# THERMAL COMFORT IN SCHOOL BUILDINGS IN THE TROPICS

**Kerrie Prescott**
PO Box 1510
Townsville Qld 4810
fax: 61 7 4779 1399
email: presdunn@hotkey.net.au

*In the mid 1990's the 'need' to mechanically air condition school buildings became a political issue in North Queensland. Research suggests that school children are susceptible to heat stress, acclimatisation or cultural factors aside. Cooling strategies are also desirable to protect capital investment in building fabric, resources and electronic equipment. Community expectations suggest that air conditioning in the tropics is a 'necessity' to maintain an acceptable 'standard of living'.*

*Investigative Post-Occupancy Evaluations (POE) of a number of schools in the Townsville and Mt Isa region revealed:*

- *Varying teachers' responses to the existing thermal environment;*
- *Teachers generally considered that air conditioning is necessary;*
- *Management of the existing classroom thermal environment is frequently impaired by lack of maintenance or understanding (of passive principles), laziness or for other usage reasons.*

*School designers must recognise that it is not a teacher's role (or interest) to manage the thermal environment of a classroom and therefore should design school buildings so that human comfort conditions are easily and efficiently maintained through the variety of passive and active means available. Air conditioning is but one tool available to achieve thermal comfort.*

## 1 Introduction

Recent government moves regarding climate control for schools in North Queensland, inspired by community demands, will see the introduction of air conditioning and other forms of cooling into some parts of schools in the tropics. There has long been the argument that if schools in the southern parts of Australia are heated during winter, why are tropical schools not artificially cooled in summer, when conditions can be equally stressful to children and teachers?

When inspecting schools that required extensions or further architectural work, the writer was repeatedly told "this is a hot classroom" or "the children don't concentrate after lunch" or "we need air-conditioning". On looking around the room, it was often noted that the windows were closed, the fans were on 'high' speed, emitting a mesmerising hum and often the windows themselves were plastered with posters and students' artwork. This suggested that the 'problem' may be a complex one, and that such complaints probably have a valid, but not necessarily obvious, basis.

As observed by Robson over a century ago, "much of the restlessness, inattention and apparent stupidity, often observable among children, is due more to want of freshness in the air than dullness in the scholar." (Robson 1874). Nearly 125 years later, we are still struggling with the question of how to provide buildings that facilitate the process of learning.

## 2 Post-occupancy evaluation

This paper is prepared from the results of a post-occupancy evaluation (POE) study of a number of schools in North Queensland. The Study Area ranged from Townsville and Palm Island (humid tropical climate) to Mount Isa (dry tropical climate) and included research on nine schools and inspection of a further 14. As a practising Architect, the writer was interested in the reactions of the teachers and students i.e. the users, to their surroundings. Professor Wolfgang Preiser, in his lecture on POE at James Cook University (22 March 1995) noted that up to 90% of the data from POE surveys and interviews will relate to relatively minor but immediate details of design. These are elements which daily affect the users' perception of the building.

During this research, the writer has noted almost universal complaints from primary school teachers of:

- not enough pinboard space,
- cross-wind blows items off pinboards (by inference, wrong or poorly positioned windows),
- not enough or wrong type of storage (however the "wrong" type for one was the "right" type for another.

It must be realized that these facilities are the teachers' "tools of trade" and therefore their opinions are relevant to the designer.

## 3 The need for cooling

The need for cooling strategies in tropical climates is related to:

- human health and comfort;
- protection of capital investment in building fabric;
- to prolong the life of resources and electronic equipment.

The first of these is very important because the provision of buildings is primarily to shelter humans from the elements of the external environment.

While the sensation of comfort will ultimately depend on climatic variables of temperature, humidity, air movement and radiation, individual thermal preferences are influenced by a number of factors such as activity, acclimatisation, age, health and clothing. In reality, thermal comfort is achieved when the range of variables does not cause a sensation of discomfort.

The 'adaptive model' of measuring thermal neutrality, recognises that people's preferences depend on the thermal conditions prevailing at their location and vary with the seasons (Aynsley & Szokolay 1997). Givoni (1994) states "People who live in naturally ventilated buildings, usually accept.. a wider range of temperatures and air speeds as normal."

