Initiative Neue Qualität der Arbeit

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Noise in Educational Institutions

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0 Introduction

"Joint action, everyone on his own responsibility" – this principle of INQA has proven successful in practice. Under the auspices of the Initiative, specialised working circles have been formed called Thematic Network Groups. The Groups draw up targeted activities for individual key issues and implement them autonomously. The knowledge gained is transferred into company practice. Whether an employer, employee representative or health expert – every INQA action group is open to individuals who want to get things done.

This brochure gives an introduction to the problem area of "acoustic ergonomics in educational institutions" and describes the current state of knowledge, the objectives envisaged and the approaches already adopted in practice. The work of the Thematic Network Groups is based in particular on the research reports "The Stresses and Strains Suffered by Teachers" (Fb 989), "Noise in Educational Institutions – Causes and Reduction" (Fb 1030) und "Acoustic Ergonomics of School" (Fb 1071) from the publication series of the Federal Institute for Occupational Safety and Health.

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What are Educational Institutions?

The present brochure describes the acoustic-ergonomic parameters of educational institutions taking mainly the example of school teaching. But the relationships described can be applied to many other kinds of educational institution:

- **kindergartens**
- **schools**
- **universities**
- **adult education premises**
- **and many more!**

1 Noise as a load factor in teaching and learning

Apparently schools have increasingly developed into loud buildings over the last few decades. In any case, the number of complaints about "school noise" has been growing steadily for some time. Such complaints concerning a conspicuously heavy noise exposure from the teaching situation have now been studied scientifically. A number of current studies conducted simultaneously by the Institute for Interdisciplinary School Research at the University of Bremen (ISF) have, over the past few years, thrown light on the possible causes and consequences of this "school noise".

As early as 1999 a survey[1] was conducted among more than 1200 teachers with regard to load factors at their workplace and it gave a very clear picture. In answer to the question as to the "noise which school students make" more than 80 % of those questioned indicated that this noise imposed a strain on them. This is reason enough to examine this phenomenon more closely. The BAuA therefore commissioned a research project in the year 2000 on the subject of "Noise in Educational Institutions".[2] With measured sound levels during teaching of, on average, approximately 65 dB(A) (median), examinations conducted in this project certainly yielded figures which render communication processes considerably more difficult and, in many case, even impossible. On the other hand the levels measured – at least in the regular school situation – were in no way in the order of those which could cause permanent hearing damage (> 80 dB(A)).

In addition the sound pressure levels measured in the classroom do not, of course, consist only of "noise" since, for example, the teacher's voice and the school student's voice desired are included in the measurement. The overall noise in the school therefore arises during teaching, parallel to the teaching and through the teaching! (Even so, even if these levels were caused exclusively by the teacher, this would mean at least that the latter would have to make a considerably greater effort in speaking the whole time).

1 Schönwälder, H.-G.; Berndt, J.; Ströver, F.; Tiesler, G.: Belastung und Beanspruchung von Lehrerinnen und Lehrern. BAuA Publication Series Fb 989, Dortmund, 2003

2 Schönwälder, H.-G.; Berndt, J.; Ströver, F.; Tiesler, G.: Lärm in Bildungsstätten – Ursachen und Minderung. BAuA Publication Series Fb 1030, Dortmund, 2004

In this context school teaching has been analysed in the most recent work at ISF[3] as a working process – similar to that at the industrial workplace. In connection with the teacher's specific educational approach, the study's focus of interest was in particular the ergonomic parameters under which teaching takes place. The question of an "acoustic ergonomics of school", linked with the current educational trends, may at first glance appear surprising. But it yields amazing insights into the phenomenon of "school noise", its causes and effects and the relevant room-acoustic parameters, such as reverberation time and speech intelligibility. It is clear today that the educational process is determined largely by the working conditions – both in a positive and in a negative sense.

