Modern School Acoustics

On teaching styles, room acoustics, teachers' health and pupil behaviour

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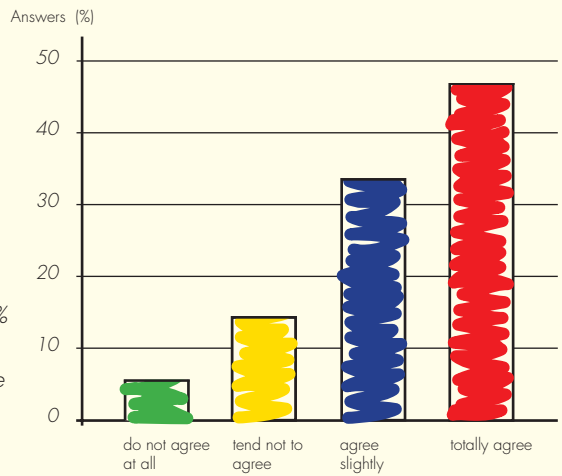
1. Noise in schools – current status of school research

Schools have become much noisier in recent years, with the number of complaints about this steadily increasing. In 1999, a study by the ISF (Institute for Interdisciplinary School Research) of the University of Bremen, with about 1,200 teachers participating, gave a very clear picture of the stress factors that arise in schools. When questioned, more than 80% of those taking part admitted experiencing stress caused by pupil noise. One year later, the Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (German Federal Institute of Occupational Health) was commissioned to carry out the most extensive research project to date on "Noise in educational establishments". Observations from more than 570 lessons showed an average classroom **SPL (sound pressure level) of approximately 65 dB(A).** Levels that are this high mean that communication can be extremely difficult or even impossible.

"I am stressed by the noise that pupils make."



ISF study, 1999: 80% of teachers complain about the noise made by pupils

Of course, the sound pressure level measured in the classroom does not only consist of unwanted noise, since the teacher's voice and a necessary contribution of pupil voices are also involved. Thus, overall classroom noise is generated by the two-way teaching process as well as by other factors. Even if this overall level were generated exclusively by the teacher, this would mean - at the very least - that he or she would have to speak in a raised voice throughout the entire lesson.

The question of noise in schools is therefore extremely complex. How, for instance, does the general noise level in the classroom affect the communication processes that take place there? How it is possible to differentiate between **disturbing noise** on the one hand and **useful noise** (sound) on the other hand, when carrying out a scientific teaching analysis? How do SPL and poor understanding of communication affect pupil performance and/or teachers' work stress? And, not least, what are teachers really talking about when they complain about noise in the classroom – the measurable SPL or, rather, the way in which their teaching is disturbed?

All these issues resulted in the most recent ISF study in 2005 on the **"Acoustic ergonomics of schools"**. Based on 175 lessons, the first stage involved researching the effects of different teaching methods (direct teaching vs. student-centred teaching) on the basic* and working** SPL in the classroom. The second stage involved an investigation into how **changing room acoustics** (reverberation time and speech intelligibility) **affects this level for each respective teaching method**. It was possible not only to analyse average values for lessons but also to gain insight into actual teaching phases that showed clear, pedagogical characteristics.

*The Basic SPL: the general basic noise level in a fully occupied class over a defined time period.
** The Working SPL: the noise level parameter describing a working situation.

The third stage then addressed how noise, in terms of natural, working sounds, affects teachers during lessons. **How do room acoustics affect teachers' measurable physiological stress in relation to actual teaching events?**

These kinds of ergonomic questions, linked with actual educational trends, may be surprising at first glance. However, they give an interesting insight into the concept of noise in schools, its causes and effects, and into other acoustic factors such as reverberation time and speech intelligibility.

2. Teaching past and present - schooling reflected in educational trends

The education system in most industrialised countries is changing faster than ever before, not just since recent OECD-Reports[1]. The organisation of schooling in general, and **teaching methods** in particular, **have changed a lot in recent years.**

Is noise in schools a new problem, one that did not exist previously? This question is certainly justified, since complaints by teachers about noise do not occur in the literature from the beginning of the 1900s. The "modern", "student-centred" and "non teacher-centred" teaching methods (e. g. partner, group or project work) that are promoted by educational experts do certainly produce totally different communication scenarios

School with predominantly student-centred teaching method.

