Design for Indoor Environmental Quality in schools

Richard Daniels,
Technical Manager,
Education Funding Agency

16th June 2016
UKIEG Conference

"Health and wellbeing throughout the life course: the role of residential and learning environments"

Education
Funding
Agency

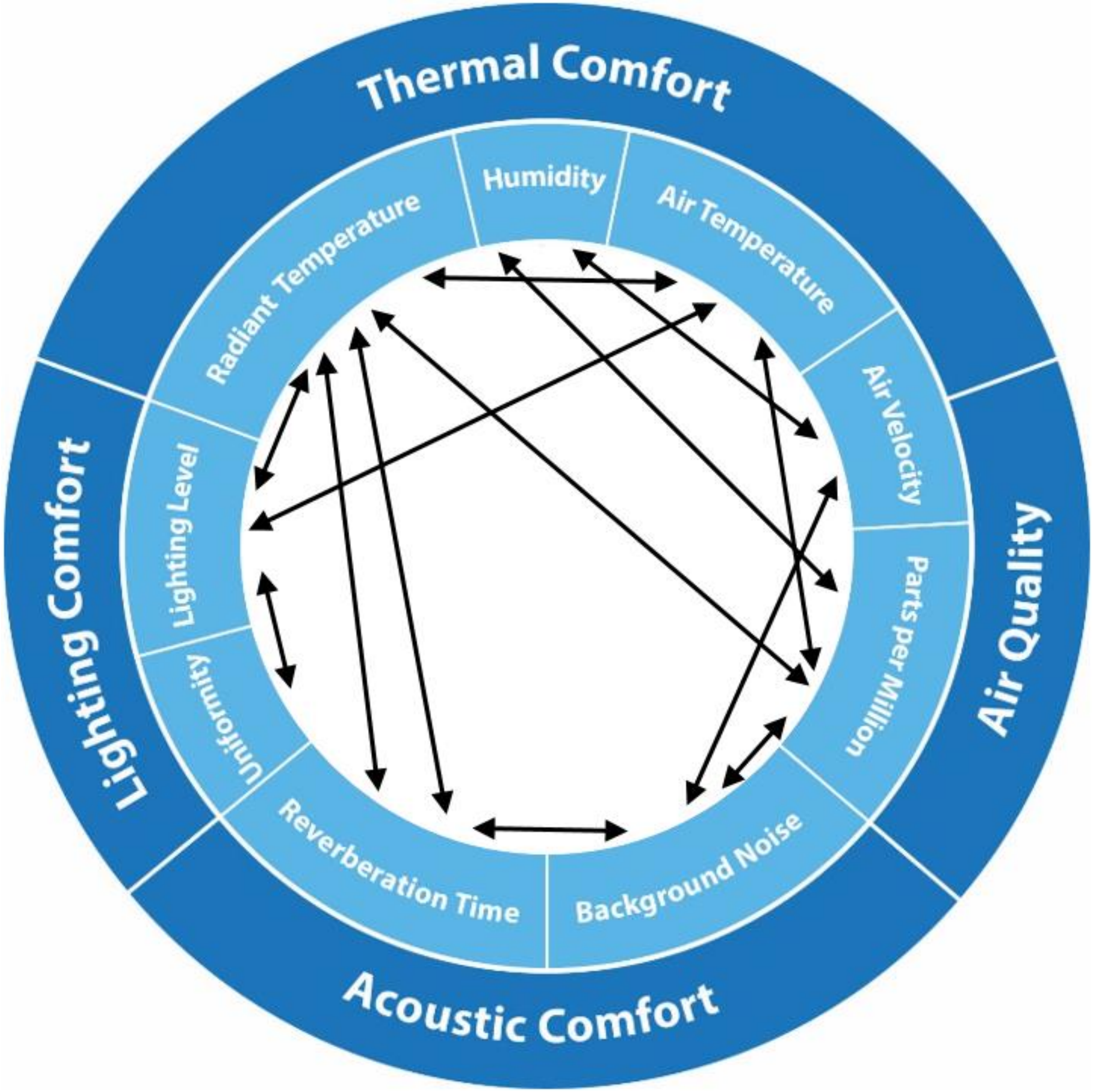
Main factors to consider for health and wellbeing

A. Air Quality and Ventilation

B. Daylight and visual comfort

C. Acoustics

D. Thermal comfort



Education Funding Agency

Montazami et al., (?) ‘A comprehensive review of environmental design in UK schools: History conflicts and solutions’, Journal, REF?

A. Indoor Air Quality and Ventilation

Areas covered in BB101 recommendations on IAQ

- WHO Indoor Air Quality Guidelines (WHO, 2010) &
  UK ambient air quality guidelines (DETR, 2007);
- ADF performance levels (2010);
- Indoor air pollutants (including Sinphonie's project, 2014);
- Sources of indoor air pollutants and source control.