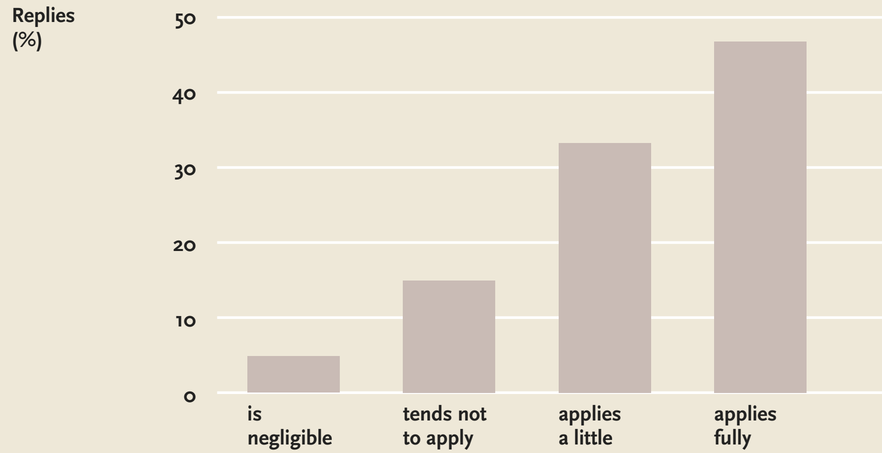
This is hardly surprising. No school planner would dream of designing a classroom for a working temperature of 30° C and without daylight and a supply of fresh air. It is therefore a major objective of the present brochure to expand this awareness to cover acoustic working conditions of teachers and school students as well.

What is school noise?

The question of "school noise" is decidedly complex in the context of the teaching situation. How does the general noise level in the teaching situation, for example, affect the communication processes in progress there? How can interfering sound and desired sound be distinguished in a scientific analysis of the teaching situation? What are the consequences of sound levels and unintelligible communication for the performance of school students or for the teachers' workload?

And last but not least: What are teachers actually thinking when they complain about noise in the classroom – are they actually referring to the measurable sound level or more to the perceived disturbance of the teaching?

"The noise school students make places a strain on me"



3 Oberdörster, M.; Tiesler, G.: Acoustic Ergonomics of School. BAuA Publication Series Fb 1071, Dortmund, 2006

2 Where does the “noise in the school” actually come from?

Everywhere people are, they cause noises – and that is no different in schools and kindergartens. Many sound sources contributing to the basic noise level in our classrooms are not caused primarily by teaching. And once again we don’t want to hear all of these sounds; many are perceived as interfering noise. Sound waves are also highly successful in travelling as airborne sound or through building parts.

Factories in the vicinity can also be the source of interfering noise.

Sound can travel between rooms via ventilation systems. Ventilation and air-conditioning installations very often also cause interfering low-frequency noise themselves.

Noise from work rooms, music rooms, canteens and other loud environments travels, among other things, through walls and beams into classrooms.

In the classroom itself a lot of noise arises from the scraping of chair legs, squeaking, talking, laughter, calling and people generally making a din – as well as from the teaching itself when several students in the room are talking simultaneously, moving around, engaging in discussion etc., for example in modern forms of teaching such as group work or project work. We should also not forget interference from children themselves as they murmur, whisper or giggle.

