

Research-based recommendations for achieving high indoor environmental quality in classrooms to promote learning

Short summary report

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Summary of research evidence

Research has shown how to improve classroom environmental quality in Denmark. Below is the set of recommendations for main components of indoor environmental quality in classrooms, ensuring optimal performance of schoolwork and learning. They are compared with the current recommendation and requirements regarding classroom environments in Table 1 below and presented graphically in Figure 1.

Thermal environment

- Keep classroom temperatures in the range 21-23°C; optimizing temperatures for the performance of schoolwork will ensure that they are energy-efficient, thereby conserving energy.
- Ensure that windows can be open to reduce classroom temperatures, especially outside the heating season, as adjusting clothing to restore thermal comfort may not guarantee the optimal performance of schoolwork.

Indoor air quality (and ventilation)*

- Keep CO₂ below 900 ppm at all times.
- Ensure that windows can be open when needed to improve classroom air quality at any time of the year.
- Provide CO₂ sensors that inform when windows shall be open to restore IAQ and closed to conserve energy.

Acoustic environment

- Keep background noise in classrooms low to ensure high speech intelligibility.
- Avoid long reverberation times.
- Insulate classrooms acoustically to exclude external noise.
- Create quiet adjoining rooms for teaching children with hearing or attentional difficulties and for children being taught in their second language.

Visual environment

- Ensure that classrooms have both daylight and a green view-out while avoiding window glare and sun penetration.
- Illuminance levels should be adjustable between 300 and 1000 lux depending on activities and time of day.

** Applicable also to reduce the risk of airborne transmission of infectious diseases incl. SARS-CoV-2*

Table 1. Existing recommendations and requirements for school buildings

Building regulations (BR18)		
CO ₂ concentration	≤1000	ppm
Ventilation (sum of per person and per floor area)	≥5 ≥0.35	L/s per person L/s per m ² floor area
Temperature	20-24 23-26	°C (during the heating season) °C (outside the heating season)
Noise (from outdoors)	≤33 ≤46 ≤52	dB(A) with closed windows dB(A) with open windows (roads) dB(A) with open windows (train tracks)
Noise (from building technical installations)	≤30	dB(A)
Reverberation time	<0.6	s (frequency 125-4000 Hz)
View out		windows to allow a view out and sun protection
Daylight	10 ≥300	% glass area in relation to the floor area lux for at least half of the relevant floor area and at least half of daylit hours
Artificial light	≥500 19	Lux Unified glare rating

The Danish Working Environment Authority		
CO ₂ concentration	≤1000 ≤2000	ppm (recommended) ppm (maximum allowable)
Formaldehyde	≤0.15	mg/m ³
Temperature	20-22 18 25	°C (recommended) °C (minimum) °C (maximum unless heatwave)
Relative humidity	25-60	%
Air velocity	≤0.15	m/s
Light	200-500	Lux