School with predominantly direct teaching method.

1) OECD (Organisation for Economic Co-operation and Development)/PISA (Programme for International Student Assessment, Learning for Tomorrow's World, First Results from PISA 2003, OECD Publishing, Dec 2004, 478 p, ISBN: 9264007245. (Available in English, German, French, Portuguese and Spanish)
OECD/Centre for Educational Research and Innovation (CERI), Schooling for Tomorrow: Think Scenarios, Rethink Education, OECD Publishing, April 2006, 200 p, ISBN: 926402364X (Available in English and French)

in the classroom in comparison with those produced by traditional, direct teaching. The image of the teacher as a distributor of material, a channel of knowledge, is fading. Pupils now have to independently investigate, weigh up, discuss and acquire the knowledge and skills to solve the problems they are presented with. **Modern teaching** relies much more on shared learning, and **deliberately permits several people to talk in the classroom at the same time.** Even in a disciplined discussion environment, however, higher noise levels than before occur, when teachers used to lecture the class as a whole. This is particularly the case when the teacher exercises a high level of discipline.

Nowadays we tend to find a mix of direct and student-centred teaching styles in the classroom (key phrase "frontal teaching discussion"). The methods chosen are generally dependent on the personal preferences of the teaching staff and on the prevailing teaching style at the school in question. The layout of the classroom and the arrangement of the desks are sometimes relevant, since these indicate the teaching methods that are used to determine what happens in the classroom.

Shortsighted analyses, which have attributed the much higher noise levels in recent decades exclusively to social or educational trends, fall far short of the truth. Even early investigations proved the **relationship between a room's acoustic working environment, the quality of communication and the development of noise in the classroom.** It is therefore important to ask: What are the determining factors for teaching in respect of modern, educational methods?

The presence of technology was only unfamiliar for a short time. After just a few hours, children saw the measuring instruments and loudspeakers as just another part of normal classroom equipment.

3. The peculiarities of noise in schools

When discussing noise in relation to education and schools, its quality and quantity are very different from that of the noise occurring in commercial workplaces, be it an industrial or an office environment. While the noise produced by machinery is generally felt to be noise interference, **the noise level in educational environments should be regarded as a useful signal with a widely varying degree of interference factor.** Its differentiation and evaluation depend on the teaching method being used in the case in question. For example, while text being read out in a voice with a speech volume of around 65 dB(A) must be rated as a useful or wanted signal, general pupil murmur of around 55 dB(A) during a quiet working period might be rated as noise interference. A straightforward increase in the noise level in a classroom, without taking the actual teaching situation into consideration, is only a small part of the noise in schools concept.

A first, decisive criterion for appraising noise in schools is the ratio of "useful signal" to "interference signal" in the classroom, taking into account the communication processes in the lesson. **For an adult, the useful signal must generally be around 9 dB higher than the interference signal** if error-free speech

intelligibility is to be achieved. Since an adult voice is designed for a normal speech volume of around 50 to 55 dB(A), this means that the noise interference level must be less than 40 dB(A). Even in quiet work periods, however, the SPL in schools seldom measured under 50 dB(A), i.e. teachers usually have to raise their voices in order to pass information on to the pupils. In addition, specialist literature points out that primary-school children need to specifically learn how to listen and understand before they can develop their as yet untrained acoustic memory. **Young hearers therefore need a useful signal level that is about 15 dB louder than the ambient noise interference.** An added difficulty is the fact that the noise interference in a classroom is relatively evenly distributed, while the teacher's voice is transmitted from only one point and – depending on the size of the room and the position of the teacher - may need to travel over a distance of up to 6 m to reach pupils sitting at the back. If the basic noise is unchanged, this involves either a distinct additional strain on the teacher's voice, leading to long term health consequences, or an interrupted flow of information to pupils sitting further away, resulting in negative effects on their learning.

