critical to reducing exposure to UV radiation. New relocatables will incorporate shade and shelter while factoring in the existing shade provided within the school.

Shading of outdoor spaces associated with relocatable classrooms will need to include the following considerations:

- Balancing the provision of summer shade with maintaining solar access in winter in temperate climates, but ensuring year-round shade in tropical climates.
- Providing a combination of built and natural shade from direct and indirect UV radiation.
- Surface materials and colours can reduce the reflection of UV radiation into shaded areas (refer to Surface Reflectivity table above).
- Providing shade and shelter to areas of high activity such as movement corridors between classrooms and gathering spaces.
- Ensuring that shade is attractive to encourage use, preferably incorporating both natural and built shade elements.

Extreme Weather

Climatic conditions in Australia are highly variable, with a range of extreme weather events seen in various parts of the country in recent years, e.g. bushfires, flooding and cyclones.

Extreme weather events reinforce the need to provide for an uncertain future in the way that we plan for and provide school landscapes.

There is an opportunity to create resilient landscapes in conjunction with new prefabricated learning environments in schools, and to tailor these to the site and local climatic conditions in a way that can be adapted over time and respond to change.

For example, in the State of Victoria, approximately 30% of schools are in high fire risk areas. These will need to be adapted to comply with new requirements for clearance to vegetation and structures around school buildings.

Marymede College, South Morang, Victora

1. Strawberry Vale School, Victoria, Canada
Architect & Photographer: Patkau Architects

2. Kindergarden Kekec, Lubljana, Slovenia
Architect: Arhitektura Jure Kotnik
Photo: Miran Kambic

Looking out>

Children looking out

While not facilitating movement between indoors and outdoors, windows that can be opened and closed by the users of the building in response to climatic conditions can also provide a greater level of control and an increased sense of connection to the outdoors (Nair & Fielding, 2005).

From inside the relocatable, opportunities exist for good views to the outside. Window heights need to enable the child, whatever their age, to see outside. Little people like a view too!

Why is a view important?

Providing visual connections

Providing views to the outside is recognised as an important element of school design, because it broadens the horizons of students and connects them to the world beyond the classroom (Nair & Fielding, 2005).

The quality of the view is also important. Studies of high school students have shown that providing views from classroom and cafeteria windows with a high proportion of trees and shrubs improves school performance and behaviour compared to schools with views of featureless landscapes such as lawns, sports fields and car parks (Matsuoka, 2010).

GreenStar (the Green Building Council Australia's voluntary environmental rating system)[5] recognises the value of external views from buildings, and encourages designs which provide a visual connection to the external environment or to an adequately sized internal, day-lit atrium (GreenStar IEQ-14).

We encourage views to the external landscape.

Transparency

Creating transparency, through providing a high level of visibility, light and openness in school building design while maintaining acoustic separation, conveys a message that learning should be on display and celebrated (Nair & Fielding, 2005).

Eye Height of Students

When considering the provision of views to the outdoors, an obvious (but often overlooked) consideration is the eye height of the students who will be using the room.

Eye Health

For eye health, external views should extend as far as possible beyond the work area (at least 15 metres) to allow a change in focal length. This exercises and provides relief for tired eyes (Nair & Fielding, 2005). Recent medical studies suggest that too much attention close in, such as to the computer, can lead to myopia!

5. See 'Sustainable School Environments'.

Distraction

The benefits of creating a nurturing learning environment through views to the outdoors and green areas would offset any concerns about distraction caused by activities outside the classroom. Distraction and loss of concentration can take place whether these views are provided or not, and the level of engagement is more an indicator of a student's interest in what is happening inside the classroom (Nair & Fielding, 2005).

Glazing and Climate

Providing strong visual connections to the outdoors requires clear glazing to enable students to see outside.

Full length glazing might be suitable in some southern Australian climates but in other climates screening devices might be needed to protect the classroom from the sun. Glare has been identified by teachers as a nuisance in the classroom.

Facades and the relationship between relocatables and their landscape

The design and finish of a building's exterior is critical to how well the building integrates into its context. This includes its relationship to surrounding buildings, to landscape character, materials and surfaces.

Prefabrication can enable a flexible building design and tailoring of the facade to respond to an individual site.

The Kekec Kindergarten in Ljubljana (above) creates a facade that becomes a dynamic part of the play landscape, as well as providing visual interest and shading for the windows

1. Kindergarden Kekec, Lubljana, Slovenia
Architect: Arhitektura Jure Kotnik
Photo: Miran Kambic

2. Suresnes Open Air School, France
Architect: Beaudouin and Lods
Photo: Christoph Theurer

Open Air School Movement

'Open Air Schools' began in Europe at the beginning of the 20th century, with a formal movement between the First and Second World Wars. Open Air School designs were based on principles of maximising the visual and physical relationships between inside and outside in order to create a healthy school with light and air.

The open air school at Suresnes, near Paris, designed by Beaudouin and Lods in 1935 (see below), had a large influence on school design. Its 8 classroom units have retractable glazing panels on 3 sides which can be opened open up to the surrounding garden, and integrate roof terraces with the school (Dudek, 2000; Imagine: Inspirational School Design - www.imagineschooldesign.org).

1. Winship Elementary, Massachusetts, USA
Landscape Architect: Klopfer Martin Design Group
Photo: Boston Schoolyard Initiative, www.schoolyards.org
2. Children playing with parts of the trunk of an Australian 'balga' (grasstree) at school in Perth. Image provdied by a teacher.

What might the school landscape be like with relocatables?>

What will children born in the 21st century remember of their school's outdoor spaces?

We have no excuse to provide inferior quality landscapes in schools with relocatable classrooms.

How can your design of the relocatable classroom direct and inform better quality spaces for children and teachers?

How can your design provide plasticity to enable rapid or dynamic change — within a particular site to respond to new needs, or for different climatic demands?

How can you ensure that a school's landscape can be integrated — with permanent buildings, with a family of relocatables, with internal educational spaces, and with the needs of shade, play, exploration, fun and quiet?

Let us envisage new designs for relocatables which allow for the creation of memorable and gorgeous spaces between and surrounding these dynamic buildings in our future schools.

Wiluna Remote Community School, Western Australia

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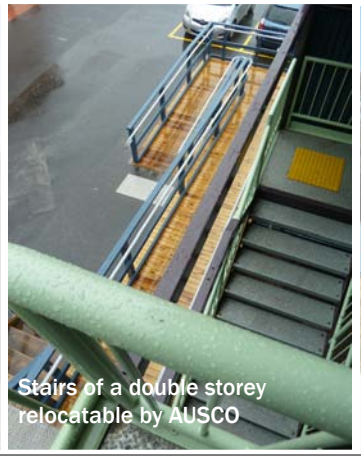
“My vision for 2020 is one where construction methods will minimise on-site labour - more prefabrication. Buildings may be more transportable, moving or growing as required. Sustainability and re-use of building materials will drive materials and construction methods.”

[Quote taken from Hampson & Brandon’s 2004 Report by the Cooperative Research Centre for Construction Innovation, Australia]

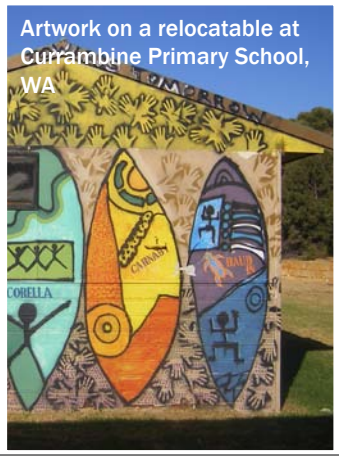
4. Prefabrication


Marymede P-12 School, South Morang


Wiluna Remote Community School by TAG Architects


Stairs of a double storey relocatable by AUSCO


Pepper Green Farm Training Centre, Bendigo by Eco Villages Worlwide


Artwork on a relocatable at Currambine Primary School, WA

This Brochure>

"If I had asked people what they wanted, they would have said *faster horses!*"

[Henry Ford discussing the mass production of the automobile]

This brochure is about **prefabrication**.

It presents ideas and themes that can help **redefine the way we design and construct buildings**.

