Topic B14: Policy, standards & regulations

THERMAL ENVIRONMENTS AND INDOOR AIR QUALITY OF P-12 EDUCATIONAL FACILITIES IN AUSTRALIA: A CRITICAL REVIEW OF STANDARDS, REGULATIONS AND POLICIES

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SUMMARY

This paper presents the key findings of a review commissioned by the Department of Education and Early Childhood Development (DEECD) in Victoria, Australia, that explores thermal comfort, indoor air quality and ventilation requirements for Preparatory to Year 12 (P-12) educational facilities. The objectives of the review are to identify and compare national and international standards, regulations and policies associated with the provision of thermal environment and indoor air quality in these facilities, and to examine current knowledge on the relationship between indoor conditions and educational outcomes for the P-12 group. The review shows there is a knowledge gap concerning the benefits, costs and consequences of indoor environment quality improvements in schools, and a poor understanding of the relationship between the indoor environment and learning outcomes. This paper establishes the need for research that determines the current state of indoor environments in Australian educational facilities and the relationship with the learning outcomes of students.

INTRODUCTION

Extremely hot weather conditions are becoming more common and severe in Australia (BoM, 2014a). The 2003-2012 decade remains one of the country's warmest with a temperature anomaly of +0.44 ºC (BoM, 2013). All capital cities recorded warmer-than-average maximum temperatures (Climate Commission, 2013). The average ambient air temperatures in Victoria have risen approximately 0.8ºC since the 1950s. In Melbourne, the long-term annual average number of days above 35ºC is approximately equal to 10 but rose to 13 during the decade 2000-2009 (BoM, 2013). The number of hot days is likely to increase to 15-26 days by 2070 (BoM and CSIRO, 2014). The January-February 2009 Melbourne heat wave and the record 2012-2013 summer temperatures were consistent with a shift to more extreme hot weather events (BoM, 2014a).

Victorian school buildings, as with much of the state's critical infrastructure and facilities, are vulnerable to poor performance during hot weather. With increasing frequency of hot days, there is growing public concern about the about the effects of school indoor environments on students (WA Department of Education, 2011) Poor indoor air quality (IAQ) and thermal conditions are known to decrease productivity and cause dissatisfaction for building occupants (Lan et al., 2012; Wyon, 2004). However, much of the research on indoor environments focuses on adult workers in offices (Clements-Croome, 2002). There is limited information on the relationship between indoor environment and the learning performance and behavior of children in school buildings (Mendell & Heath, 2005; Weinstein, 1979).

This paper presents the key findings of a literature review of the thermal comfort, indoor air quality and ventilation requirements for educational facilities. Commissioned by the Victorian Department of Education and Early Childhood Development (DEECD), the purpose of the review is to identify and compare national and international standards, regulations and policies associated with the provision of thermal environment and indoor air quality in P-12 educational facilities in Australia. In addition, the review examines current knowledge on the relationship between health and educational outcomes for the P-12 group and the indoor thermal environment and air quality.

SCOPE OF REVIEW

The scope of the literature review undertaken for the DEECD includes: (1) effects of thermal comfort, IAQ and ventilation on the health, educational outcomes and economics of P-12 educational facilities; (2) effects of building energy efficiency measures on the thermal comfort, IAQ and ventilation within P-12 educational facilities; (3) Australian and best-practice international policies, standards and guides applicable to the thermal environment, IAQ and ventilation within P-12 educational facilities; and (4) empirical evidence of the thermal environment, IAQ and ventilation within P-12 educational facilities in Victoria. This paper mainly focuses on cooling policies and protocols for P-12 educational facilities, since overheating and mechanical cooling costs are important issues for Victorian school buildings.