References

WHO (2010) WHO Guidelines for Indoor Air Quality: Selected pollutants.

DETR (2007) The Air Quality Strategy for England, Wales and Northern Ireland

Approved Document F1 (2010) Means of ventilation

Kephalopoulos et al. (2014) *Guidelines for healthy environments within European schools, Sinphonie project;* ISBN 978-92-79-39151-4

Chatzidiakou et al. (2012) *What do we know about indoor air quality in school classrooms*? Intelligent Buildings International, 4:4, 228-259

Education
Funding
Agency

Indoor Air Quality and children's health (1/2)

- Asthma is the most common chronic disease and the leading cause of hospitalization among children (WHO)
- The UK has one of the highest prevalence rates of childhood asthma among European countries, with almost 10% of children (1.1 million) suffering from symptoms (WHO, 2010).
- In many northern hemisphere countries, a significant increase in asthma hospital admissions among asthmatic children peak in September and coincide closely with their return to the school environment (Julious et al. 2007).

Education
Funding
Agency

Indoor Air Quality and children's health (2/2)

- The data indicate that a sub-population of school-aged children with asthma receive challenges when returning to school that trigger their asthma.
- Particulate matter monitoring (PM) in classrooms is complicated by large differences in studies' design, including duration, number of schools monitored and instrumentation used.
- Only a few studies address the epidemiological associations with exposure to PM_{10} in school children and the health impacts of $PM_{2.5}$ and PM_1.

Education Funding Agency

Occupant density of classrooms and perceived IAQ

Average primary class size (Eurostat, 2011)

- EU countries and US: average 20.8 ± 2.0 pupils; density ranging from 2 to 3.1 ± 0.3 m^2/person.

- UK recently built classrooms: density of 1.72m^2/person

High occupancy densities in school classrooms result in high internal gains, emissions of body odour together with various indoor pollutants.

BB101 requirements on CO_2 level (Ventilation)

In addition to the general ventilation requirements of Section 4 of Approved Document F 2010 (ADF), the following DfE performance standards for teaching and learning spaces apply.

Sufficient outdoor air should be provided to achieve:

1. Mechanical ventilation or hybrid systems:

- **daily CO2 concentration < 1000 ppm (when occupied)**
- **max CO2 concentration < 1500 ppm (for more than 20 min, each)**

2. Natural ventilation

- **daily CO2 concentration < 1500 ppm (when occupied)**
- **max CO2 concentration < 2000 ppm (for more than 20 min, each day)**

3. - CO2 concentration < 800 ppm above the outside CO2 level for the majority of the occupied time during the year (ie the criteria for a Category II building in the case of a new building)

- CO2 concentration < 1350ppm above the outside CO2 level (ie, a category III building, in the case of a refurbishment).

See Table 3.7 of BB101 for definitions of comfort categories.

Education
Funding
Agency

Ventilation

Fresh air is critical for learning, health and hygiene

The CO_2 levels required of 1000ppm-1500ppm in classrooms can be exceeded within 20 minutes of the start of a lesson.

What can go wrong?

- *Levels in poorly ventilated classrooms of over 2500ppm throughout the day are common in schools. At these levels concentration fades.*
- Openable areas too small and single sided ventilation does not provide adequate ventilation in summertime mode
- Lack of user/management control

Challenges

Does the ventilation solution work under all weather conditions and is it robust, simple to operate and maintain, and is it energy efficient?

Education
Funding
Agency

Key points – Ventilation

Cold draughts in wintertime

Window and ventilation design needs to allow large volume flow for summertime ventilation and prevent dumping of cold air onto occupants during winter . Air supply temperature should not be more than 4°C cooler than the room air temperature.

Blinds and restrictors

Windows, vents and blinds need to be robust, easy to operate and supply the necessary air:

- Window ventilation openings should not be obstructed by blinds or curtains when these are opened
- Blinds should not cut off all daylight and views out
- Where dim-out blinds are required, they should provide a suitable daylight illuminance in the space and should not restrict ventilation

B. Daylight

What's the issue?

Daylight is essential to prevent the development of short sight in children.

Recent research suggests :

- Strongly linked myopia with absence of daylight and excess time spent indoors.
- High daylight levels are beneficial to visual development particularly in young children.
- Children should spend 3 hours outdoors in the daylight every day.

High levels of daylight must be controlled to avoid disability glare to allow children to see their work clearly.

With good daylighting, the lighting energy use over a year can be reduced by 40%.

Education Funding Agency

Daylight: What can go wrong?

- Daylight factor design can lead to too much glass at the perimeter, which can cause glare and overheating, especially if uniformity is not achieved;
- Dark gloomy internal spaces can be devoid of daylight;
- Halls with minimal daylight;
- Blinds that can conflict with opening of windows;
- Suspended ceilings, high cills and downstand beams can reduce daylight.