21st century design technologies present us with endless possibilities to 'rethink' how we design and manufacture and:

- create a shift from mass-production to **mass-customisation**;
- embrace **parametric modelling** for site specific, value driven responses;
- maximise the interface of these technologies with manufacturing.

Social, economic and environmental factors suggest an urgent need to consider new ways to build. These factors include:

- shortages of skilled trade labour in many communities;
- need for increased construction quality and lower costs;
- need to improve construction productivity;
- need for more sustainable, cradle to cradle solutions;
- increased acceptance of quality prefabrication.

It is an exciting time to embrace these 'tipping points' and explore the interface between design and manufacture and engage architects in that process.

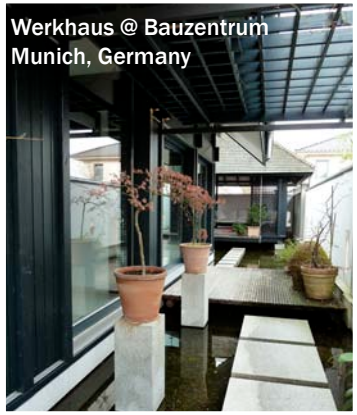
Although the focus of our research is the **relocatable classroom**, prefabrication has the potential to have a much wider impact on the design and construction of schools - and beyond - as we seek more efficient, sustainable, quality-driven and economical ways of creating our built environment.

It is time to continue prefabrication's 'design-led transformation'.


Millmont Elementary School, Pennsylvania by NRB Inc, Ephrata


Student Housing, Spacebox ® by CoCon BV, TU Delft Campus, The Netherlands


A variety of styles and approaches @ Terrapin-Ltd UK


Werkhaus @ Bauzentrum Munich, Germany

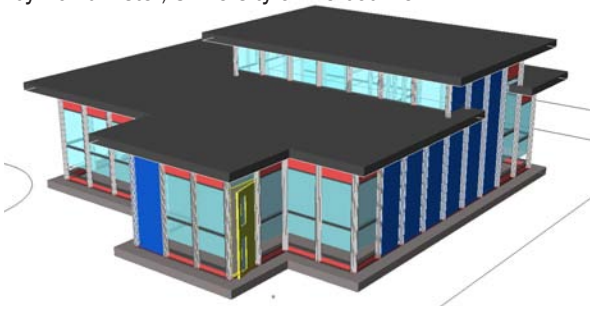
Background>

The Social and Historical Context

Prefabrication has long played a major and positive role in design and construction innovation, addressing social challenges, urgency, and economic drivers, particularly in the housing market.

Although prefabrication is perhaps **architecture's oldest new idea** [Harker 2007] , it has gone through alternating cycles of being 'the next best thing' or being shunned.

Digital model based on the 1933 Schindler Shelter System by David Lister, University of Melbourne



A Prefabrication Timeline...

1500's	Nonsuch House was built in Holland of timber and assembled in London, fixed with wooden pegs. It was painted to give the appearance of brick and stone.
1624 +	Simple prefabricated houses were transported by ship to new settlements in British Colonies [Kelly 1951].
1851	Prefabrication meant that the Crystal Palace was completed in less than six months. The Crystal Palace was then dismantled and relocated elsewhere [Kelly 1951].
1914 +	Prefabrication helped address British and German housing shortages in the post war era.
1916 +	Nissen Huts [WWI] and Quonset Huts [WWII] provided a relocatable housing solution for the army. The Nissen Hut typically took four hours for six men to assemble.
1933+	Architect RM Schindler created his Panel Post construction system with 9 base components [Park 2004].
1950 +	Architect Ernest J Kump Jnr designed prefabricated school systems in California.
1950 +	Prefabrication helped alleviate the skilled trade labour shortfall in post war Europe.
1990's	With prefabrication, McDonald's Restaurants reduced build time from months to weeks.
1996	Japan's automated production lines produced high quality houses in record time [Gann 1996].
2002	Arieff + Burkhart's book *Prefab* inspired designers and architects.
2004	CRCCI Report *Construction 2020: A vision for Australia's property and construction industry* highlighted the important role of off-site manufacture in future construction
2008	Waugh Thistleton's Stadthaus at Murray Grove, London, was built of cross laminated timber panels which were factory cut by CNC routers then assembled on site to create the 9 storey tower.
2010	Sekisui House, one of Japan's high quality prefabricated housing manufacturers, launched in Australia.
2011	Time for a paradigm shift in Australia's prefabrication building industry...

"Sadly, much of the negative stigma associated with prefabrication stems from the building category that's central to our research - the relocatable..."
[Future Proofing Schools Research Team]

...prefabrication is "modern architecture's oldest new idea"
[Harker 2007]

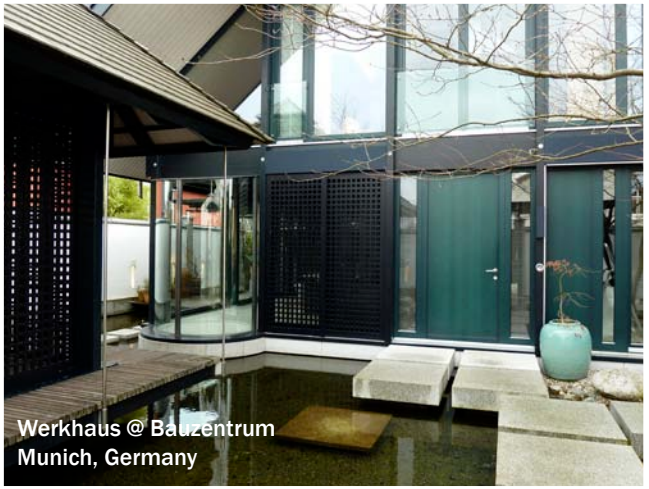
"a long continuum of noble failures"
[Arieff & Burkhart 2002]

There are a number of reasons for this:

- For many decades, prefabrication has been used for utilitarian, low cost projects or products;
- Historical association with cheap catalogue housing solutions in Australia, the USA and UK;
- A long association with poor quality relocatable classrooms in Australia, the USA and UK;
- Manufacturers have led much of the development of prefabrication, with little architectural input;
- Concerns from architects that prefabrication will lead to monotony and reduction in choice and variety [Engstrom *et al* 2007; Anderson & Anderson 2006];
- Psychological association of prefabrication meaning 'not permanent' because of its extensive use in 'temporary' applications;
- Tendency for these temporary structures to be retained well beyond their design life;
- Often, relocatable classrooms that are intended to be 'temporary' instead become permanent fixtures of the school.

Why prefabrication?>


Baufritz Display Village
Erkheim, Germany


Werkhaus @ Bauzentrum
Munich, Germany


Gruber @ Bauzentrum
Munich, Germany

"Off-site fabrication is about reinventing the way we build, carefully considering how we assemble and ultimately disassemble our buildings."

[James Timberlake, KieranTimberlake, research interview December 2011]

Time for Change

Prefabrication is now on government agendas in Europe, the United States and Australia where it's seen as an important way of improving quality and cost within a slow changing construction industry.

Some notable reports are:

- In the UK, the 1998 *Egan Report: Rethinking Construction* [9]
- In the USA, *Advancing the Competitiveness and Efficiency of the U.S. Construction Industry*[10]
- In Australia, the 2004 *Construction 2020: A vision for Australia's property and construction industry*[11]

The convergence of these factors, combined with emerging technologies and the recent resurgence of interest in prefabrication in the design community, means that prefabrication is more viable and relevant than ever.

9 The 1998 Egan Report critiqued the British construction industry as inefficient, adversarial, and slow to embrace change

10 This report highlighted a central role for off-site manufacture in the future of US construction.

11 The vision included an increase in off-site manufacture but the authors also noted the natural conservatism in the local market.

Speed

Site preparation can occur in parallel to building manufacture on the factory floor. This saves time, and can also save money.

Quality

It can consistently achieve predetermined quality in a factory controlled environment.

Safety

In a factory environment most of the work can be conducted at waist height. Health and safety is also easier to control in a factory.

Skills

In communities with a shortage of skilled trade labour, the production line can be organised to employ less skilled labour. Some systems can be installed or assembled by low-skilled labour under supervision.