REVIEW OF POLICIES AND PROTOCOLS FOR AUSTRALIAN EDUCATIONAL FACILITIES

Australia features a wide range of climatic zones. The Australian Bureau of Meteorology (BoM) (2014b) identifies six main climatic zones (*hot humid; warm humid; hot dry summer-warm winter; hot dry summer-cold winter; temperate; cool temperate*) using air temperature and relative humidity. With different locations having different heating and cooling requirements, the energy efficiency provisions of the National Construction Code – Building Code of Australia (ABCB, 2013), specifies the same climate zones using BoM climatic data with two supplementary zones added to accommodate an additional temperate zone (*mild to warm summer, cool-cold winter*) and alpine area (*alpine*) (ABCB, 2012) and with climate zone boundaries aligned with local government areas. For all parts of the country, July is the month with the lowest average temperatures and in the south, the months with the highest average temperatures are January or February (ABS, 2012).

No unified set of policies and guidelines exist for air conditioning (heating, cooling and ventilation) of P-12 educational facilities in Australia. While international standards such as *ASHRAE Standards 55 and 62.1* (ASHRAE, 2010a, 2010b) and guides such *CIBSE Guide A* (CIBSE, 2006) are referenced, each State has its own unique set of policies and guidelines. These are summarised in Table 1.

Climate zones form the basis of the cooling policy of Victoria (DEECD, 2011, Section 5.8, p89). Schools are cooled if they are located in NatHERS[1] Zones 20 or 27. These zones are hot and dry during the summer, with the mean maximum air temperature exceeding 30ºC during January. This is similar to New South Wales' policy of providing cooling for schools in locations where the mean maximum air temperature during January exceeds 33ºC, although

New South Wales also accounts for the effect of building design on cooling demand by allowing ‘hot spots’ classrooms to be cooled when the mean maximum temperature is 30-33ºC. The Relative Strain Index (RSI)[2] used in Western Australia is also a location-based cooling policy. The Cooler Schools zones in Queensland are likewise based on the climate map of the state. In contrast, the cooling policy of South Australia does not specify geographical locations. The state’s policy takes a performance-based approach to cooling by specifying indoor air temperature requirements. Adopting a performance-based approach to cooling in educational facilities would objectively meet the appropriate requirements of young students.

Table 1. Australian policies and protocols on air conditioning (heating, cooling and ventilation) in schools

State	Policies and protocols
Victoria (VIC)	The Building Quality Standards Handbook (2011) of the Department of Education and Early Childhood Development provides guidance on the policy requirements on thermal comfort, cooling, heating and ventilation: • Cooling systems are provided to schools on the basis of their location within the Nationwide House Energy Rating Scheme (NatHERS) – Zones 20 and 27. All schools in these areas receive full air conditioning to their entitled spaces under the space and area guidelines. The remaining schools are not provided with cooling systems except in limited number of circumstances, e.g. where a concentration of mainframe computing is located (DEECD, 2011, Section 5.8, p89). • Air conditioning is provided to all special development schools (DEECD, 2011, Section 5.8, p89). • Thermostat setting for cooling should not be lower than 24ºC (DEECD, 2011, Section 5.8, p92). • Thermostat setting for heating should not be higher than 19ºC (DEECD, 2011, Section 5.6, p81). • No cooling system shall be considered, designed or installed until the use of natural ventilation has been considered (DEECD, 2011, Section 5.8, p91). • Ventilation conforms to the BCA requirement on a minimum area proportional to the occupied room floor area. Fixed or opening devices must be 5% of the total floor area. If this area can be achieved, the room is deemed to comply with the natural ventilation requirements of the Code (DEECD, 2011, Section 5.7, p83). • If natural ventilation requirements of the Code cannot be met, then outside air must be supplied to conditioned spaces at the rate prescribed by Australian Standard AS 1668.2 (DEECD, 2011, Section 5.7, p83).
New South Wales (NSW)	The Air Cooling Policy of the NSW Department Education and Communities (2012a) ensures that: • Schools with a mean maximum January temperature of 33ºC or above are provided with air cooling to all habitable spaces. • Schools with a mean maximum January temperature between 30ºC and 33ºC are eligible to apply for air cooling of ‘hot spots’ classrooms. • Air cooling is provided to all demountable classrooms and libraries in NSW public schools. • Bureau of Meteorology data is used to ensure the hottest parts of the state are addressed first. • Air cooling measures can include evaporative cooling or air conditioning, depending on local conditions. • The department is developing a Thermal Comfort & Resource Efficiency Framework that aims to maximize the performance of existing buildings through passive design measures (such as roof insulation and sun shades) complemented where necessary by mechanical systems to meet extreme heating and cooling requirements. (NSW Department of Education & Communities, 2012b).
South Australia (SA)	The Air Conditioning Protocol (SV001) of the SA Department of Education and Child Services (2007) provides guidance on the policy requirements for the provision of air conditioning in public schools: • Learning areas in schools and children’s centres shall have heating and cooling equipment capable of maintaining temperatures within the range of 20ºC-26ºC when the outside temperature is between 6.5ºC and 37ºC (for Adelaide). When the outside temperatures fall outside these ‘design temperatures’, then room temperatures may be below 20ºC in winter and above 26ºC in summer. • General learning areas, learning support areas and administration areas in schools and children’s centres are to have temperatures maintained within the range of 20ºC-26ºC on a Design Day as per comfort conditions detailed by ASHRAE Standard 55. This identified comfort conditions are being where there is a dissatisfaction rate of less than 10%. • For the Adelaide metropolitan area, the ‘design temperatures’ are 6.5ºC for winter and 37ºC for summer. For design temperatures for other parts of South Australia refer to Australian Institute of Refrigeration Air Conditioning and Heating (AIRAH) Application Manual DA9-Air Conditioning Load Estimate. • All occupied areas in schools and children’s centres shall comply with the Building Code of Australia