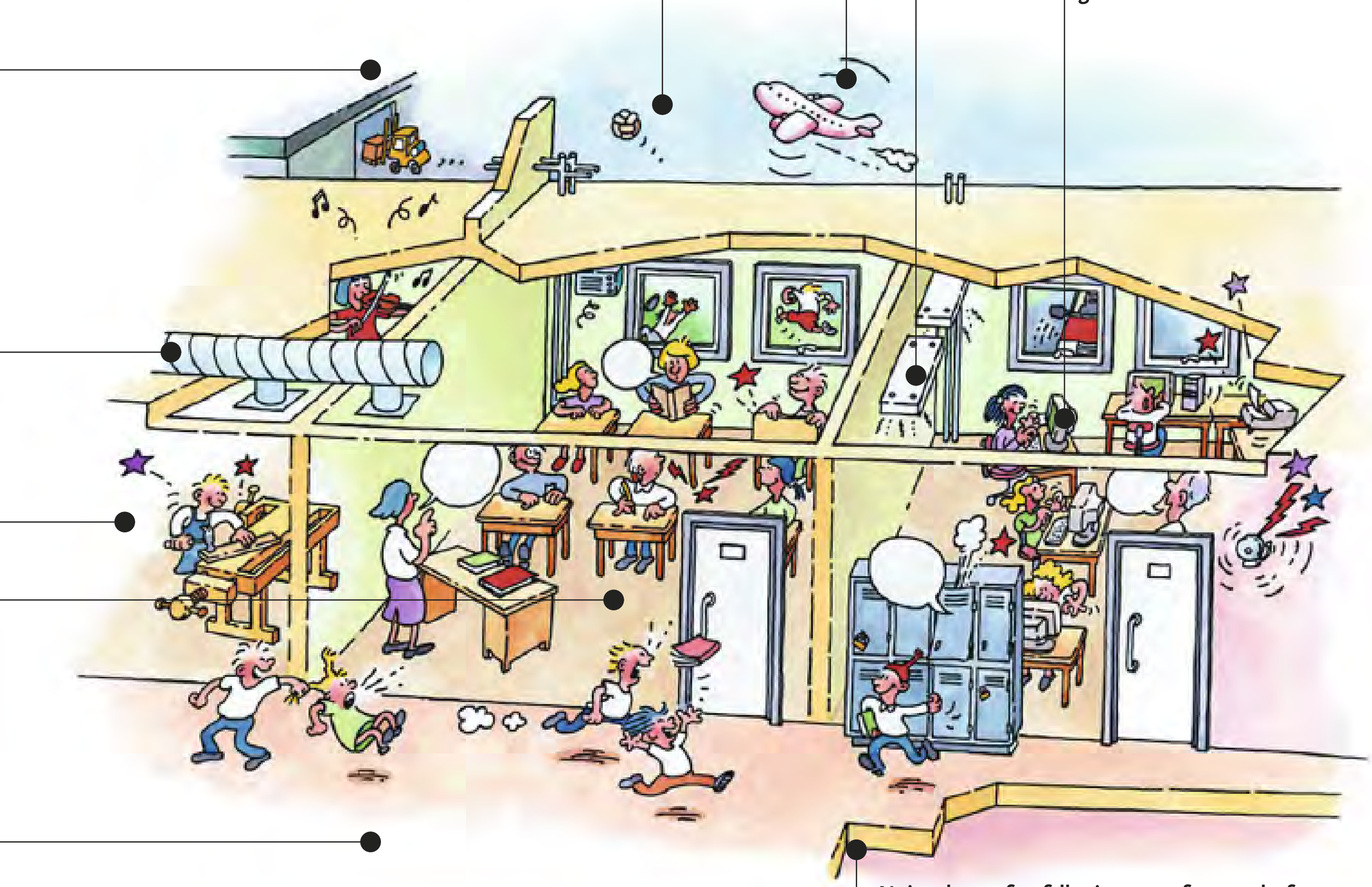
Corridors and communal areas are often very loud. The sound spreads along the corridor and from there it can penetrate adjacent classrooms, often due to poorly insulated partitions and doors. Dull and interfering noises creep through the floor and through load-bearing structural elements into the rooms.

Busy roads and nearby airports are highly unsuitable environments for schools and other learning institutions. Poorly insulated doors and windows are hardly a hindrance for this extraneous noise.

Fluorescent tubes not equipped with an electronic ballast can begin to vibrate in their fixture and thus generate noises in the low-frequency range.

Playgrounds and sports grounds in the proximity can involve interfering noise.

Computers, printers and other items of equipment cause interfering background noise.

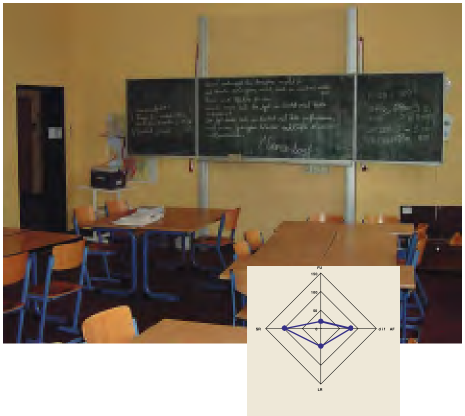


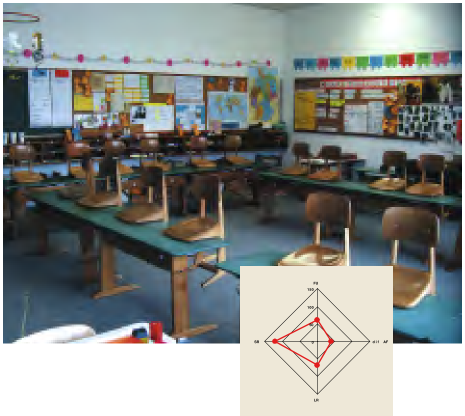
Noise due to footfall arises very frequently, for example with wooden floors. If the load-bearing structures are poorly insulated, the sound can also easily penetrate rooms located below.