Sustainability

refer 2

Minimum site disturbance, tightly managed material flow and construction waste, and pre-planned disassembly can reduce overall environmental impact of construction.

Cost

Although there is often a cost premium associated with the transport to site or cranage, these front-end costs should be balanced against the faster time to occupation which can: generate income earlier; lead to lower site overheads due to less time on site; offer greater cost certainty due to minimal weather delays; and provide an earlier design freeze due to requirements of the manufacturing process.

Impermanent Site

A client may lease rather than own the land for a proposed project. Some sites may have title or zoning restrictions that disallow a permanent structure. A prefabricated building can be moved to a new location at a later date.

Terminology>

Overview

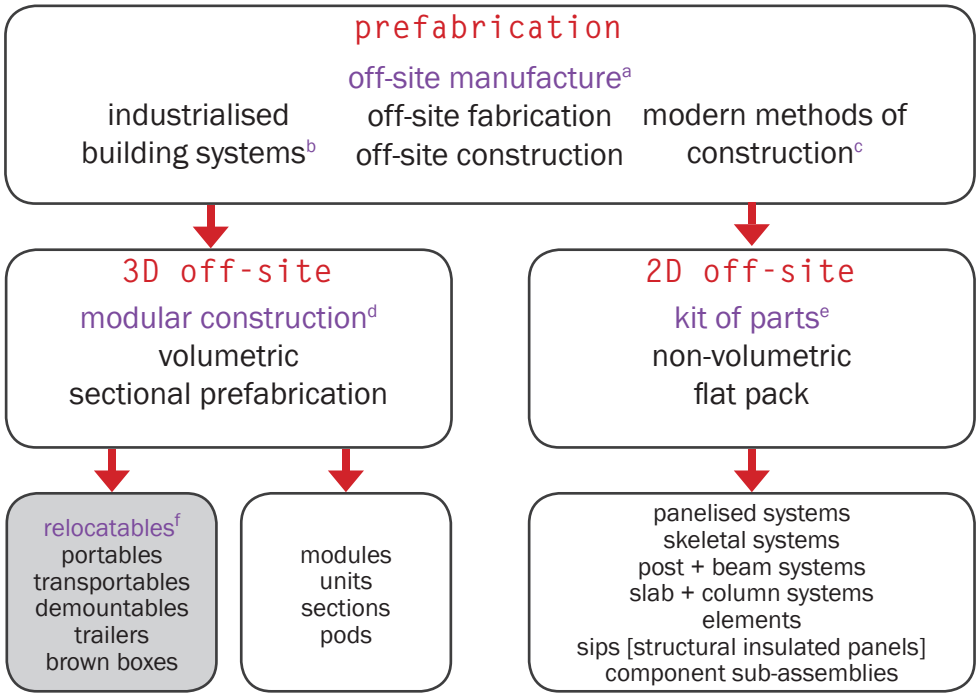
Within the design and construction industries, prefabrication is a broadly understood concept, however the large number of terms used to describe it can lead to misunderstandings and confusion.

Prefabrication is an 'umbrella term' and there are a wide range of construction types and processes that sit under this heading. The following diagram categorises some commonly used terms that we have come across during our research,highlighting the category of 'relocatable' classrooms as just one small sub-set of prefabrication.

There are two main approaches to prefabrication:

- **3D off-site** or modular construction: factory finished modules that are joined together on site. This approach is most commonly used for current relocatable classrooms.
- **2D off-site** or kit of parts: factory made | prepared | drilled components that are assembled on site.

"There's a wide range of different terms and systems, so let's make sure that we're all talking about the same things!"
[Future Proofing Schools Research Team]



Relocatable classrooms need to make a full transition from temporary quality towards a permanent quality

a. The preferred 'umbrella' term in Australia
b. Term used extensively in Asia
c. A UK term covering construction innovation to which off-site manufacture is pivotal
d. The most widely used term for this category
e. A commomly used term which is well understood by designers
f. The term used to refer to this category of classrooms in the context of our research

The School Context

Across Australia, our States use different words to describe the same type of moveable classroom structures. Currently, Australia's education departments use the terms as follows:

State	Term(s) used
VIC	relocatables / portables
NSW	demountables / portables
QLD	relocatables
NT	transportables
WA	transportables / demountables
SA	demountables
TAS	demountables
ACT	transportables

In the media, we also hear these classrooms being described as temporary or prefabricated classrooms, and in the United States and the UK we have also come across the terms modular classrooms and terrapins[4].

For the purpose of this document we will use the term relocatable[s] to refer to this category of classrooms.

4 Terrapin Ltd has been providing prefabricated school infrastructure to the UK market for more than 60 years.

Relocatables>
The Status Quo

Overview

refer 1

The Department of Education in each Australian State is responsible for procuring its own relocatables, however even within the confines on a single State there is a wide range of climatic and contextual variables.

Current relocatable classrooms are generally factory manufactured as **3D off-site** or modular units that are transported to a site in sections or modules and installed and joined together on-site, providing significant efficiency, cost and safety benefits. The speed of installation is an important factor as buildings can be installed during school holidays so that there is minimal disruption to the school community. The nature of the modular units also means that they can be moved in the future *if required*, even if the intention is that they are to be installed as a permanent solution.

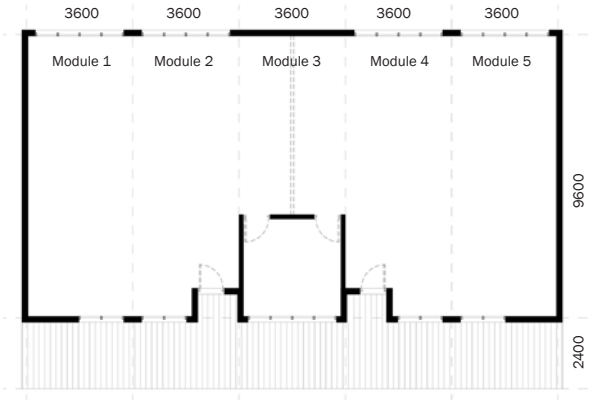
In Australia, relocatable classrooms are often named after the number of modular units that make up the whole building, for example a Mod 5 or a Mod 10 classroom product comprises 5 or 10 modular sections that are joined together on site. The Mod 5 Classroom product is an example of a typical Australian relocatable classroom.

"Relocatables are getting better in terms of comfort, but they're still quite ugly..."
[A parent, Victoria, February 2011]

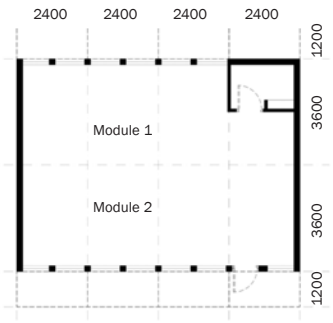
"Recent natural disasters mean that many schools will have relocatables for at least 2 years during re-building programmes."
[Department of Education, Queensland]

"We don't use our Smartboard any more ... the floor vibration means they need to be re-calibrated on a daily basis..."
[A teacher, research interview March 2011]

A typical Mod 5 Classroom [VIC]



A typical WA Mod 2 Classroom [WA]




A Mod 5 Classroom interior


Mod 5 Classrooms at the factory


WA relocatable installed at a school

How do we develop future relocatable infrastrucuture for schools that appropriately balances: the client brief, end user aspirations, site constraints, transport logistics, fabrication strategies, performance and economy?

Relocatables>
And tomorrow?

"This new relocatable is great as it has sliding doors that open on to the deck..."
[A teacher, Victoria, research interview May 2011]

"It would be great if all the walls were pin-up surfaces, otherwise they just get covered in blu-tack."
[A teacher, Victoria, research interview April 2011]

"We can't use some of the relocatables for younger children as it's quite a walk to the toilet block."
[A teacher, NSW, research interview June 2011]

Common Problems

refer 2

Heat gain and loss: difficult to manage in current 'generic' products;

Indoor environment quality: acoustics and light levels are often less than ideal;

Floors: generally low thermal mass, sometimes undesirable floor movement;

Floor level: typically circa 600mm above ground for connection crawl space;

Connections and views: generally limited, both visually and physically;

refer 3

Placement: often disconnected from other school buildings, hidden from view;

Toilets: usually not provided due to distance from soil waste connections;

Extras: no standard range of 'extras' that are also 'relocatable';

Temporary: often look and feel temporary, yet can become permanent;

Details: joins between modules and other details add to 'temporary feel';

Appearance: utilitarian in appearance, generally designed by manufacturers;

Transport: design is largely defined by transport logistics rather than end use.