Daylight design

- Climate Based Daylight Modelling should be use rather than Daylight Factor design.
- Balanced daylight is best – there is a benefit from using two-sides/directions where possible – light shelves, light wells and light slots,
- Rooflights and clerestories can provide good daylight quality.
- Halls must be well daylit.
- Acoustic panels in classrooms should not block the daylight nor restrict the distribution of daylight to the rear of the room
- Carpet and floor reflectance should be as high as practicable – Where do we want carpets in schools? Rugs to an area of rooms may be better than carpets.
- All spaces should have some daylight where possible as circadian receptors affect mood and health.

C. Acoustics in schools
Research review findings (1/2)

- Noise has a detrimental effect upon the learning and attainments of primary school children.
- Chronic noise exposure has a marked detrimental effect upon the reading ability of young children.
- Children with additional needs such as hearing, language or communication difficulties are more seriously affected by noise and reverberation than those with normal hearing.
- Distraction of children and teachers by noise from neighbouring classbases is a problem in open plan classrooms.
- A major effect of noise and poor acoustics in the classroom is the reduction of speech intelligibility.
- A child's understanding of speech in noise and reverberation does not reach an adult level until the late teenage years. Before this time, the younger the child the greater the detrimental effect of noise and reverberation, with children under about 13 years of age being particularly susceptible.

Acoustics – Research review findings (2/2)

- At any one time up to 40% of children in a primary school class in the UK or USA may have some form of hearing impairment, due to either permanent damage to their hearing or a temporary condition such as a cold or ear infection.
- In work with adults Bradley *et al* found that noise, rather than reverberation, was the most significant factor in understanding speech and that the most important parameter for speech intelligibility is the signal (that is, speech) to noise ratio. As the levels of teachers' voices vary, this means that it is particularly important to reduce the background noise level in a classroom.

Reference:

The Effects of Noise on Children at School: A Review Bridget M Shield and Julie E Dockrell, 2010

Education Funding Agency

Requirements of BB93

- Indoor ambient noise levels
- Sound insulation between rooms
- Sound insulation between rooms and corridors
- Impact sound insulation
- Reverberation times of main spaces
- Absorption in corridors, entrance halls and stairwells
- Design checks, eg, on flanking transmission.

Education
Funding
Agency

Building Bulletin 93: upper limits for indoor ambient noise levels and reverberation times for a selection of school rooms

	Indoor ambient noise level, dB LAeq,30min	**Reverberation time, seconds**
Primary school classrooms	35	<0.6
Secondary school classrooms	35	<0.8
Large lecture room (> 50 people)	30	<1.0
Classrooms specifically for hearing impaired pupils	30	<0.4
Library study area	35	<1.0
Assembly halls	35	0.8-1.2
Science lab	40	<0.8
Gymnasium	40	<1.5
Dining rooms	45	<1.0

Education Funding Agency

D. Thermal Comfort
Thermal comfort standards

Values in BB101 are derived from experience but related to EN 15251, PPD related research (for adults) and t**he following** thermal comfort standards.

- **Workplace Regulations on Ventilation and Temperature**
- **PD CR 1752: 1999 Ventilation for buildings – Design criteria for the indoor environment**
- **BS EN ISO 7730: 2005 Ergonomics of the thermal environment (PMV and PPD indices) –local comfort criteria**
- **EN 15251 for adaptive thermal comfort is being revised and will supersede what is CIBSE TM52**
- **ASHRAE 55**
- **EFA cold draught criterion**

Areas covered by BB101 recommendations on thermal comfort in schools

- Operative temperature range
- Categories of thermal comfort for different activities and types of pupils[1]
- Adaptive thermal comfort criteria for the avoidance of summertime overheating for free running buildings
- Cold draughts
- Radiant temperature difference
- Vertical Temperature Difference (stratification)
- Hot or cold feet caused by floor surface temperature