If the 'adaptive' approach is adopted for school building design, it will have major implications for:

- sizing of mechanical plant, equipment and electricity supply mains,
- running costs and life cycle costs of buildings,
- immediate health issues, and
- future health of the students if they retain or lose adaptability to the natural climatic environment.

### 3.1 Heat stress

Heat stress "may be defined as that combination of air temperature, radiation, moisture content of the air, air movement, clothing and behaviour that induces a physiological inability of the body to maintain its temperature within limits that permit normal physiological performance." (Aynsley et al. 1996).

Heat disorders which can affect children include "prickly heat", extreme sweating, giddiness, weakness, irregular breathing, nausea and heat cramps from loss of salt in muscle tissue. Heat stroke, which can lead to unconsciousness and dehydration due to loss of body fluids, must be identified and treated immediately. Children are more susceptible to heat disorders than adults because they have a larger surface area to body mass (causing children to gain heat more rapidly) and children do not instinctively drink enough fluids. This last item highlights the need for teachers (or other adults) to be observant of the children's condition; some management strategies will be discussed later.

### 3.2 The effect of heat on learning capacity

Human behaviour can be affected by heat stress. During interviews with teachers, comments were made regarding the excitable and/or lethargic behaviour of students after the middle-day lunch break and that concentrated learning could not be expected at this time. From surveys carried out at schools in Townsville, Mount Isa, Weipa and Palm Island, teachers reported that at high temperatures children were: tired, restless, sweaty, frustrated, lethargic, bored, not responsive and were unable to concentrate, thus exhibiting a wide range of behavioural descriptions. Primary school teachers frequently mentioned the unpleasant odour associated with many young children in a room, particularly after outdoor activities.

Temperatures which were considered high were generally noted as 30°C and above, while a small number of teachers thought that temperatures over 28°C were too high for comfort (Prescott 1998). The teachers' reactions to the question of effects of cool temperatures were mostly dismissive. "It's never <u>too</u> cool" was a typical response. A number of teachers on Palm Island, however, indicated that children were calmer on dry, cold days (i.e. in winter) and wanted to sleep more.

### 3.3 Management strategies to minimise heat stress

Some management strategies can render school buildings more pleasant to be in, and thus more effective for their purposes. A normal inexpensive dry bulb thermometer can be used by teachers to monitor the thermal conditions in their classrooms and take management action where appropriate.

Some strategies are summarised below:

- Adjust the start and finish time of the school day to avoid the mid-afternoon heat.
- Program classes and activities appropriately eg. classes requiring mental concentration in cooler morning, no physical education classes prior to sedentary studies.
- Ensure that the classroom is "managed" correctly i.e. available ventilation options (windows opened, fans on) are used.
- If air conditioned, close windows and doors.
- Ensure an adequate supply of cool drinking water is available. (Aynsley et al. 1996).
- Specify appropriate uniform or clothing.
- Hold classes outdoors in the shade, if appropriate.
- Provide refrigerators or cold room for students' lunches; food left in a school bag can spoil in a few hours of tropical heat.

### 3.4 The perceived need for air conditioning in tropical schools

While the human body can adapt to fluctuations in climatic conditions including changes in relative humidity, technical equipment is often sensitive to the climatic environment. The need for air conditioning is often related to equipment such as computers being located in the space; the comfort of occupants is a second consideration. Also, where humidity must be controlled, such as a library or paper handling workroom, air conditioning is desirable in the tropics.

Because of a social shift, mechanical air conditioning is becoming standard in residential as well as commercial buildings in tropical Australia; therefore the community's insistence on air conditioning of schools is understandable. Where people have an expectation of comfortable living and working conditions, it is reasonable that they should demand that facilities for their children are also comfortable and conducive to the work of a learning environment.

POEs carried out in North Queensland revealed that most teachers would like to work in air conditioned spaces. Most schools studied exhibited both passive and mechanical cooling systems. This is because the air conditioning may have been retrofitted (often simply room air conditioners (RACs) fitted into existing window openings) or because it is only used during summer or on extreme heat days.