There is another aspect to consider in relation to modern, student-centred teaching methods. If there are several groups speaking in the room at the same time, **the signal from one group becomes noise interference for the other groups.** This results in a negative chain reaction. The other groups will compensate for the poorer speech intelligibility in their groups by raising their voices, which in turn increases the noise interference level for the others, and so on. The noise level in the classroom therefore gradually increases even if the number of people actually communicating remains the same. This is known in acoustic circles as the Lombard effect.

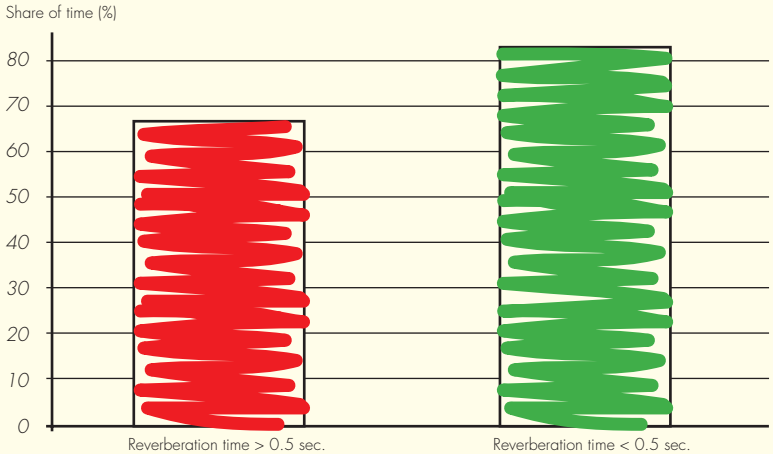
In more than 570 lessons, as well as the SPL being measured, the activities in the classroom such as teaching methods or proportion of speech were recorded every second.

4. "Acoustic Ergonomics" – noise in schools and teachers' health

Room acoustics are particularly significant with regard to modern teaching. For instance, short reverberation times result in a precise speech signal (especially in respect of consonants), and people can communicate with a lower signal-to-noise ratio. The study *Acoustic Ergonomics in Schools* (2005) showed that the **build-up of noise is considerably less, or does not occur at all, in classrooms that have good acoustics.** On the contrary, under optimum conditions the noise level measured during student-centred teaching phases was even lower than during direct teaching.

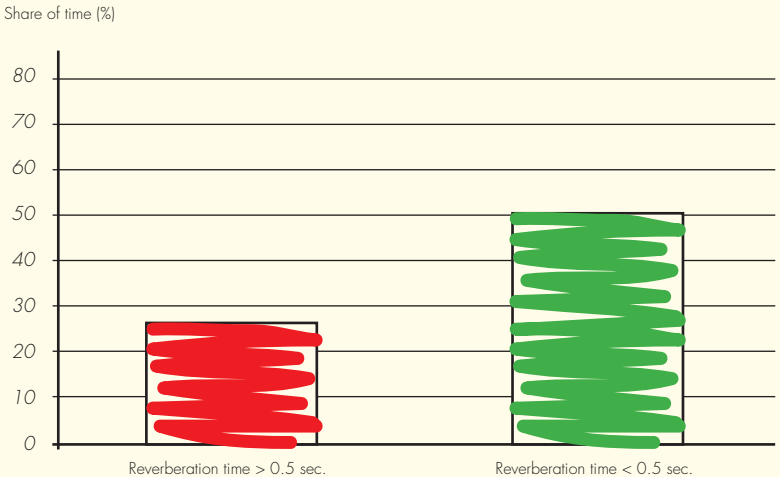
Overall, the basic SPL in classrooms with reverberation times of less than 0.5 seconds were 8 dB lower than in classrooms with reverberation times of between 0.6 and 0.8 seconds.

Share of "quiet" teaching phases (overall) in classrooms with good/poor acoustics.