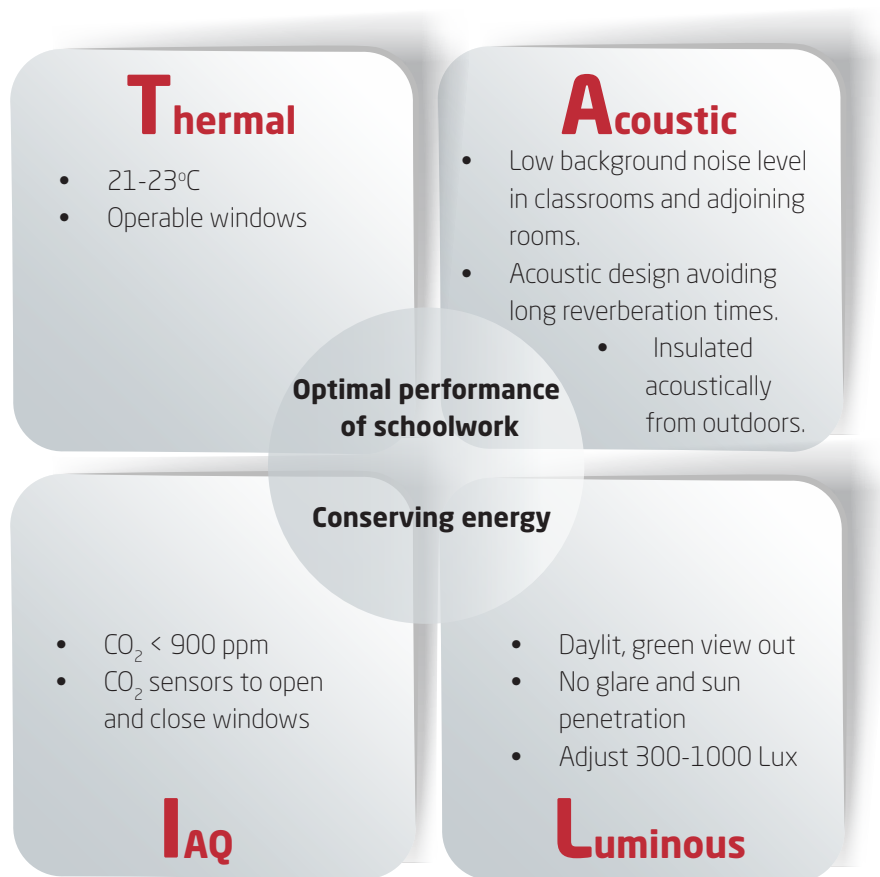


Figure 1. Environmental conditions in classrooms securing optimal performance of schoolwork and at the same time allowing conservation of energy

Summary of future research needs

The following research needs are outlined that will lead on the one hand to understand better the mechanisms behind the effects of classroom environment on the performance of schoolwork, interactions between the parameters defining environmental quality in classrooms as well as further improvement of the conditions and advancing supporting technologies.

- 1 Interaction effects between different parameters defining the quality of the indoor environment in classrooms and how they affect cognitive performance and learning.
- 2 Effects of indoor environmental conditions in classrooms on teachers and how these affect translate to the effects on learning by children.
- 3 Methods to reduce the risk of cross-infection in classrooms.
- 4 Mechanisms underlying the effects of indoor environmental quality in classrooms on the performance of schoolwork and learning, in particular identifying specific parameters and factors that are mainly responsible for these effects. This applies to specific pollutants, types of noise, and descriptors of the acoustic environment, amount of daylight, light quality, and view-out.
- 5 Development of indices that describe the quality of the indoor environment in classrooms, especially indoor air quality (IAQ) and indoor environmental quality (IEQ)
- 6 Impact of sleep quality and bedroom environment on next day-performance and progress in learning.
- 7 Energy-efficient technical solutions for achieving indoor environmental quality in classrooms to promote learning, including methods for reducing temperature, improving air quality and reducing risk of cross-infection, ensuring adequate exposure level to daylight and acoustic insulation that reduces background noise level and noise from outside the building.

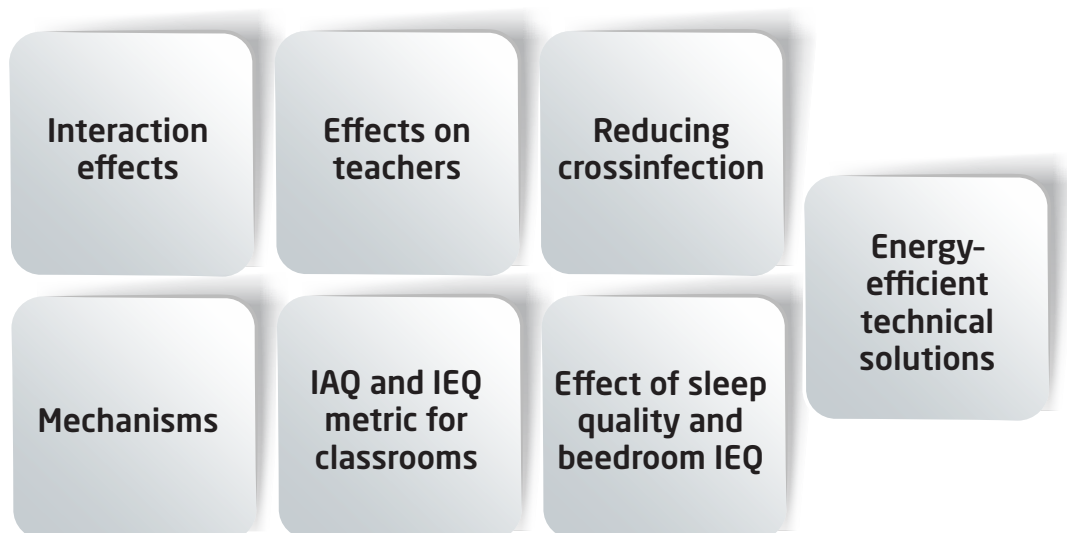


Figure 2. Future research and development needs