3 Teaching yesterday and today – school noise as reflected in educational trends

There can be no doubt that the education system in Germany is in a state of flux that it hasn't experienced for many a year. And not only since the TIMSS or PISA studies. In numerous federal states educational reforms are imminent or are already being implemented. Alongside the external school organisation, the modes of working in the classroom situation in particular have changed over the past few years – the acquisition of knowledge proceeds today via different routes, using different forms of working.

In teaching practice there is normally a mixture of frontal and differentiated modes of working today (the key word is "frontal teaching discussion"). The crucial factors are normally the teacher's personal preference and the general pedagogical style of the respective school. Sometimes it is evident from the classroom installations and the orientation of the workplaces what forms of working determine what happens in the classroom. The pictures on the right give an impression of the astonishing range of variation of "teaching" currently in progress in German schools.[3]

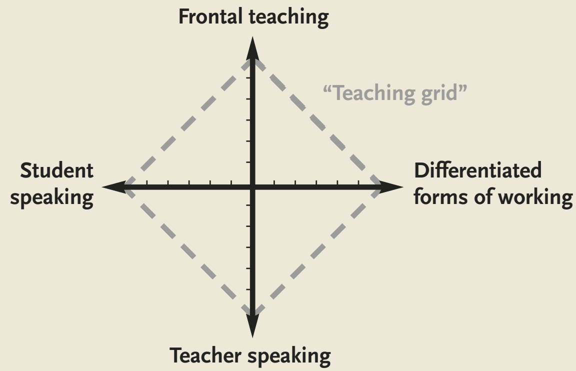




3 Oberdörster, M.; Tiesler, G.: Acoustic Ergonomics of School. BAuA Publication Series Fb 1071, Dortmund, 2006

Acoustic ergonomics of school

The study entitled "Acoustic Ergonomics of School" examined 175 lessons and recorded the time distribution of the various forms of working and the speaking proportions in "teaching grids". This revealed very different pedagogical approaches in the respective schools.[3]



Is school noise a problem of our age? Didn't it exist in former times?

Certainly this question is justified because in the literature at the beginning of the 20th century there is no record of teachers' complaints about noise. The question cannot simply be dismissed: "modern", "differentiated" and "non-teacher-centred" forms of working (e.g. co-operative, group or project work phases) as demanded by modern pedagogy generate completely changed communication scenarios in the classroom as compared to classic frontal teaching. The teacher withdraws in his role as the imparter of subject matter, as the presenter of a specified stock of knowledge. The school students, on the other hand, are expected to try things out for themselves more, to discuss amongst themselves.

Modern teaching thus goes for communal learning and deliberately allows for a situation where a number of people are speaking in the classroom at the same time. Even if the discussion discipline is good (which probably cannot always be assumed), such situations naturally tend to generate a higher noise level, however, than was usually the case when the teacher simply lectured (especially when this involved a high degree of discipline in the classroom).

4 The particular physical features of "noise" in the school

When we talk about "noise" in the context of education and schools, we mean something that is something different in terms of both quality and quantity than that at an industrial workplace, such as in the metalworking industry or in an office. While the noise emitted by machines can normally be classified as interfering noise, the noise level encountered in educational institutions must be described as a desired signal with a highly fluctuating fraction of interfering noise. Its differentiation and evaluation is largely dependent on the relevant teaching process.

Hasty analyses of the phenomenon which attribute the rising background noise level experienced in schools over the past decades only to social and pedagogical developments are therefore too short-sighted. The acoustic parameters for teaching also play a role in the context of modern pedagogical forms of working!

4 McKenzie, D.; Airey, S.: Classroom acoustics. A research project. Summary report. Edinburgh: Heriot-Watt-University (Dept. of Building Engineering and Surveying), 1999

5 Klatte, M.; Meis, M.; Nocke, C.; Schick, A.: Lernumwelt = Lärmumwelt?! Akustische Bedingungen in Schulen und ihre Auswirkungen auf das Lernen. Grundschule 2 (2004), 38–40

The ratio of desired signal and interfering signal

For example: Whereas a text read in a loud voice with a speech level of approximately 65 dB(A) can certainly be classified as a desired signal, a general murmur of 55 db(A) caused by school students in a silent work phase would normally be regarded as an interference signal. A simple survey of the noise level in the classroom which does not take account of the concrete teaching situation therefore only describes the phenomenon of "school noise" to a very limited extent.