The *Cool Schools Report* (Macks & Robinson 1997) recommends cooling of classrooms only when the indoor temperature exceeds 27°C, and then only reducing the temperature to 27°C. However, from interviews with teachers, principals and mechanical engineers, the writer suggests that this may not be an acceptable temperature to most adult users. Temperatures of 25°C and 24°C were suggested as more tolerable.

## 4 Cooling strategies for schools

The Queensland Government's 'Cool Schools' program introduced in 1996, has assisted schools, both state and private, in North Queensland to assess their building stocks and provide some cooling strategies where needed. This does not mean simply air conditioning all buildings.

In many instances, funds have been allocated to projects that enhance passive cooling of buildings, such as replacing sliding windows with louvres, installation of insulation, etc.

### 4.1 Types of cooling systems

Designed strategies for cooling buildings can be loosely categorised depending on the input and type of fuel energy required for cooling to take place. These are:

- ***Mechanical systems***, into which fall air conditioning and evaporative cooling units, heat pumps, etc. which use electricity, gas or other fuel to drive machinery and equipment.
- ***Solar cooling strategies*** which use the sun's energy in either active or passive modes:
  - *Active* solar cooling concepts include solar activated absorption, heat engines, heat pumps and photovoltaic cells.
  - *Passive solar* techniques include uncontrolled methods such as shading devices, ventilation, insulation, ground coupling and controlled methods including roof ponds, cooling ponds, nocturnal radiation, movable insulation (Le Chevalier 1978).
- a ***combination*** of approaches, with the intent to keep both capital costs (i.e. equipment size and complexity) and running costs to a minimum.

Passive solar techniques are frequently designed into a building as a first approach to cooling and ventilation, and as such can offer a high ratio of performance to costs, especially running cost (for cooling) which is nil. Most architects and building designers who live and work in the tropics, understand the need for thermal insulation and shading of walls and windows in the tropical climate. Buildings in which these essential elements have been ignored can be very uncomfortable in summer conditions.

It should be noted that many passive cooling techniques/strategies are incompatible with the principles of efficient air conditioning. If a building is to be air conditioned, it should be designed accordingly from the outset (Macks & Robinson 1997).

### 4.2 Passive design principles applicable to school buildings

The principles of an 'environmentally interactive' building, according to the Defence Housing Authority (DHA) Tropical Housing Research Committee (1995) are:
- promotion of cooling breezes,
- dissipation of rising heat,
- reducing radiation of heat,
- sheltering of openings,
- provision for the winter response,
- minimising the problem of dust, and
- minimising glare.

Cooling strategies appropriate to tropical schools will not be discussed in detail in this paper, as they are adequately covered elsewhere (Prescott 1998). However, the common strategies observable in existing tropical Queensland schools including the following:

- Building orientation and shape for shading of walls and windows; generally long shaded wall to north and short east and west walls, with overhang to shade south wall during midsummer (midday) when the sun is to the south of the zenith. Since schools are currently in use from approximately 8.45 am to 3.30 pm, the width of overhangs for shading of walls and windows could be designed only to limit sun penetration during these hours of use. However, this may compromise the usefulness of buildings for before or after school use.
- Building orientation and shape for natural ventilation to remove the build-up of heated air within the space, produced by occupants, equipment and solar absorption. Grouping of buildings should ensure that each will receive as much breeze as possible and avoid the possibility of breeze "skimming" over the top of the roofs (Lee 1997). 'One room wide' designs facilitate good cross ventilation, especially if small openings are positioned on the windward side and large openings on the leeward side (Fry & Drew 1964).
- Provision of air movement over the skin of occupants which will promote cooling of the body by evaporation, particularly at student body height, i.e. generally from floor level to 1100 mm high. Ceiling fans, 'Cardifair' and similar can assist air movement, but can create noise problems in classrooms. Landscaping and devices such as 'wing walls' and adjustable vertical louvres can assist or hinder natural ventilation to a building
- Insulation and heat reflective materials.
- Roof Colour; buildings with light coloured or reflective roof surfaces generally show lower ceiling temperatures than buildings with dark roofs (AITA Research 1997).