State	Policies and protocols
	(BCA) requirements for the provision of outside air by means of opening windows or vents, which shall be preferably manually controlled. • The minimum ventilation rate in learning areas shall be 10 litres per second per student, and assuming a maximum capacity of general learning area (GLA) classrooms of 30 students. • Students are dismissed at 12.30pm on days when the forecast maximum is 38ºC or higher, or up to one hour before normal dismissal time when the estimated maximum temperature is to be at least 36ºC.
Western Australia (WA)	The WA Department of Education uses the redefined 25 Day Relative Strain Index (RSI) line and extended 20 day RSI as the boundary for the 'Air Cooling Zone'(WA Department of Education, 2011): • All new schools within the 20 day RSI boundary will be provided with air cooling / air conditioning to the extent required. • All existing schools within the 20 day RSI boundary will be eligible to have air cooling / air conditioning into classrooms and offices where air cooling has not previously been installed. • The 20 day RSI line is to be considered a general guide (rather than a fixed demarcation line) that allows schools east and north of the line to qualify for air cooling / air conditioning. • No funding assistance will be provided to self-fund air cooling / air conditioning to schools to the west or south of the 20 day RSI boundary.
Queensland (QLD)	The Queensland Government introduced the 'Cool Schools' program in 1996 and 'Cooler Schools' in 1998 (Prescott, 2001). These programs: • Assist both state and private schools in North Queensland to assess their building stocks and provide some cooling strategies, where needed. • Recommend cooling classrooms only when the indoor temperature exceeds 27ºC. • Implement passive cooling techniques /strategies, such as replacing sliding windows with louvers, installation of insulation, etc. • Have no temperature limit for dismissing students (Chilcott, 2012). The Design Standards for DETE Facilities (2012) states: • Schools located in the Cooler Schools zones are provided with air-conditioning systems. It is the intention that air-conditioning is used only during the hot summer periods and natural ventilation is used for the remainder of the year. Also, where air-conditioning is not provided as part of the initial design (for example, in southern schools not in the Cooler Schools zone), it is important to consider that air-conditioning may be retrofitted to the facility at some point in the future. Therefore, a balance should be achieved between a design that optimises natural ventilation, and a design that can be thermally sealed should air-conditioning be installed (DETE, 2012, Section 3.2.3, p16). • The provision of natural ventilation in rooms that are not air-conditioned: Rooms designed for use by more than 15 occupants shall have external windows/doors/skylights with a minimum open-able area of 10% of floor area. Open-able windows and doors to be located on opposite sides of a room where possible (DETE, 2012, Section 3.2.1, p14). • Outdoor air supply rates in air-conditioned spaces should be sufficient to control contaminants and minimise the build-up of pollutants in the indoor environment. Provided the space meets the requirement of an open-able area of at least 5% of floor area, the outdoor air supply requirement is 5 l/s per person. If not the higher rate of 12 l/s per person specified in AS 1668.2 applies (DETE, 2012, Section 3.5.1, p32). • Air supply rates for kindergarten and prep spaces should meet the higher rate of 12 l/s per person specified in AS 1668.2 applies (DETE, 2012, Section 3.5.1, p32). The Schools Standard Air Conditioning Specification (DETE, 2010), specifies the following air conditioning design and performance parameters (Section 2.3.1, p31): • Summer: 26ºC ± 1K DB, 55% RH (not controlled) • Winter: 21ºC ± 1K DB, 55% RH (not controlled)