An initial crucial criterion for assessing "school noise" is therefore the ratio of desired and interference signals in the classroom against the background of the communication processes in progress in the teaching situation. For an adult individual the desired signal should normally be about 10 dB louder than the interference signal to enable one to talk of an almost faultless communication. Since the voice of an adult is designed for a normal speech level of about 50 to 55 dB(A), this would demand an interference signal level of less than 40 dB(A). Even in so-called "silent working phases", the sound levels measured in schools are, however, rarely lower than 50 dB(A), i.e. the teachers mostly have to speak with raised voices if they wish to impart their information to the students. In addition the specialist literature expressly indicates that the speech communication of children at pre-primary and primary school age is much more impaired by interfering noises than that of adults (see section 5). Listeners who are children therefore need a desired signal level which is about 15 dB louder than the ambient interfering noise (the so-called signal-to-noise ratio "SNR"). This applies in particular to non-native-speakers and for learning a foreign language.

To aggravate this there is the fact that the interfering noise is distributed roughly evenly in a classroom, but the teacher's voice is transmitted from a single point and – depending on the room size and the teacher's position – may have to travel as much as 8 metres to reach the students in the back row. With unchanged background noise, this means either a substantial extra burden on the teacher's voice, which in the long run cannot fail to have health implications, or an impaired information flow to students at a great distance and thus restricted learning conditions.

Lombard effect

With the modern, differentiated forms of teaching there is a further aspect. If, for example, a number of working groups are speaking simultaneously in the same room, the signal of one group will be an interference signal for the others. A chain reaction is set off in the classroom: the parties will compensate for the speech intelligibility thus impaired in their group by increasing the speech volume, which in turn will lead to a raising of the interference signal level for the others, etc. The noise level in the classroom is therefore pushed steadily upwards over time, although the number of communicating parties remains the same. A phenomenon described in acoustics as the Lombard effect.

In this connection the particular significance of room acoustics for modern teaching also becomes clear: if, for example, short reverberation times ensure a precise speech signal (especially in the consonant spectrum, see chap. 6), the individual parties can make do with a lower signal-to-noise ratio. The build-up of the noise level is substantially less or no longer takes place.[5] This is not an isolated case: as early as the 90s the connection between the room-acoustic environment and communication behaviour and hence the noise development in the classroom was documented in Great Britain by a study of the Heriot Watt University.[4]

5 A child-friendly and learning-friendly "school as listening environment"

Speaking and understanding speech

Oral teaching can only be successful if the children listen attentively. This in turn assumes, alongside many other factors, that speech can be understood in the room clearly and without effort. But noise and reverberation in the classroom impair the speech quality considerably. The understanding of speech under such difficult conditions demands that background noises are blocked out and missing information is continuously supplemented. Adults can master this relatively well, but children cannot.

Knowledge from psycho-acoustics[5]

Children's processing of speech is in no way well trained and robust and is therefore much more susceptible to interference than that of adults. Numerous studies testify to the fact that pre-primary and primary school children in particular rely on optimum hearing conditions to be able to absorb spoken information, to retain it and to process it. This applies especially to children with hearing, learning and/or attention impairments and for children being taught in their second language.

But mental processes which do not involve hearing and listening are also disturbed by noise. Sudden loud and/or unfamiliar noises automatically attract attention and distract from the current activity. Children are affected by this to a particular degree. They are much less able than adults to direct their attention to a certain matter and to ignore irrelevant audio stimuli. These processes are also influenced by the room acoustics. In very reverberant rooms background noises such as coughing, leafing, rummaging in satchels, scraping feet etc. give the impression of being so loud and penetrating that they come to the fore in terms of perception. This makes it even more difficult of course to take no notice of them.