Future Needs

refer 1

Relocatables of the future will need to respond to:

- a range of climate zones;
- a range of architectural vernacular;
- a wide variety of physical contexts;
- a range of pedagogies and student ages;
- and address the common problems.

How do you:

- develop a design idea that responds to a range of parameters and contexts?
- develop a design idea that is both customisable and economical?
- make it easy to add elements that allow buildings to evolve as needs change?
- deal with the relocation of buildings to new contexts at some point in the future?

Other issues to consider are:

- procurement models
- the role of architects
- the role of manufacturers
- the interface with end users.

Moving Forward

Many of the issues with today's relocatables stem from the challenges faced by a generic, mass produced product that is required to perform in a wide variety of contexts.

Yet they are not specifically customised for any of these contexts, and are generally a 'one size fits all' response.

The challenge ahead is to explore design ideas that address the complex issues associated with relocatability and transferability.

Transformations>
Looking forward

"Society needs better quality yet less expensive solutions to the built environment. To achieve the necessary advances in construction, the whole process needs to become increasingly interdisciplinary - engineering, industrial design, architecture, economics, physics, sustainability, manufacture..."

[Professor Thomas Bock, TU München, research interview November 2010]

Supply|Demand Nexus

The current supply|demand nexus illustrates that today's relocatable classrooms are largely defined by manufacturers and facilities managers.

Adoption of new digital technolgies, and increasing their interface with the manufacturing process presents exciting opportuntities for re-defining prefabrication.

These offer the potential to transform relocatables, and prefabrication in general.

Key Challenges

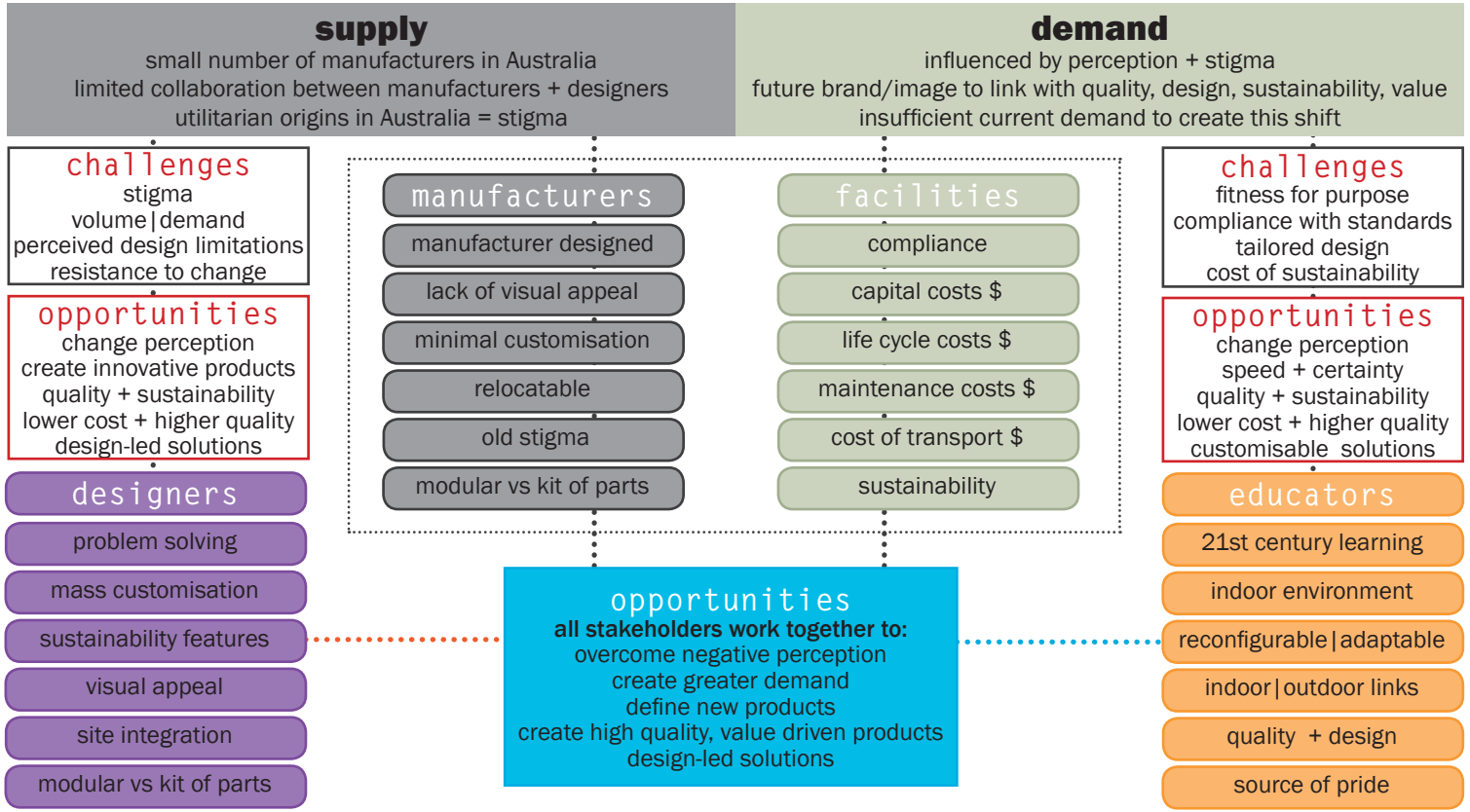
- In Australia, a largely low tech prefabrication industry needs greater designer and client demand prior to investing in new digital design technologies and the associated training.
- Communication between architects and manufacturers is often limited during the design stage as a result of contractual relationships and competitive bidding requirements. This commonly leads building designers to adopt conventional construction approaches.

Key Opportunties

The benefits to consumers far outweigh the challenges, so now is the time to start investigating new procurement models, new construction systems and a new offer to the market place.

The following pages outline some trends and opportunities that lie ahead.

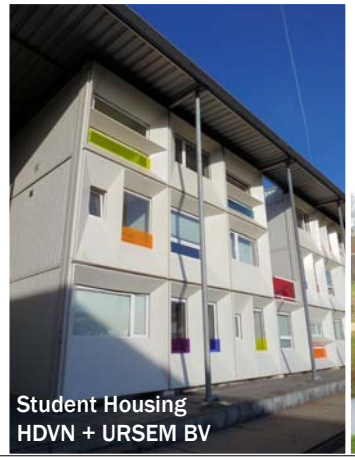
Key Stakeholders and Their Drivers

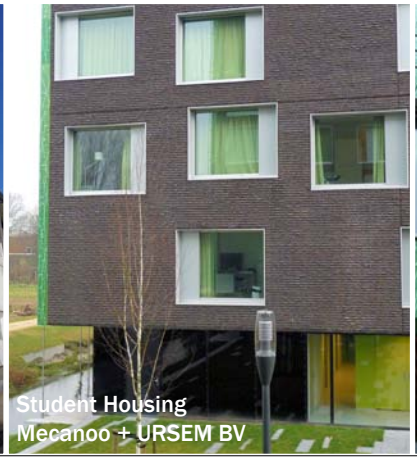


International trends>

"Prefabrication cannot transform poor design, but prefabrication can be transformed by good design and considered details."

[Professor Alistair Gibb, University of Loughborough, research interview November 2010]


Student Housing
HDVN + URSEM BV


Student Housing
Mecanoo + URSEM BV


Student Housing
Mecanoo + URSEM BV

Key Lessons

- Importance of a strong, innovative industry body with a research and development wing;
- Investment in cutting edge manufacturing equipment is a significant investment that requires a certainty of volume;
- The housing market plays a vital role in creating demand for prefabrication innovation;
- Lean manufacturing principles and systems thinking are critical to innovation and development in prefabrication;
- Prefabrication has a vital role to play in the future of a more sustainable, efficient construction industry;
- Architects have an important role to play in the design and development of future prefabrication systems;
- Architecture Schools in Europe will increasingly include more teaching of industrial design thinking to help bridge the gap between architecture and manufacture.