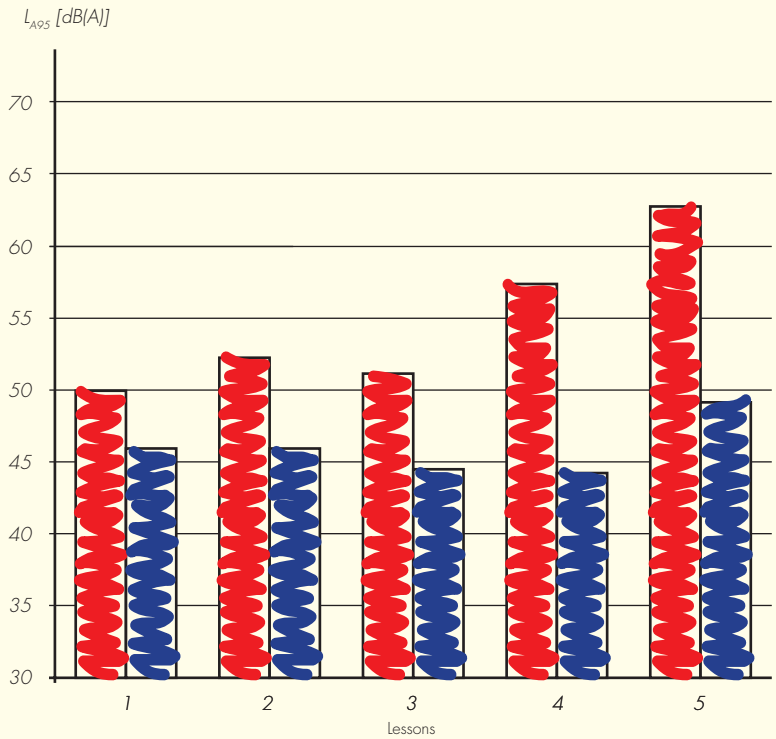
Under better acoustic conditions, the proportion of "quiet" teaching units was more than 80% compared to approximately 67% under poorer conditions (in relation to the average speech volume of an adult - approx. 62 dB(A) - taken as normal teaching speech).

Pupil-centred teaching phases are frequently quieter under good acoustic conditions.



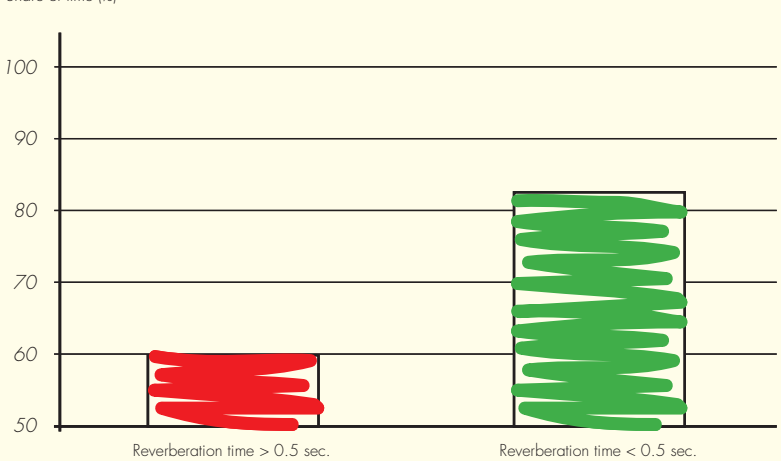
Even more obvious is the change in classroom conditions during student-centred teaching phases. In this case the proportion of quiet time units doubles! This clearly indicates an absence of the Lombard effect during partner, group or project work. The difference in levels between rooms with good acoustics and those with poor acoustics while these teaching methods were used was more than 13 dB!

The rise of the basic SPL over the morning is much less in rooms with short reverberation times.



An additional, important aspect was revealed by this comparison of teaching situations. The normal increase in the basic noise level over the course of the school day did not occur in the classrooms with short reverberation times (< 0.5 seconds). This has a significant effect on the teaching process and provides an initial indication of the physiological reactions that take place as a result of the acoustic working environment.

After acoustic refurbishment, the teacher works with a relaxed heart rate for more than 80% of the time compared to just 60% before refurbishment.