Education
Funding
Agency

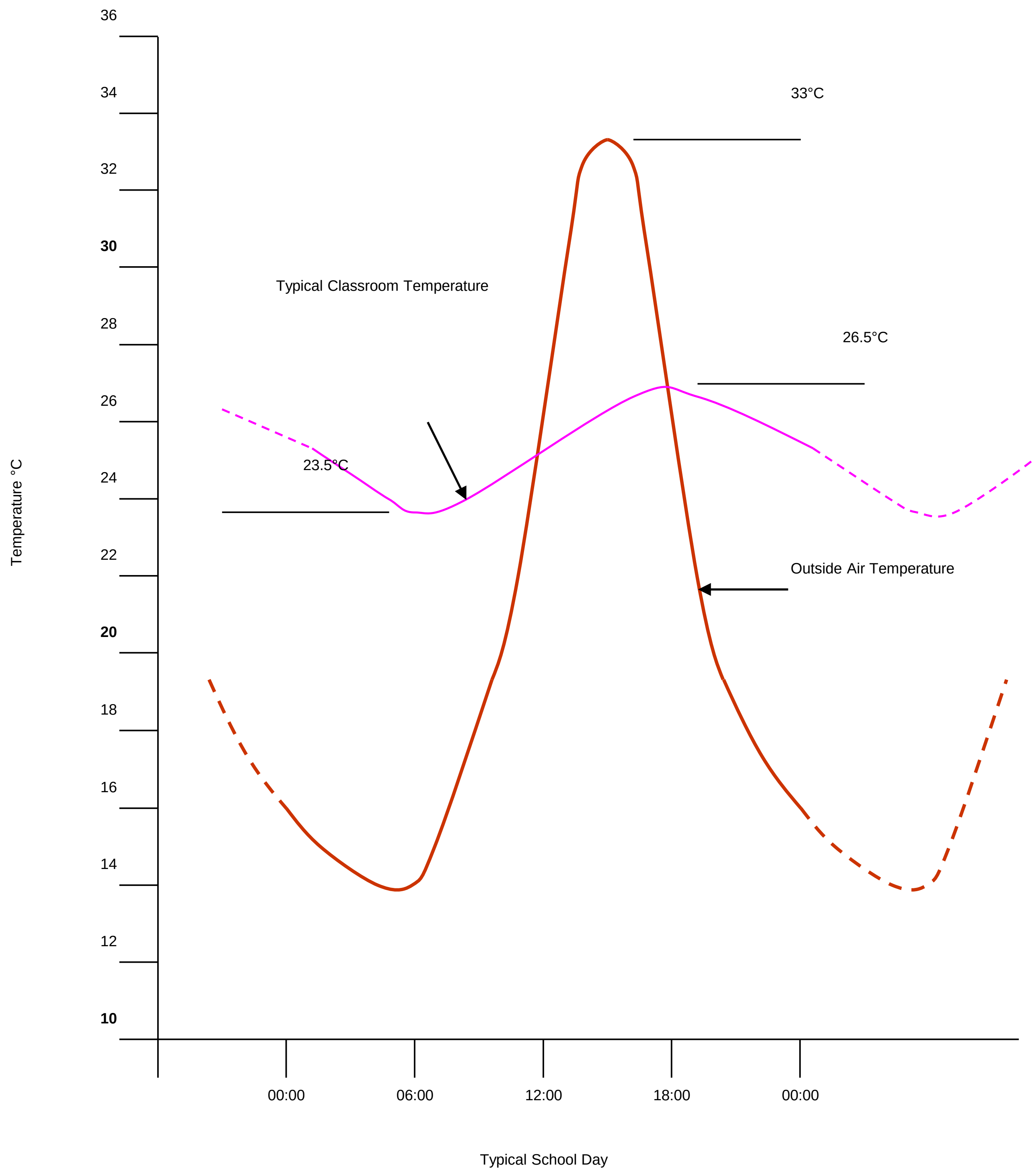
Thermal comfort in summer

High temperatures affect student performance

What can go wrong?

- Design to fixed temperature limits in BB101 e.g. max. 28^0C is inadequate for mechanical and hybrid systems.
  - FOS now requires design to CIBSE TM 52/European Standard EN 15251 Adaptive thermal comfort criteria
- High solar gain due to too much glass
- Lack of thermal mass and less openable area than needed for summertime ventilation
- Ineffectiveness of single sided ventilation for summertime ventilation.

Design to prevent overheating



Output from BMS 15th July 2006

English Classroom 6

Concrete ceilings and timber-frame external walls

Typical classroom held at 26.5°C when outside temperature 33°C

High mass structure and the high levels of thermal insulation mean building damps down the internal temperature variations

Design to prevent overheating

Ventilation close to ceiling level is effective for cooling the slab

CFD – thermal comfort in cold weather. Discomfort from introducing outside air at high level