Japan

In Japan, prefabrication is synonymous with innovation and quality, particularly in the housing market. Toyota has been applying their lean manufacturing principles to their Japanese housing division since 1976.

Japanese companies such as Sekisui Heim work with finite component sets[5] from which they can offer their clients a controlled degree of customisation while building high quality, architect-designed, competitively priced homes in a fraction of the time of conventional site-built methods.

Most of these companies did not evolve from traditional craft based construction firms, but were set up by building material companies to create a showcase for their products [Gann 1996].

5 In 2005, Bock wrote of Sekisui Heim's prefabricated houses composed from a set of some 2 million standard components.

Europe

In Sweden, a large percentage of families live in high quality, fair priced, prefabricated houses. In Germany, display villages show houses from different manufacturers, demonstrating that there is something for every taste and every budget, and that sustainable design is vital.

European research projects such as ManuBuild[6] seek to harness the potential of digital technologies to streamline manufacturing and building construction. From Lapland to Munich there are house manufacturers use fully computerised CAD CAM production lines, many working with timber.

Hotel chains such as Travelodge build their hotels using 3D modules, and often the fittings and furnishings are already in place. Recently, prefabricated student housing projects in excess of 20 floors have been completed.

The UK's industry body Build Off-Site is working hard to redefine prefabrication as efficient, sustainable, and quality driven. It has have a strong research focus. Larger manufacturers are becoming increasingly innovative and design-led[7] .

USA

The USA has an active industry body, The Modular Building Institute, which conducts research and hosts seminar, conferences and exhibitions. Despite tough economic times, prefabrication's speed and greater cost certainly could give it a real edge in a difficult economic climate.

Prefabrication in the USA has shared some of the issues of stigma with the UK and Australia [Arieff & Burkhart 2002]. However, in the past decade architects have embraced design-led prefabrication. This has led to a 'renaissance' although price has kept some of these 'designer versions' out of reach of the masses.

6 This industry-led, pan-European research project ManuBuild ran from 2005-2009 with 25 project partners including the CIRIA, Technical University of Munich, Loughborough University and The University of Salford. Research papers can be accessed at: www.manubuild.org

7 Compiled from research interviews with Professor Alistair Gibb, Keith Lyon of Caledonian UK, Stephen Wightman of Modular UK and Adrian Day of Terrapin Ltd.

Prefab World>
Bauzentrum Munich

"The Bauzentrum near Munich is a display village with something for every taste and budget... wonderful! It demonstrates a range of prefabricated construction approaches and style choices from different manufacturers... excellent quality, energy performance and value for money are common to all the products."

[Clare Newton on Bauzentrum in Poing near Munich, Germany, research visit November 2010]

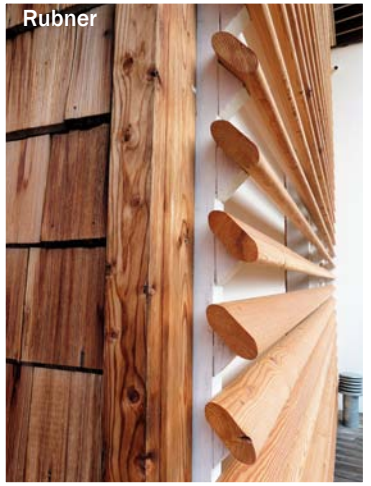
http://www.fertighauswelt.de/musterhaeuser/ausstellung/muenchen/index.html


Gruber


DaVinci Haus


Elk


Baufritz


Rubner


Rubner


Huf Haus

The Energy Centre

Different approaches>

2D off-site kit of parts non-volumetric flat pack

3D off-site modular volumetric unitised

"The parallel is not with building cars on a production line; it is with designing and planning the production of a new car model."
[Egan 1998]

Overview

Manufacturers describe a common scenario of architects approaching them in same way they would approach a general builder, when seeking a tender price on a finalised, bespoke design.

Yet manufacturers are in the business of production: they have their own systems, they need volume and - where possible - a level of repetition.

So there is a knowledge gap.

Central to the success of prefabrication in any project is adoption of a **systems + manufacturing philosophy**, rather than a conventional construction approach in a factory environment.

We need to embrace a level of product or industrial design thinking. Prefabrication needs to be central to the design and construction concept of a project and considered from the outset for maximum benefit.

A key opportunity for the future is that of architects, engineers, industrial designers and manufacturers working together to develop *inter-changeable product families* for the market place.

2D Off-site Approach

2D off-site covers the non-volumetric systems including kit of parts, flat-packs and elemental systems. There are both positive and negative features:

For:

- Lends itself to mass customisation - a 'family' of elements can be composed in various ways;
- Well designed systems can be assembled with low-skilled labour;
- Components can be flat-packed to facilitate transport and delivery;
- Transport logistics and costs can be less onerous than those of 3D off-site approaches.

Against:

- Installation not as fast as the 3D off-site approach;
- Shortage of standard, inter-changeable products on market.

Requires:

- Careful consideration of components and their interfaces for effective manufacture and ease of assembly;
- Building Information Models facilitate design, assembly and procurement.

3D Off-site Approach

3D off-site includes volumetric and modular systems. There are both positive and negative features:

For:

- Manufacture concurrent with site preparation can significantly reduce on-site time;
- Factory environment not affected by adverse weather;
- Shift work is possible in a factory environment;
- Modules can be joined to create larger spaces;
- Well suited to projects that can readily be 'unitised'.

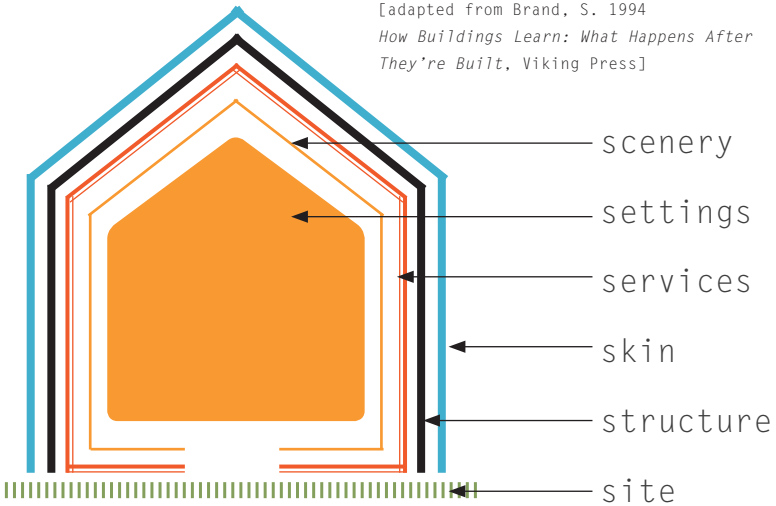
Against:

- Criticism of 'transporting air';
- Logistical challenge of transport and associated costs.

Requires:

- Understanding of a manufacturers systems and parameters;
- Understanding of transport constraints;
- Careful design of junctions and joints between modules.

A Systems Approach>
Old and new ideas



[adapted from Brand, S. 1994 *How Buildings Learn: What Happens After They're Built*, Viking Press]

"The *cradle to cradle* approach to design doesn't currently enter a typical building designer's framework, yet it will become increasingly critical as we meet our obligations to the environment through a more effective use of our resources."

[Professor Thomas Bock, TU München, research interview November 2010]

Lessons from the Past

In 1933, the architect R.M. Schindler of California explored and designed his concept for *Schindler Shelters*[8] which sought to create a new construction system that not only reduced construction costs but also improved building efficiency, speed of fabrication, interchangeability of parts, reduction of labour, durability, better design, and personalised housing designs.

The beauty of the Schindler's post and beam system was that it was based on only 9 components. It was designed so that components were both easy to assemble on site and easy to replace or exchange over time.

This is just one of many examples from the past.

What could Schindler, Gropius and others have achieved with access to today's digital technologies?

What could we achieve today and in the future if architects and manufacturers were to *work together* to develop new systems?