REVIEW OF INDOOR ENVIRONMENT QUALITY AND EDUCATIONAL OUTCOMES

There is limited information on indoor environmental conditions of Australian educational facilities. The indoor environment in schools has been much less studied than in other types of building such as offices. Similarly, there have been very few studies on the link between the indoor environment and educational outcomes.

Mendell and Health (2005), in a wide-ranging and authoritative review of research of the factors that might influence student performance, suggest that increased classroom temperatures can have negative effects on the learning performance of young students. Wyon and Wargocki (2007; 2009) conducted field studies to determine whether avoiding elevated temperatures in classrooms can improve the learning performance of children, and if so, by how much. The studies also sought to determine whether classroom air quality affects learning. These field experiments show that reducing moderately high classroom air temperatures in late summer from the region of 25°C to 20°C by providing sufficient cooling and increasing effective outdoor supply rate from 5 l/s per person to 10 l/s per person, improved the performance of numerical and language-based tasks resembling schoolwork. The EU-SINPHONIE project (2011-2013) is the first project to monitor the indoor environments of schools in 25 European countries in parallel (Institute for Health and Consumer Protection - European Commission Joint Research Centre, 2011). Project final reports and information on the findings of the study are currently not available.

DISCUSSION

This paper reports the findings of an evaluative review of the cooling policies and protocols in Australia for P-12 educational facilities and a literature review of the relationship between educational outcomes and thermal environment and indoor air quality for the P-12 group.

Standards and design guides on thermal comfort, indoor air quality (IAQ) and ventilation

The review of design guides and standards for cooling and heating, thermal comfort and ventilation in educational facilities indicated that most guidelines, policies and protocols follow the American *ASHRAE Standards 55* (2010a) and *62.1* (2010b) and the European *ISO 7730* (ISO, 2005), *CIBSE Guide A* (2006), *EN 13779* (CEN, 2007) and *CR 1752* (CEN, 1998). The thermal comfort standards prescribe numeric and descriptive criteria for comfort primarily for mechanically conditioned buildings – 19.7°C-26.7°C, 20%-60% RH. Whereas *Standard 55* does not provide specific guidance for naturally conditioned spaces, *CIBSE Guide A* prescribes summer design temperatures and over-heating criteria for free-running buildings, where 25ºC is an acceptable indoor temperature. These thermal comfort standards have been promulgated as applicable across all types of buildings, all climate zones and all populations. Yet, by far the majority of the thermal comfort data underpinning these standards have been obtained from studies conducted with healthy and 'fit' men and women workers in a workplace (in an office environment).

The guidance for offices was deemed to be applicable to educational facilities, assuming that influences of these environments on adults have relevance to the influences of school environments on children. Using the recommended criteria set by international standards in school guidelines, findings of studies on the effects of office environmental conditions on the performance of office work by adults have been viewed as surrogates of the effects of school conditions on student schoolwork. However, studies have found that environmental conditions in schools are inadequate and much worse than in office buildings (Daisey et al., 2003; Wargocki & Wyon, 2006). The criteria and recommendations in the international standards are adopted as normative references by Australian national standards, guidelines and codes of practice.