The positive effects of good room acoustics also reduce the teacher's stress level. After an acoustic refurbishment, the same teacher was subject to comparatively little work stress for a much greater part of the lesson. Further investigations also showed that the teacher was less sensitive to the stress-inducing noise, with work thus becoming much more relaxed. It is undoubtedly true that there is an ergonomic dimension to the acoustic design of classrooms. It directly affects the levels of work stress, activation and fatigue of the people who teach (and learn) in these premises.

5. Consequences and outlook

With a change in educational approaches, a steady increase in student-centred teaching methods and a corresponding reduction in direct teaching, it may be necessary to re-evaluate school buildings that have functioned well for many years. **New teaching methods place new demands on the basic ergonomic conditions.**

It would be absurd to claim that teachers themselves have no influence on noise in their classrooms. They do, of course – and it is important that they exert this influence. This issue is addressed in depth in the research report of the study "Noise in educational establishments" (2004). This study also showed the level reductions that can be expected after fairly immediate intervention by individual teachers: approximately 2 dB. At the same time, however, in rooms with resembling acoustic conditions and a comparable pupil social structure, there was evidence of similar differences (5 to 6 dB) in the noise levels of different schools. The relationships were easily identifiable. Only the schools where the staff followed a common, accepted educational concept were really quiet. In schools where the same rules apply in all classrooms, during all lessons and in all the different areas of the school, and where the children can expect the same teacher reaction if they do not comply with those rules, the noise levels measured over a long period were lower. The recipe is therefore as simple as it is effective. The only requirement is that staff work as a team and are consistent.

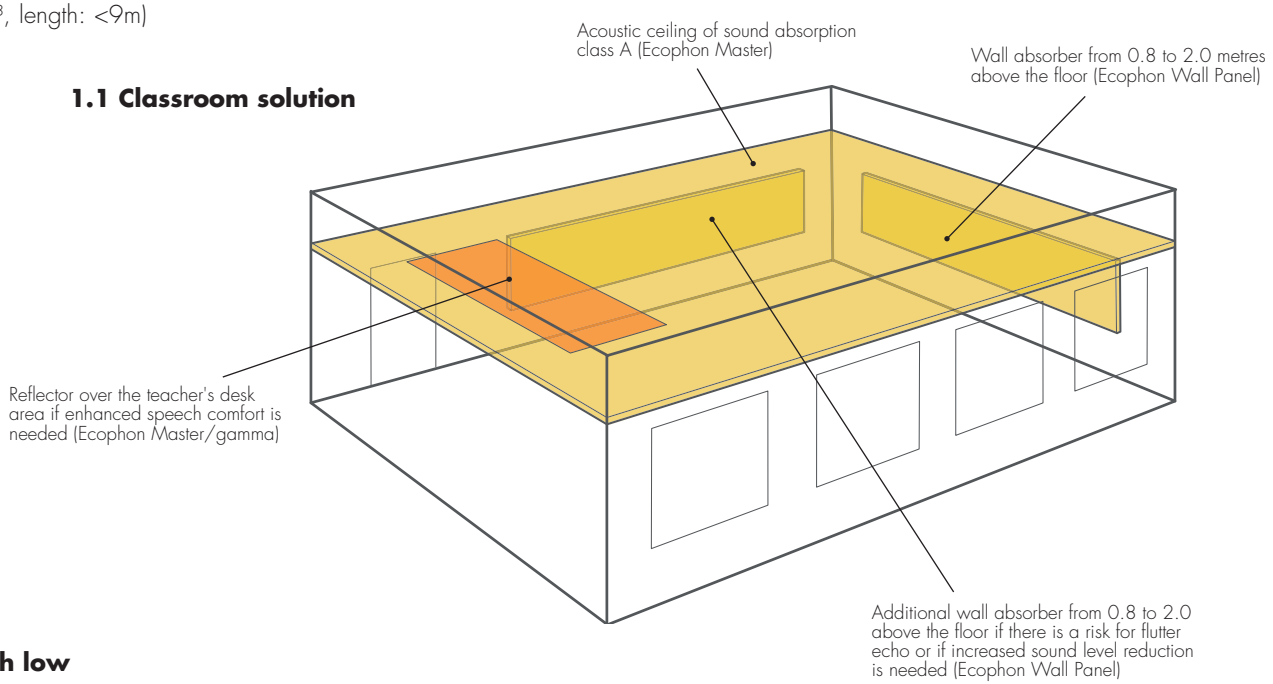
The school organisation and the personal contributions of individual teachers are essential factors in effectively reducing noise in schools. The ergonomic conditions provide the necessary foundation for the teaching activities of the school day. Neither of the two aspects can be replaced nor offset by the other. They are mutually interdependent and need to interact if the teaching process in context of modern pedagogical communication is to function properly.