8 Park's 2004 review highlights that Schindler's system was – quite simply – before its time.

The Six 'S'

Designing for prefabrication requires us to think about buildings and their construction differently.

Relocatable classrooms bring their own unique set of parameters into the equation as building and site are no longer permanently inter-dependent.

If we consider that different elements of a building will have a different life span, then we can start to factor this into the long term adaptability within the life cycle of a building or system:

site	eternal
structure	30-300yrs
skin	20 yrs +
services	7-15 yrs
scenery - fitout	3-30yrs
settings - furniture	1yr +

Thinking in terms of these layers helps us explore issues such as assembly, disassembly and future re-use. We also need to consider all of these building layers - inclusive of loose furniture and fittings - as integral to the design and procurement of relocatables.

Industrial Design

In coming years, the introduction of advanced robotics to the construction industry will require a different design approach from architects. Thinking in terms of construction systems, their digital representation and the interface to fabrication will need to become part of the future 'designer toolkit'.

These ideas may seem distant however in Japan, companies such as Samsung don't just make computers and mobile phones; they have advanced robotics and construction divisions.

In response to this future potential, a number of post-graduate architectural courses such as those of the Technical University München are recognising the need for greater training in industrial and product design. Their aim is to prepare a future generation of architects for a greater interface with advanced manufacturing technologies and systems.

Logistics>
Getting to site

"There are parts of the Northern Territory which can only be accessed by barge for around 7 months of each year. This is a real challenge for us when providing infrastructure!"

[Ian Winch, Department of Education, Northern Territory, research interview 2010]

Source: Catholic Education Office, Melbourne

"We need to design with an understanding of how buildings will be fabricated and delivered to the site. This is a huge shift in design thinking for many architects, but it can result in a new rigour and purity that is appropriate for the future."

[James Timberlake, KieranTimberlake, research interview December 2010]

"Today's relocatables fit a truck, not a learning experience..."

[A teacher, research interview April 2011]

Transport

Transportation logistics play a major role in selecting or developing an appopriate prefabrication system.

- Size and weight limitations;
- Route restrictions;
- Availability of lifting equipment;
- Site accessibility.

Optimum freight load dimensions:

- 3.45m x 12.0m long x 4.0m high are the standard dimensions of a freight container;
- The following dimensions are inclusive of both **load + vehicle**:

	general oversize dimensions *			+ pilot vehicles + police escorts *		
	W	H	L	W	H	L
VIC	3.5	4.6	25.0	5.5	5.0	35.0
NSW	3.5	4.3	25.0	5.5	5.0	35.0
QLD	3.5	4.6	25.0	5.5	5.0	35.0
NT	2.5	4.3	19.0	4.5	4.9	30.0
WA	3.5	4.6	25.0	5.5	-	40.0
SA	2.5	4.3	19.0	5.0	4.9	26.0
ACT	3.5	4.6	25.0			
TAS	3.5	4.3	25.0	3.9	4.6	28.0

* all dimensions are in metres

Snapshots

RSPB, Rainham Marshes, UK

This RSPB Observation Platform[9] was carefully crafted so that installation would have minimum impact on the sensitive wetland nature reserve. *Haysom Ward Miller Architects* worked with *Modular UK* to develop modules that were craned in and installed in a morning, to minimise people and vehicle movements.

Loblolly House,Chesapeake Bay, USA

Working in a delicate eco-climate, all cutting and forming had taken place in the factory and the house was then **assembled** on site. Central to *Kieran Timberlake*'s design approach was that the building would leave virtually no trace if it were disassembled and recycled – or moved to a new location – in the future.[10]

9 http://www.haysomwardmiller.co.uk/page1/page7/page64/page64.html, viewed 30 June 2011

10 *Loblolly House: Elements of a New Architecture*

Strategies

Designers and manufacturers have explored various systems to address the challenges of transport constraints and rapid site installation, for example:

- unfolding buildings, almost origami style, for example those by Prebuilt[11] in Australia and Blu Homes[12] in the USA. These facilitate transport and allow for quick unfolding and site installation;
- 3D off-site buildings with hinged verandahs or decks that 'flip up' during transport;
- hinged cladding that flips up during transport and flips down upon installation to cover module joins;
- Ming Tang's conceptual ideas for folding bamboo shelters[13];
- transformable, adaptable, folding building structures such as those by Hoberman[14] and Quadror[15].

11 www.prebuilt.com.au/

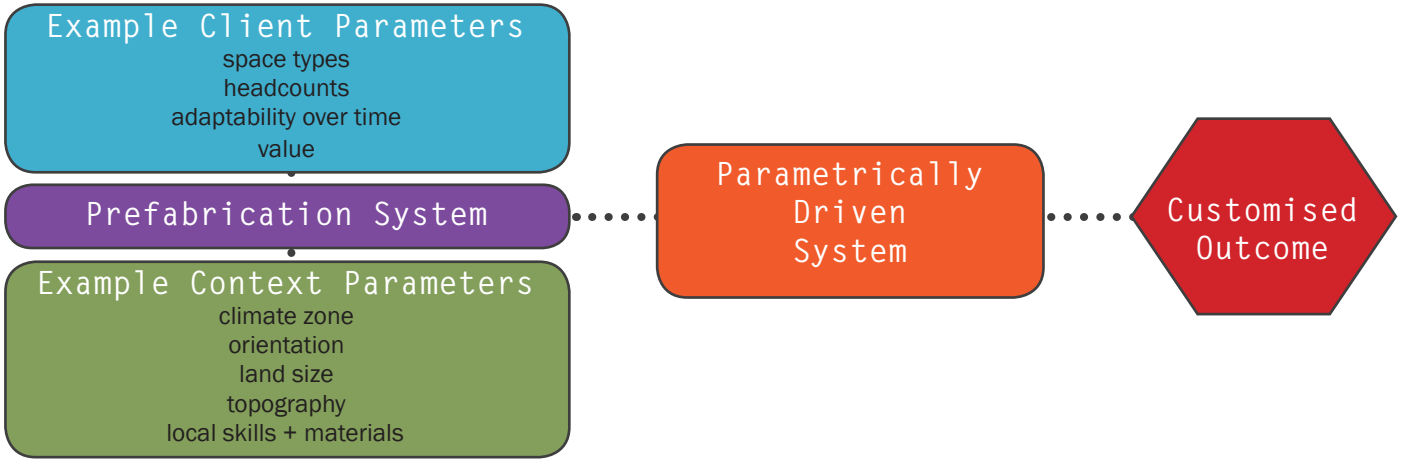
12 www.bluhomes.com/video/blu-element-unfolds-in-north-carolina/

13 www.treehugger.com/files/2008/10/ming-tang-folding-houses.php

14 www.hoberman.com/home.html

15 www.quadror.com/

Digital Design>
Parametric Design



"Parametrics... a powerful conception of architectural form ...replacing stable with variable, singularity with multiplicity."
[Kolarevic, 2009]

"Architects love parametric design's potential to create free-form designs ...but mention its potential interface with manufacture or production and many architects avoid the discussion..."
[Professor Thomas Bock, TU München, research interview November 2010]

An Overview

Parametric design has been used by design engineers and industrial designers for decades, for example in the design of cars, aircraft, and ships. It is a system of defining key criteria or constraints that we want a completed object to respond to.

For many within the architecture profession parametric design has become a digital tool for **form-finding**, leading to exciting free-form shapes for one-off designs.

However it is also important to embrace the much broader potential of these sophisticated professional tools to produce new and meaningful paradigms; addressing contextual and real-world issues such as sustainability, quality, constructability and affordability.

The application of this kind of digital technology is particularly relevant to prefabrication, as one can develop a system and adapt it to a specific set of site and other contextual parameters or client responsive conditions.

Optimisation

Through the use of key parameters of the designers choice, preconceived notions associated with particular typologies can be challenged and rethought and instead, innovative and optimal design solutions can be developed. Once values representing individual requirements are assigned to specific variables, personalised instances are created from a potentially infinite range of possibilities.

Parametric models have a 'transactional' quality that allows a sequence of alternative decisions to be constructed, exercised, and evaluated. This corresponds to the process of design at its most fundamental. These qualities translate to an ability to improve workflow and be rapidly adaptable to changing input and the inherent precision of information for both performance analysis and fabrication.