Indoor air quality (IAQ) standards pertain to reducing the quantity of indoor air contaminants by providing criteria for ventilation rates. The international standards (*ASHRAE Standard 62, European standards EN 13779* and *CR 1752*) provide both the prescriptive and analytical methods to calculate the ventilation rates. The regulatory actions related to IAQ in Australia are limited and there is a lack of information on the emissions rates of and exposure levels to pollutants in specific building categories. As an alternative to calculating the concentration levels, exposure to pollutants and actual monitoring, using the ventilation rates, for example those prescribed for educational facilities, is deemed to adequately address the achievement of the required IAQ for a space or building. The ventilation requirements in the *Australian Standard AS 1668.2* (Standards Australia, 2012) for educational facilities (10-12 l/s per person) align with those prescribed in the international standards.

Policies on thermal comfort, indoor air quality (IAQ) and ventilation
Policies on the provision of cooling and ventilation of Australian educational facilities typically follow one of the following approaches: (1) compliance with relevant performance standards, where heating, cooling and ventilation equipment is designed to maintain prescribed indoor temperatures/temperature ranges, ventilation rates and CO_2 concentration levels; or (2) the requirement for mechanical cooling is based on external (climatic) conditions of the facility's location rather than the requirement to maintain prescribed indoor conditions. In Australia, South Australia follows the first approach and outlines the conditions of occupied school spaces which require the provision of air conditioning. The states of Victoria, New South Wales, Western Australia and Queensland specify the requirement for cooling based on external (climatic) conditions rather than prescribing the indoor conditions (temperature, air quality) of school spaces. Setting the indoor conditions in educational facilities based on performance objectively meets the appropriate requirement of young students.

Indoor environmental conditions and educational outcomes
Information on indoor environmental conditions experienced in Australia's P-12 schools is very limited. Compared to other building types such as offices, the indoor environments in schools are less studied. Very few data and scientific studies on measurements of school environments, particularly on thermal conditions and IAQ are available. Moreover, majority of the studies in the review have been conducted in the northern mid-latitudes. This lack of knowledge poses a big concern considering that children, unlike adults, are much more vulnerable and perform different work that is often non-optional.

The prescribed conditions and temperature limits recommended by the standards were based on studies which did not take people's work performance into account. Available peer-reviewed literature and studies on the effects of classroom thermal conditions and air quality on student performance are likewise very sparse. However, the findings of the few research studies suggest that increased classroom temperatures can have negative effects on the performance of schoolwork by children. These studies indicate that air quality and temperature were improved by increasing ventilation and cooling. However, assumptions that the results of these studies can be generalised to other developed countries where the climate, classroom conditions, level of education and educational approach are similar to those in the northern mid-latitudes will have to be validated by replicating the study in temperate, sub-tropical, tropical and humid climates.

A knowledge gap exists in indoor environment research in schools and little research has been undertaken in Australia to establish potential benefits of indoor environmental quality improvements in schools. This review establishes the need for a study grounded on addressing the absence of clear documentation on the state of indoor environments in educational facilities in Australia backed by measurements and surveys of temperature, comfort conditions, indoor quality and the relationship between these aspects of indoor environments and student performance. The minimisation of temperature extremes within school buildings and IAQ-related impacts may yield significant educational learning outcomes to Australia's P-12 education sector but as yet there is little evidence to back this proposition.

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END NOTES:

[1] Major building simulation programs in Australia, such as the Nationwide House Energy Rating Scheme, NatHERS (2010) use an expanded number of climate zones (Lee & Snow, 2005). The NatHERS zones consist of 69 climate zones and in contrast to eight (8) climate zones of the National Construction Code – Building Code of Australia (NCC-BCA) which are harmonized with local government area (LGA) boundaries (ABCB, 2012, 2013), postcodes are allocated in the NatHERS climate zones. The NatHERS Zones (20 and 27) currently adopted by the DEECD in Victoria loosely correspond to those in the geographical locations of Zones 4 (*hot, dry-zone with cool winter*) and 6 (*mild to warm summer, cool-cold winter*) of the NCC-BCA climate zones, characterised by hot, dry zones with average January maximum temperatures of above 30ºC.

[2] The Relative Strain Index (RSI) is a means for assessing climate with respect to the stress it imposes on people and the index takes into account the factors of air temperature, wind movements, vapour pressure, metabolic rates and insulating effects of clothing (WA Department of Education, 2011).