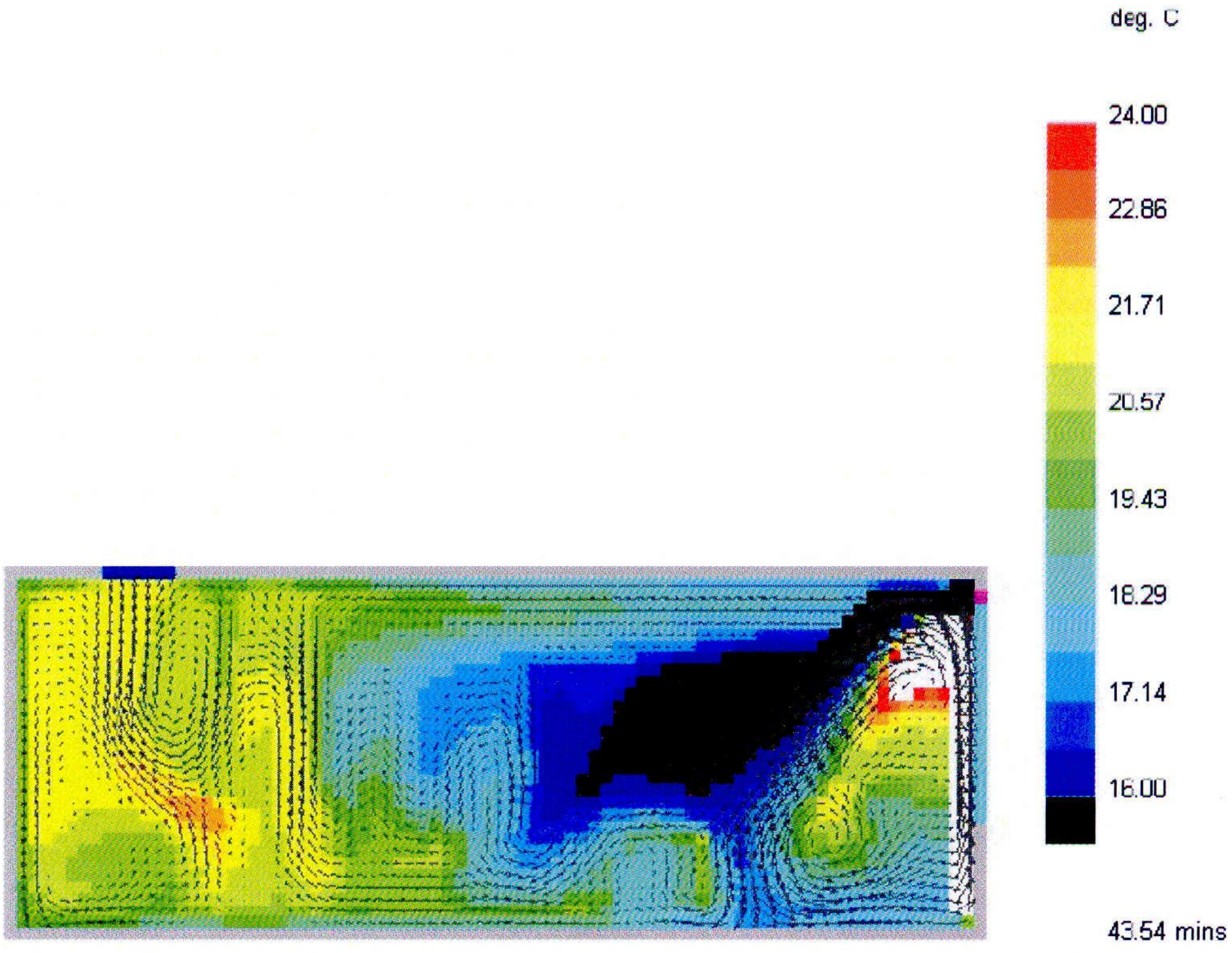


Table 3.11: Recommended draught criteria to provide thermal comfort

Category of space/activity	Draught criteria to provide thermal comfort			
	Winter		Summer and mid-season	
	ΔT (Min maintained operative temp - plume local air temp)	Maximum air velocity	ΔT ($T_{room, operative}$ - plume local air temp) When T_{room} ≤25^{o}C or T_{comf}	Maximum air velocity
		(m/s)		(m/s)
I	1.5	0.15	1.5	0.15
II	2	0.2	2	0.2
III	3	0.25	3	0.25
IV	4	0.3	5	0.3

Table 3.11 assumes an activity level of 1.2 met, a clo value of 1.1 in winter 0.9 in mid-season and 0.7 in summer, and a minimum maintained air temperature as in Table 3.10 in winter and mid-season and 23^{o}C in summer.

The values in Table 3.11 apply to the supply air plume which delivers air to the occupied zone. The occupied zone should be taken as from 0.6m to 1.4m above floor level

Education Funding Agency

Features of 2015 UK school designs

Room based ventilation systems with CO_2 and temperature control.