From a representation point of view, parametrics allow designers to produce details that are **programmed rather than drawn**. The rules of generation are always the same but the results can be different.

Kuka Robotic Brick Assembly
Source: www.kuka-robotics.com

Robofold
Source: www.robofold.com

Concrete Printing @
Loughborough University

Concrete Printing @ Loughborough University

Digital Design>
Digital Fabrication

"When an author produces a drawing which becomes the information that drives the machine, it compresses the world of design and fabrication into a single process."
[William Massie, 2010]

"Automated technologies are major investments for manufacturers... so we need to be confident of a corresponding volume of turnover..."
[Jan Gyrn, Modscape, research interview March 2011]

A Technology Timeline

1940s

CNC systems created by the US Air Force for fabrication of aircraft components.

1970s | 80s

CAD CAM initially adopted by the automotive and shipping industries. As affordability increased, other areas of manufacturing and industrial design adopted the technologies.

mid 1990s

Parametric modelling, building information modelling (BIM) and mass customisation begin to emerge to transform both design practice and project delivery. These technologies dovetail with CNC systems in Japanese prefabricated housing manufacture.

late 2000s

Robotic systems allow for fully automated deconstruction of high rise buildings in Japan. This urban mining approach is very clean and materials can be reclaimed for re-use. These principles also offer much potential for future construction.

Digital Design Tools

Complexity of form, surfaces, structure and detail in design in recent decades has, by necessity, led many designers to be closely involved in the fabrication processes and materiality concerns to enable their projects to be realised.

Such involvement has required the incorporation of this information into modelling and representation. This approach has given designers control of the digital information that can be used directly in fabrication and construction, informing computer-controlled machinery.

In turn, opportunities of feedback from fabrication, cost and performance analysis etc. can be integrated into an iterative design process, and prototype and scale models can be easily produced to test and prove concepts.

Increasing fabrication knowledge has reduced the gap between design, prototype and realisation. Digital information enables rapid prototyping of scale models and is moving the construction industry towards full-scale automated fabrication.

Future Technologies

Kuka Robotic Brick Assembly

Accurate to 1mm, Kuka[16] is a CNC robot that can create unique brick wall panels. Following in the footsteps of Uraguan Eladio Dieste's elegant brickwork, this technology can add beauty and performance to an automated cladding system.

Concrete Printing / Contour Crafting

A full scale rapid fabrication system, such technology allows for extremely accurate control over a plastic material. Opportunities stem from the geometrical freedom, single material construction and integration of function/services[17].

Robofold

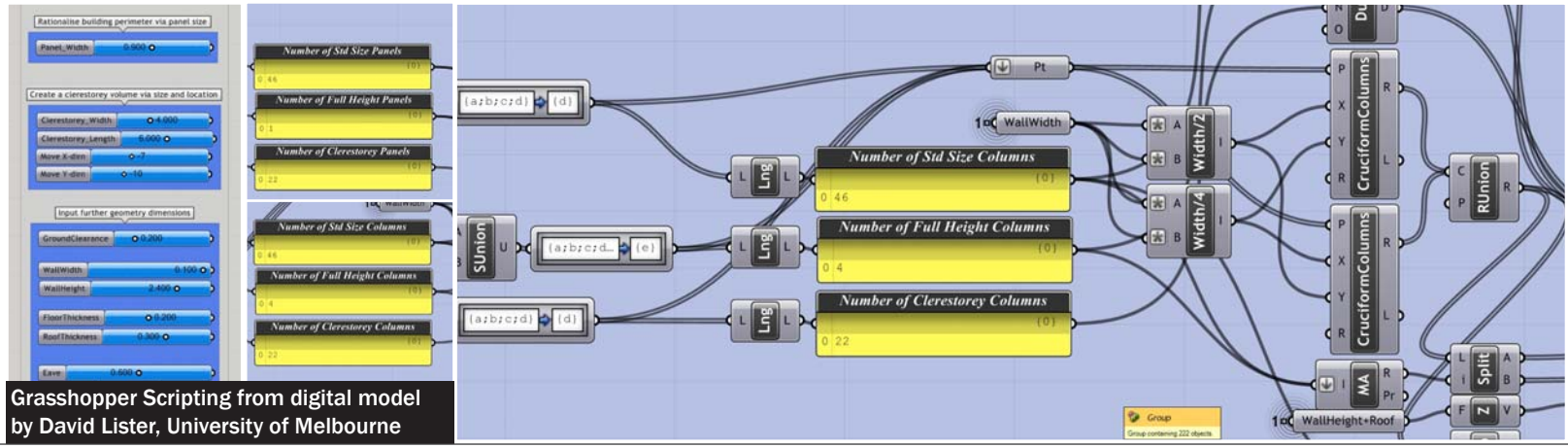
Similar in ways to the Kuko robot, it allows for the automation of an infinite number of unique metal folding operations without need for expensive moulds and press equipment[18].

16 http://www.kuka-robotics.com/

17 http://www.buildfreeform.com/

18 http://www.robofold.com/

Mass Customisation>
Consumer Choice



Grasshopper Scripting from digital model by David Lister, University of Melbourne

"Producing goods and services to meet individual customer's needs with near mass production efficiency."
[Tseng and Jiao, 1996]

"What these technologies offer is the potential to 'try before you buy' at all stages of the development cycle of a building, from inception to design, construction, demolition and rebuild."
[Hampson & Brandon, 2002:22]

An Overview

Architects have generally seen prefabrication as synonymous with mass production which is perceived to be *at odds with the one-off nature of architect designed buildings*.

The concept of **mass customisation** changes that.

It combines the economies of scale of production processes with the latent capabilities of computer-aided design and computer-aided manufacturing (CAD/CAM) technologies to offer greater choice for the individual customer, improved control of the total construction process, and flexibility of assembly options.

Flexible design and manufacturing systems reduce the long term costs of production and logistics while increasing personalisation and customer-perceived value.

Learning from the experiences of the automotive and retail goods industries, mass customisation could help architects to broaden their consumer base by providing increased financial accessibly.

Benefits of Re-use

Creating a digital model in which the parameters of the design and construction process are retained after the first implementation allows for constant optimisation of all facets of production; building upon knowledge, experience and capabilities to increase suitability, efficiency and performance.

As requirements evolve, new units can be introduced to the digital model further increasing variety and therefore personalisation for clients and 'dynamic stability' for designers and manufacturers.

Thinking in terms of construction systems is also an important element of mass customisation. This suggests a level of interchangeability from a rich menu of elements from which to compose new design solutions.

Key Opportunities

- Architects playing a pivotal role in developing new processes and products;
- Creating innovative systems and designs adapted to the client, at reasonable costs and with high quality construction;
- Architects working with a much broader consumer base;
- Automating the fabrication process, to allow for multiple, high quality outcomes to be built from the same system at negligible cost;
- Minimising waste;
- Maximising performance.

Key Challenges

- A *perceived* loss of architectural design freedom, architects feeling they are confined within a 'system';
- A lack of common, open standards for building components;
- Need of increased software inter-operability across the industry;
- Current skills gaps in both the architectural profession and the manufacturing sector.

Case Study 1>
Het 4 Gymnasium

"This is a temporarily sited school building that is moveable and most importantly of a permament design and construction quality."
[Arie van der Neut, HDVN]

Project Overview

Approach: **3D off-site | modular**

Location: Amsterdam

Client: City of Amsterdam

Architect: **HDVN Architecten**, Amsterdam

Manufacturer: **URSEM BV**, Wognum

Date of Completion: 2008

Temporary School

The Het4e Gymnasium - the Dutch equivalent to a grammar school - is located in an area of Amsterdam that is undergoing major regeneration.

The client believes quality schools are a key regeneration catalyst, so proposed a two step solution: a temporary school building for 5 years, followed by a permanent school building once the zoning issues had been resolved.

Due to problems with the development zoning plan, the school site is currently zoned for temporary use.

In the Netherlands, temporary buildings – up to 5 years - are subject to less rigorous building codes, and the client initially approached architects HDVN to design a temporary quality school for the site.

Permanent Quality

HDVN argued that using modular construction for a temporary school that was moveable and re-useable justified higher construction quality.

