# Acoustics in open-plan schools and day-care centres – problems and opportunities

*by Claus Møller Petersen*

## Introduction

Schools with open or partial open plans are coming into fashion again in Denmark. There are two reasons for this. The Act on Public Primary and Lower Secondary Education (1) has introduced new forms of education. In addition, a current architectural trend has already promoted open-plan arrangements in many office buildings in Denmark.

Most open-plan schools built during the 1960s in Denmark had poor acoustics. Acoustic problems were so severe that almost no open-plan schools have been build since then. The rules on acoustics introduced in the Danish Building Regulations in the 1970s were not the reason that the number of open-plan schools was dramatically reduced.

Open plans involve sound propagating almost unimpeded between the teaching groups. This causes tremendous noise problems, making it almost impossible to understand what is being said. Each individual group has little influence on the overall noise level, and this is extremely disturbing. From an acoustic point of view, open-plan schools are not recommended .

Large open rooms in day-care centres in Denmark (including centres serving children of various age ranges from 0 to 12 years or more) are often poor acoustically and therefore noisy, and acoustics is a problem when these rooms are used for several purposes. These rooms require acoustic improvement to reduce the effects of noise.

## Legal stipulations

The Danish Building Regulations (2) state the following in Section 9.3.3, subsection 5.

> In classrooms equipped for teaching several classes or groups, the surfaces of the room, including the ceiling, floor and wall areas, must be built using materials with

an equivalent absorption area[1] averaging at least 0.9 times the floor space in the frequency range between 125 and 2000 Hz. Deviations from the average value must not exceed 0.2 times the floor space in any frequency range.

This stipulation means that the surfaces of a room must be chosen so that they absorb a substantial part of the noise, reducing the reverberation time.

If open-plan schools were built using current building traditions, the flooring would be hard and noise-reflecting (linoleum, wood and the like). The ceilings would have maximum noise-absorbing qualities (an acoustic ceiling – porous material, perhaps covered with acoustic tiles). Finally, the furniture would be relatively poor at absorbing sound. As the teaching rooms in open-plan schools have little wall area, using the walls as noise-absorbing surfaces is often not an option. Nevertheless, the covering of all surfaces close to the users of the rooms is important and should be included in the acoustic regulations.

The Danish Building Regulations (2) include provisions on impact sound pressure levels and total noise levels. According to Section 9.3.2, floors and stairways must be constructed so that the impact level does not exceed 63 dB(A) in the classroom. In classrooms designated for teaching music and woodwork, floors must be constructed so that the impact level does not exceed 53 dB(A) in the surrounding classrooms.

Section 9.3.4 stipulates that the noise level from technical installations in classrooms must not exceed 35 dB(A). Section 9.4 stipulates that the average reverberation time in living-rooms in day-care centres must not exceed 0.6 seconds in the frequency range between 125 and 2000 Hz.

Hoffmeyer & Petersen (3) present recent recommendations on reverberation times reducing this to 0.4 seconds in after-school and preschool day-care centres.

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[1] The equivalent absorption area measures the total quantity of sound-absorbing surfaces in the room. It is derived by multiplying the area of a surface by the acoustic absorption coefficient $\alpha$. Hard, shiny or massive surfaces reflect the noise and ($\alpha = 0$), whereas soft, porous surfaces absorb the noise ($\alpha = 1$). Hard surfaces and large room volumes create long reverberation times, whereas soft surfaces and small volumes create short reverberation times. The acoustics of a room can be described by the reverberation time or by the equivalent absorption area. A room with a large equivalent absorption area has a short reverberation time.

Few studies have examined the acoustics of schools within the last decade in Sweden, Norway, Finland, Germany, the Netherlands, the United Kingdom and the United States (4). Specific stipulations on the acoustics of open-plan schools have not been found in these countries.

## Acoustics in large rooms – objective characteristics

The reverberation time and noise level are often used to describe the acoustics of a room. In general, when the source of sound is not too close, the shorter the reverberation time, the lower the noise level in a given room with given sources of sound.

These acoustic concepts are mostly used to describe the acoustic work environment in workplaces with the purpose of limiting the noise exposure of personnel. Nevertheless, these concepts are inadequate for classrooms and must be bolstered by concepts describing the speech intelligibility in the room. Large rooms, such as those in open-plan schools, should also include the parameter of how well the propagation of sound between teaching groups is reduced.

*Speech intelligibility*

The speech transmission index (STI) is an objective measurable value describing the speech intelligibility in a room. The STI considers both the reverberation time and the sound intensity from a person speaking adjusted for the background noise level in a room (signal-to-noise ratio). The STI value varies between 0 and 1. An STI value of 0 means no speech intelligibility, and a value of 1 means optimum speech intelligibility.

*Suppressing sound propagation and enhancing the privacy of teaching groups*

The suppression of sound propagation through a room is measured objectively by determining the sound attenuation between two teaching groups or attenuation according to the doubling of the distance (5).

Privacy in a teaching group requires a low share of unwanted acoustic information. This also means poor intelligibility between the teaching groups (a low STI value) combined with substantial suppression of sound propagation.