Assisted natural mixing ventilation or mechanical ventilation with heat recover

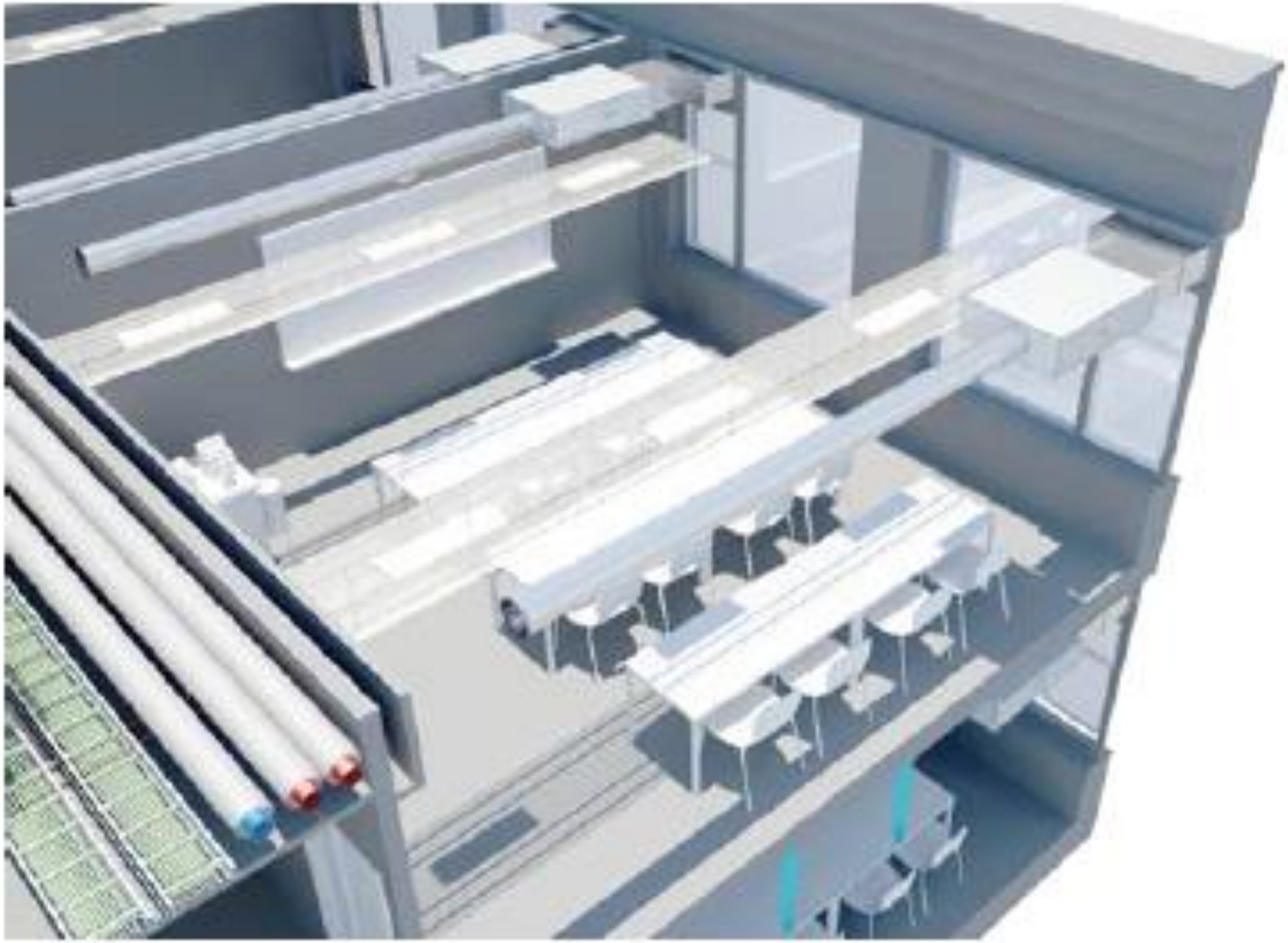
Daylight design using Climate Based Daylight Modelling