A core criteria for adopting the higher quality approach was that the 5 year temporary building period coincided with time most students would be at school.

Design as the Enabler

The architect considered how the modules could be separated and reconfigured in a variety of different ways, to respond to a number of possible future scenarios.

Coloured aluminium panels provide a colour explosion to the façade, giving the school a joyous and playful appearance. The timber rainscreen cladding provides texture, and the angled reveals give a depth to the building.

Integral to the timber cladding are hinges that allowed the rainscreen to be factory finished; the sections that cover the modules joins can be 'flipped down' for transport, then 'flipped up' to cover the joins at the completion of the installation.

A Modular Approach

The separate modules that make up the school left the factory around 85% complete. Pre-installed services were ready for connection and final testing on site.

The school's auditorium was created with a frame and infill panel system, showing how one project can embrace a variety of prefabrication approaches.

Building Envelope

Concrete slabs are important features of these reusable structures, and the thermal mass means they can utilise efficient low-temperature floor heating.

The modules have been designed to allow for up to 5 moves. This gives the client a great deal of agility in their future planning: they can continue moving the modules in response to changing needs, or they can also home them 'permanently' if required due to the quality of the building envelope.

This is considered a win-win scenario.

The structure of the modules has a design life of circa 50 years, the services have a life of around 25 years, and the cladding has a shorter life span again. Refurbishment and upgrade of these elements will occur at times of major moves.

Life Cycle Costings

Life Cycle evaluations were critical to the financial modelling of the project.

The explored scenarios highlighted reduced running costs over the 5 years if a high performance building envelope was adopted for the project, therefore validating the 'permanent quality yet moveable' concept.

Het 4 Gymnasium

Key Lessons

- **Permanent quality yet moveable**;
- Prefabrication fundamental to the design strategy, and vice versa;
- 3D off-site modular approach;
- Cladding and rainscreen as a 'skin' that can be changed over time;
- Clever details;
- Life Cycle costing supported argument for increased build quality;
- The role of good design in urban regeneration, even when buildings are temporary.

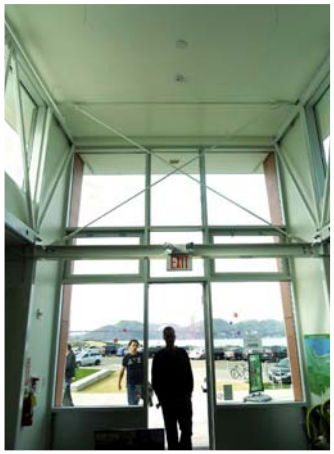
Manufacturer as Collaborator

The Westerpark School is just one of a number of projects that URSEM BV has worked on with HDVN. Together, they have applied the concept of temporarily sited yet permanent quality and moveable to a number of other projects including: a Nursing Home in Hilversum and Student Housing in Amsterdam.

In the first instance, this architect/manufacturer relationship was necessitated by a client who had identified URSEM as the preferred contractor for the Student Housing.

The manufacturer has seen a shift in the perception of modular construction in The Netherlands since their collaborations with design led, innovative architects in recent years.

Case Study 2>
Crissy Field



"...the rocket science is not in the fabrication of the components - it's in the systems thinking and design applied to the product!"
[Project Frog]

"We've created a life size erector [Meccano] set - the picture on the box may show you building a castle, but with the same basic components you can create a whole host of other things."
[Project Frog]

Project Overview

Approach: **2D off-site | kit of parts**

Client: Golden Gate National Parks Conservancy

Product Designer: **Project Frog**, USA

www.projectfrog.com/

Manufacturer: Varies for different components

Date of Completion: 2009

Total Area: 700 sq m

Better, Greener, Faster, Cheaper

Project Frog is not an architect, and not a manufacturer. Project Frog offers a customisable product.

They are bridging the gap between the rigid, no customisation of North America's 'brown box' relocatables and a highly customised architectural solution in which every building is a one off.

A Kit of Parts

Frog's essentially break down into three core system elements:

- concrete foundations which are adapted to local soil conditions;
- structural steel system which is seismic zone 4 rated and can resist winds up to 150km per hour;
- panelised building envelope.

In terms of project timeline, Project Frog was approached in April 2009 and Crissy Field Centre was fully complete and handed over in November 2009.

High Tech Design

Digital technology is core to the Project Frog offer. Clients - together with their architects - work with the 'configurator' software to plan and customise their unique Frog.

Project Frog then verifies the design and localises the product to climate and statutory requirements with their parametric modelling software. A full component list is then generated.

Project Frog does not charge design fees. The client purchases the kit of parts based on the component list that is generated during the design process, then Project Frog can arrange installation or the client | their architect can arrange installation.

The configurator allows for a controlled level of customisation. As such, Project Frog is a facilitator in the design process, however the client (or their architect) remains the controlling force.

Crissy Field

Key Lessons

- Prefabrication fundamental to the design strategy, and vice versa;
- 2D off-site kit of parts approach;
- The 'configurator' software allows for a level of controlled customisation;
- **Parametric modelling** is core to the mass customisation of the product;
- Product can be fabricated local to the site to avert long distance haulage;
- Straightforward assembly, so no specialist assembly contractors.

"Since 1950 across all industries in the USA, the average productivity increase is around 57%, but in construction it's just 7%! We have faster drills, bigger cranes and better bulldozers, yet much construction is stuck in the 20th century...
...Project Frog is committed to making things otherwise...."
[Project Frog]

"Think of buying a kitchen from IKEA, but on steroids!"
[Project Frog]

Low Tech Assembly

The instructions for assembly are straighforward, and installation does not require specialist contractors. The Crissy Field Centre construction site was run from a 3 by 10 metre solar cell as they essentially needed a crane, labour, and screwdrivers.

Not a Manufacturer

The Project Frog systems comprise a set of proprietary products integrated with the 'best-in-class components' from their partners. They don't have their own fabrication facilities, and prefer to source manufacturers local to a project to avoid the financial and environmental cost of transport.

So a Frog can be delivered in Washington or Melbourne, London, San Francisco, Sydney, Brisbane or Darwin – without the overheads of long distance haulage.

Green Frogs

refer 2

'Frogs' come with impeccable green credentials. The products are pre-approved by the State Architect and are pre-certified for the LEED points that are not site specific. A range of options are available, allowing a level of customisation in response to client needs, location, climate and budget.

With its water, energy and resource saving features, The Crissy Field Centre was expected to gain LEED platinum certification.

References>

Further reading

Overview

This brochure captures key findings from:

- Literature reviews;
- Visits to prefabricated building manufacturers in Australia, the USA, Europe, and the UK;
- Interviews with experts in prefabrication, parametric modelling and mass customisation;
- Feedback from school communities who occupy relocatable classrooms;
- Interviews with our Research Partners from 6 Australian Departments of Education to understand the past, present and future of the Relocatable Classroom.

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Het 4 Gymnasium School, Amsterdam by HDVN Architecten

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To stay updated with the *Future Proofing Schools* research please refer to:

www.futureproofingschools.com

For further information on the research please contact Clare Newton:

c.newton@unimelb.edu.au

Research Investigators

The *Future Proofing Schools* ARC Linkage Grant was awarded to:

- Associate Professor Clare Newton (Lead Investigator)
- Professor Tom Kvan [CI]
- Dr Dominique Hes [CI]
- Dr Margaret Grose [CI]
- Dr Sue Wilks [PI]
- Dr Kenn Fisher [PI]

[CI] *Chief Investigators*

[PI] *Partner Investigators*

Research Assistants & APAI

The *Future Proofing Schools* research team also includes [in alphabetical order]:

- Sarah Backhouse: *prefabrication*
- Tristan Clack: *geomatics*
- Lena Gan: *pedagogy & ICT*
- Philippa Howard: *PhD student (APAI)*
- David Lister: *parametric design*
- Jacqui Monie: *landscape architecture*

Our Research Partners

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- Gini Lee, Professor of Landscape Architecture, VIC
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- Lee Callum, Executive Director, Stratedy, Planning + Performance, DET, QLD
- Tim Fitzgerald Director of Wannick Unit, DEECD, VIC

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- Professional prizes: Melbourne School of Design
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