## The acoustic environment – subjective experiences

In open plans, the pupils are distracted and the teachers resigned because of the massive acoustic problems, including (6):

- excessive noise levels compared with vocal intensity;
- too much irrelevant information;
- the lack of privacy – poor acoustic separation between groups; and
- excessive reverberation time.

The lack of acoustic privacy far eclipses the potential advantages of open plans.

Another aspect of the acoustic environment in open-plan schools is the importance of the users' behaviour. The noise is controlled by self-discipline and peer pressure (6).

In partial open-plan schools, both pupils and adult users progressively adapt their behaviour to become quieter to accommodate to the acoustic conditions. The great challenge is to find the right balance between acoustics and practicable accommodation.

## The physical environment and education in schools – visual and acoustic openness

The Act on Public Primary and Lower Secondary Education (1) stipulates that the school must create an environment conducive to experience, motivation and concentration. Schools must be functional and educational to promote both varied forms of education and the peace to allow immersion and concentration. This includes both thematic weeks in which many pupils gather across several grade levels and group work with a few specific pupils.

Many new schools have walls with substantial glass to provide experiences through visual openness: following what is happening in other groups. Because glass is an acoustically hard and reflective material, it should be used carefully with a limited area to avoid poor acoustics. Glass in walls creates visual openness but also distracts children who are studying, working or reading. Glass in children's working areas should begin above the height of the children's eyes. Finally, the Danish Building Regulations require avoiding the risk of personal injury if glass is used in walls.

Open-plan schools were previously built with few internal walls. Glass walls integrate acoustic insulation and visual openness. The right balance must be

found between visual openness, sound insulation and room acoustics (reverberation time).

### Flexibility in open-plan schools and day-care centres

The noise and activity levels of younger and older pupils differ substantially (6). The young pupils tend to be noisier than the older ones. Just as the pedagogical framework must vary and be broad, the physical environment should be flexible: adapted to the pupils' development and the planned use of the room.

Schools and day-care centres should have rooms suitable for both vivid and noisy activities as well as rooms for quiet activities and activities requiring concentration. This is also valid for day-care centres.

Variation and flexibility in open-plan schools is therefore also important to suppress noise propagation between teaching groups and to optimise the acoustics within each teaching group.

### Options for ensuring optimum acoustics

Open-plan schools are not recommended from the viewpoint of acoustics. Acoustic options in partial open-plan schools and large rooms in day-care centres include:

- limiting the room height: less than 3.5 metres to ensure the optimum functioning of acoustic ceilings, but large height is important in ensuring optimal indoor climate using natural ventilation;
- using very effective sound-absorbing surfaces: the acoustic absorption coefficient must be optimal, $a > 0.95$ or sound absorption class A as defined in ISO 11654 (7):
  - in ceilings
  - on walls, in alcoves, in panel walls and on the front edges of balconies
  - in internal room dividers
  - in furnishing and pinboards that can be dismantled;
- constructing walls with sound-absorbing surfaces if the length or width of the room is less than 10–15 metres;

- installing variable noise absorbents, such as noise-absorbent curtains mounted in front of hard walls;
- maximizing the distance between teaching groups;
- acoustically separating (partly by glass) quiet and noisy teaching groups;
- installing mobile wall elements (which can be partly glass) or acoustic walls that fit tightly to the floor and are tall enough to interrupt the direct line of sight;
- placing glass in walls at a level that minimises unwanted visual disturbance;
- protecting openings in walls (without doors) by installing screens or semi-walls in maze-like configurations to prevent noise from entering through the opening;
- ensuring that the wall behind the teacher (often a blackboard) prevents the transmission of sound from areas outside the classroom and reflects internal sound towards the teacher's area to provide the teacher with sound reflection, making it easier to talk without straining the voice;
- installing sound-absorbing acoustic tiles on the wall in the back of the teaching area (8);
- installing flooring such as linoleum on cork, thick wooden floors or partly carpets to reduce impact noise and drum noise (wall-to-wall carpets are not currently used in Denmark);
- ensuring adequate sound insulation from environmental sound (such as traffic noise);
- managing the noise originating from technical installations and traffic; and
- using computer modelling to calculate detailed acoustics of existing rooms and of potential future rooms with specific characteristics.

The conclusion is that open-plan schools are not recommended from the viewpoint of acoustics.

### Acoustic design criteria – a checklist

The following design criteria should be observed to obtain the best possible acoustics.

*Partly open-plan schools*

- The reverberation time should be short, less than 0.3–0.4 seconds.
- The acoustic attenuation between two teaching groups should be at least 15–20 dB. This should also apply between teaching groups and corridors (using detachable screens, mobile walls or built-in walls with glass).
- The propagation should be attenuated by 5–8 dB for each time the distance doubles.
- Within teaching groups, the STI should be greater than 0.6. The STI between teaching groups should be less than 0.2; this can best be checked by using a computer model of room acoustics.

*Partly open-plan schools and day-care centres*

- The noise level from technical installations should not exceed 35 dB(A).
- Noise from external sources should not exceed 35 dB(A).
- Flooring must be selected based on its capacity to avoid disturbing impact noise (in rooms underneath, normally $L'_{n,w} < 63$ dB) or disturbing drum noise from footsteps in the same room.

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