The proud team of "scientific staff" after successfully measuring the acoustics of their classroom.

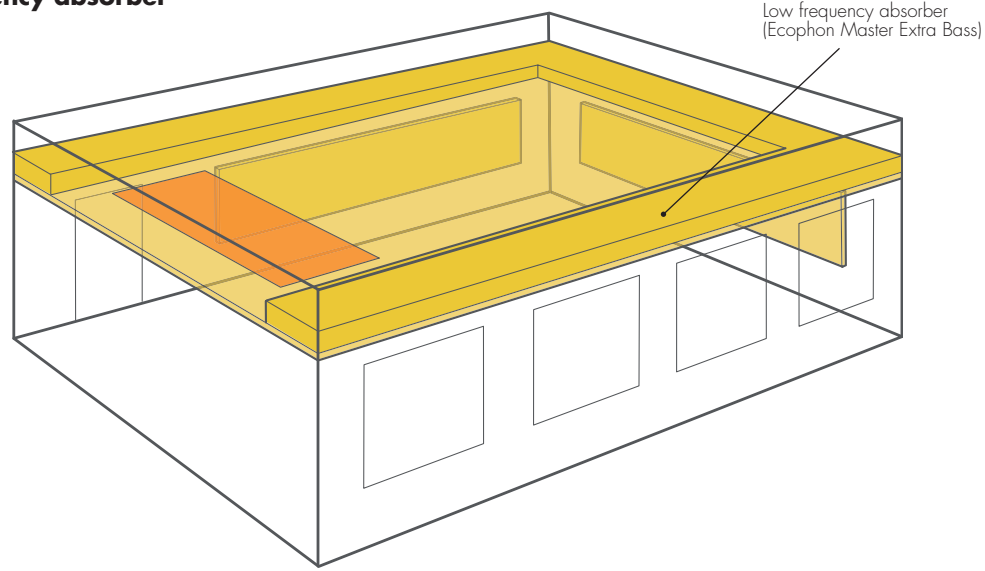
Classroom solution

Recommendation for normal sized classrooms
(area: <100m^2, volume: <200m^3, length: <9m)

1.1 Classroom solution



1.2 Classroom solution with low frequency absorber



Glossary

Acoustics
The study of sound. In everyday language also refers to how sound is perceived in particular premises.

Reverberation time, (T or RT)
The time it takes for the sound pressure level to fall by 60 dB after the sound has been turned off. Measuring the reverberation time allows us to calculate the total sound absorption. The reverberation time varies according to the frequency.

Sound pressure level (dB)
The variations caused by sound waves in air are called sound pressure. The lowest sound pressure level which can be heard is 0 dB, known as the hearing threshold. The highest level which can be tolerated is called the pain threshold and is around 120 dB.

Speech intelligibility
Speech intelligibility is directly dependent on the level of background noise, reverberation time and the shape of the room. Different methods are used to evaluate speech intelligibility, the most common ones are RASTI, STI and %ALcons.

Lombard effect
The Lombard effect is the tendency to increase one's vocal intensity in noise.

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Complaints about noise pollution in educational premises were the reason to cast a light on causes and consequences of "school noise". This interdisciplinary study investigated various kinds of teaching/ learning styles and sound pressure levels in the classroom, and moreover, how improved room acoustic conditions affect sound levels together with teachers' workload and fatigue.

This publication is a complement to the book "Don't limit your senses" Sound and the Learning Environment, Saint-Gobain Ecophon, ISBN 91-974193-2-X published in 2002.

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