Exposed thermal mass in ceilings

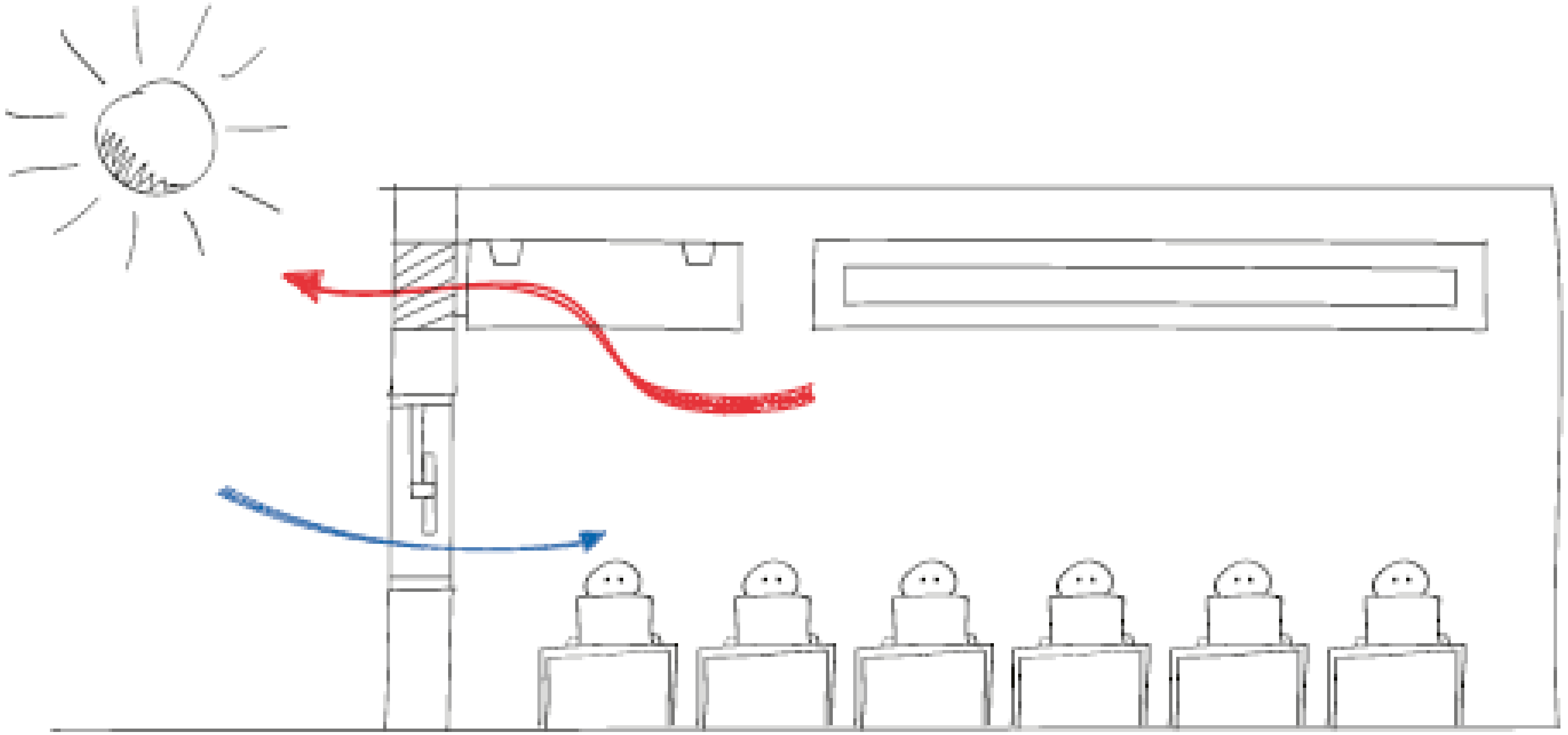
Acoustic absorbers

- Hanging absorbers or
- wings to light fittings or as
- as part of radiant panels