## 5 Management of cooling systems in schools

Many of the decisions involved in cooling system design for a school must initially be made by the school management at the planning phase of the project. Decisions regarding maximum acceptable temperature and humidity, hours of operation, funding of capital and running costs, etc. will affect the strategies selected and the design of any passive and mechanical systems to be incorporated.

The proper management of cooling systems, whether passive (eg. maximum natural ventilation) or mechanical (air conditioning) or a combination, is essential for effective and cost efficient running of the system.

Obvious management strategies include:
- opening windows and turning on fans when in passive mode,
- closing of windows and doors when air conditioning is turned on,
- reducing leakage of cold air (under doors, through louvres, etc),
- limiting the amount of cooled air lost at changeover of classes.

To ensure no alteration of the selected temperature at which the air conditioning system is activated, there should be no adjustment available in the classrooms. A simple ON/OFF switch (say, adjacent to the light switch/s) can be installed, but the system would not be activated until a thermal switch is triggered. Similarly, timing switches can be installed to activate air conditioning for a set time, eg. a period (45 minutes) or from 8.30 am to 3.30 pm. Override switches can be installed.

## 6 Conclusion

There is a growing expectation that schools should provide comfortable thermal conditions to promote concentration and minimise the possibility of heat stress, which is a problem for children in the tropics. A combination of approaches is recommended.

For new and refurbished school buildings in the tropics, an efficient and cost effective approach to cooling would be a combination of:
(a) passive design elements such as building orientation, shading of walls and windows, insulation, light roof colour, etc.,
(b) tightly sealable windows with good ventilation capacity,
(c) mechanical cooling system (air conditioning in humid tropics or evaporative cooling in arid regions), and
(d) management and/or electronic systems to control the usage of the natural ventilation and mechanical systems.

Most importantly, whatever strategies or systems are selected, they must be 'user friendly' and appropriate.

- They must fit with current methods of teaching. (This is difficult as teaching methods constantly change and all individuals have different approaches).
- The principles must be readily understood by the users; school management should not have to train new teachers on the use of their classrooms.
- The classroom must be simple to manage by the teachers, for both comfort and security.
- Mechanical parts and systems must be as robust as possible, within budget limitations, to ensure continued functioning.
- To minimise operating costs of mechanical cooling of schools, all systems can be controlled centrally with limited input required by the teachers.

By managing existing school building stock intelligently and designing new school facilities to utilize passive cooling principles in combination with the now expected mechanical systems, school administrators and architects should be able to minimise energy input and assist the environment of schools in the tropics, allowing teachers to concentrate on teaching.

## 7 Bibliography

Aynsley, R.M., Szokolay, S.V. 1997, 'Options for assessment of thermal comfort/discomfort', Draft paper for aggregation into NatHERS Star Ratings, AITA, James Cook University, April 1997.

Aynsley, R.M., Harkness, E.L., & Szokolay, S.V., 1996, *Relief from Heat Stress in School Classrooms*, Report written for Queensland Department of Education, Australian Institute of Tropical Architecture, James Cook University, Townsville, N.Q.

DHA Tropical Housing Research Committee 1995, Report to Architects' and HMC Managers' Conference, Sydney, 30/10/95, Troppo Architects Pty Ltd, Darwin

Fry, M. & Drew, Jane, 1964, *Tropical Architecture in the Dry and Humid Zones*, B.T. Batsford Limited, London.

Givoni, B. 1994, *Passive and Low Energy Cooling of Buildings*, Van Nostrand Reinhold, New York.

Le Chavalier, R.R. 1978, 'Overview of the National Solar Cooling Program' in Clark & de Winter (Ed.)1978, p.3-13

Lee, SuSan 1997, 'Ecologically Sustainable Development in the Warm Humid Tropics', paper presented at Students & Sustainability Conference 14-18 July 1997, James Cook University.

Macks & Robinson Pty Ltd in association with the Australian Institute of Tropical Architecture 1997, 'Cool Schools Report' for Qld Department of Education, AITA, James Cook University, N.Q.

Prescott, K.M. 1998, 'Developments in school design for the tropics identified through Post-Occupancy Evaluation', unpublished masters thesis, James Cook Unversity, N.Q.

Robson, E.R. 1874, *School Architecture*, first published by John Murray, London. Victoria library edition published by Leicester University Press, 1972.