Classroom based assisted mixing ventilation system



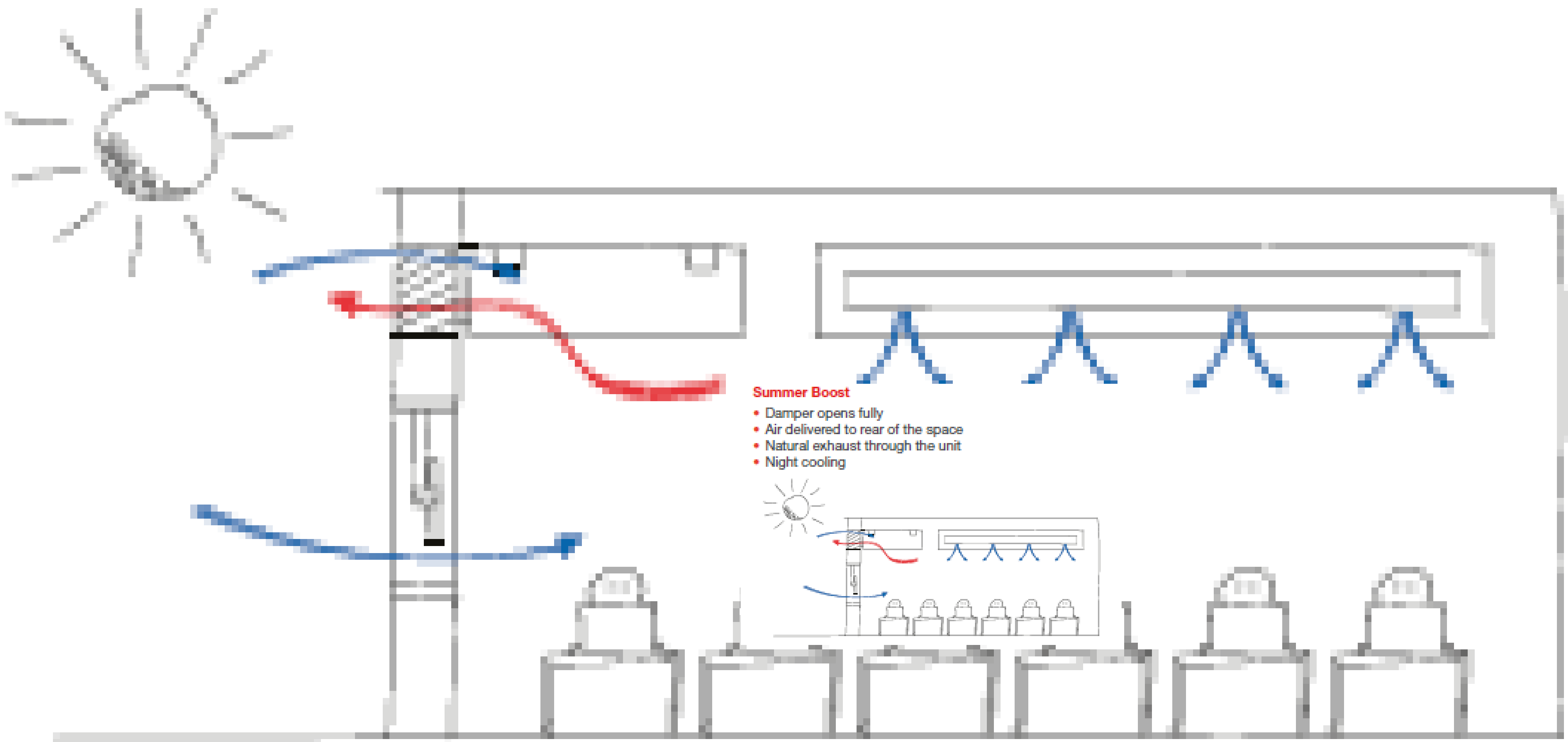
Natural Mode



Natural mode: Damper opens, single sided ventilation, works with other openings in space. In peak summertime fan assistance increases cooling

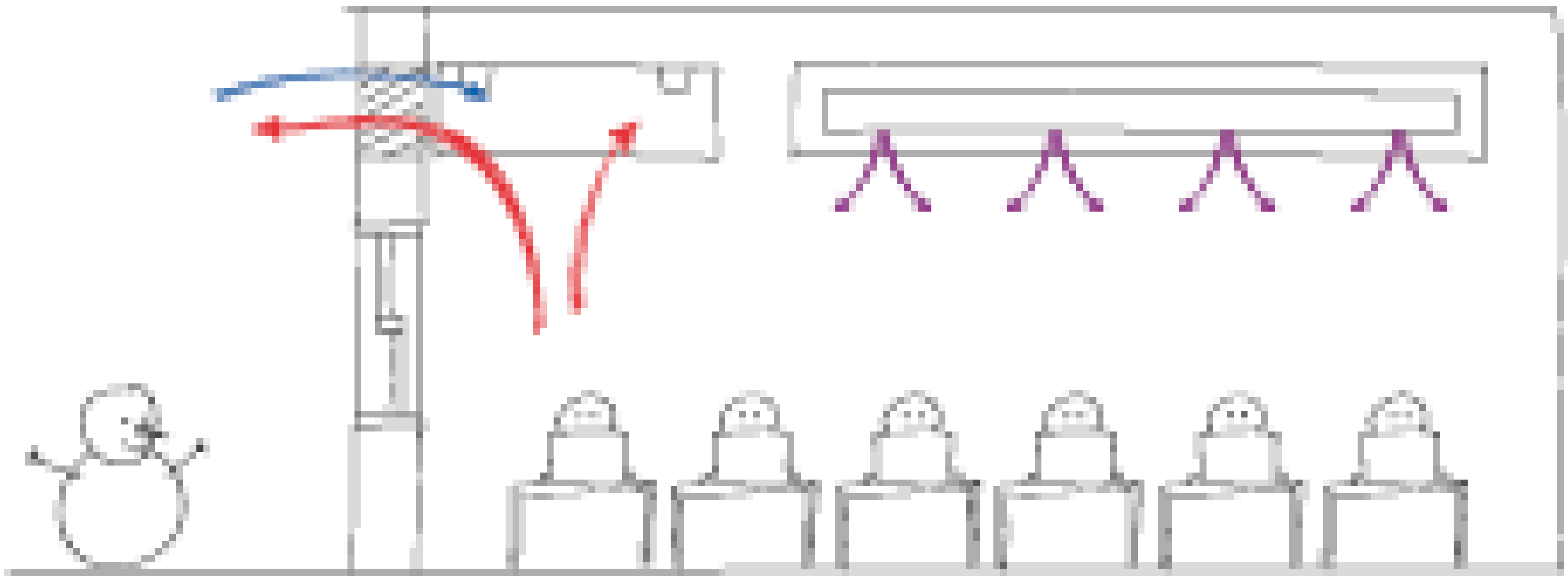
[Diagrams: www.BreathingBuildings.com]

Summer boost



Summer boost: Damper opens fully, air delivered to rear of space; natural exhaust through unit; night cooling

Winter operation



In winter assisted mixing prevents cold drafts; mixes warm room air with fresh external air; natural exhaust through unit

Mechanical Ventilation with Heat Recovery