Furthermore it is known from memory research that irregular background sounds (speech, music, certain traffic noises) interfere with the short-term speech memory even at low to medium volume. The individuals affected are often not even aware of this interference – despite a clear deterioration in performance they say that the noise did not impair with them in their memory task! This form of performance impairment due to noise also affects children much more than adults. In related studies primary school children displayed a deterioration in performance of up to 25 per cent when the memory task was accompanied by background noises. This finding is especially important for the subject of "noise in schools" since the short-term speech memory plays an outstanding role in the acquisition of spoken and written language. It must therefore be supposed that learning to speak, read and

3 Oberdörster, M.; Tiesler, G.: Acoustic Ergonomics of School. BAuA Publication Series Fb 1071, Dortmund, 2006

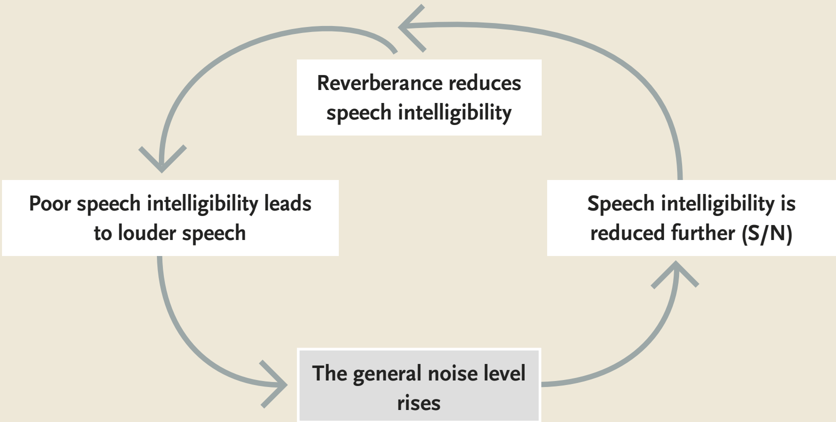
5 Klatte, M.; Meis, M.; Nocke, C.; Schick, A.: Lernumwelt = Lärmumwelt?! Akustische Bedingungen in Schulen und ihre Auswirkungen auf das Lernen. Grundschule 2 (2004), 38–40

write is impaired by an excessively "noisy" environment. With tasks which place demands on the short-term speech memory, special care must be taken to ensure a quiet learning environment. This includes in particular reading and writing exercises during early teaching, mental arithmetic and the learning of vocabulary.

These findings show that both optimum room acoustics and measures of teaching organisation are necessary to achieve a child-friendly and learning-friendly "school as listening environment".

Improved room acoustics for a quieter teaching situation

It is precisely the forms of working in "modern teaching", such as working in small groups, that normally involve lively communication. Reverberant classroom acoustics set a cycle in motion: although the number of speaking individuals remains the same, the noise level in the classroom rises further and further. An improvement in the room acoustics will therefore result in an often substantially quieter teaching situation, especially with these forms of working[3].



6 Short reverberation times for excellent speech intelligibility – the most important room-acoustic parameters in the classroom

If we consider the suitability of classrooms for what is supposed to happen in them from the point of view of room acoustics, the acoustics engineer has at his disposal a whole range of characteristic variables to describe acoustic quality.

The reverberance of the room in general is assessed as definitely its most conspicuous acoustic feature. The corresponding criterion of **reverberation time** (RT) describes in concrete terms the time span during which the sound pressure level of a test tone in the room has fallen by 60 dB after being switched off. And the main question to be answered in the classroom as well is how quickly it can reduce sound on the basis of its physical features alone. A short reverberation time has a dual effect in practice: on the one hand it contributes to a lower sound level through the rapid absorption of the sound energy in the room, and on the other with the clearer speech signal it increases the so-called speech intelligibility or acoustic quality in the room. (For the significance of **speech intelligibility** for the listener's reception of information, especially in the case of children, see chap. 5).

A modern, objective procedure for the direct determination by measurement of speech intelligibility is the determination of the so-called *speech transmission index (STI)* – with a scale from 0 (unsatisfactory) to 1 (very good) – and of the *articulation loss of consonants (Alcons)* indicated in %. The latter procedure is of interest because in terms of linguistic science the consonants are of special importance for understanding the content. Plosives and fricatives in particular (p, t, k, f, ss, z, sh) act with disproportionate frequency as carriers of the meaning of a syllable or a morpheme, alone due to their numerical variety.

The dependence of speech intelligibility on the reverberation time

The two characteristics of reverberation time and speech intelligibility are mutually dependent to a great extent: if the reverberation time is too long, this means for the speech signal that the subsequent syllables are masked by the excessively extended fading of the preceding ones. With increasing reverberation then the speech intelligibility will decline with constant interfering noise level (see table).

In this context Finnish researchers[6] already established in the early nineties that only classrooms with reverbera-

4 McKenzie, D.; Airey, S.: Classroom acoustics. A research project. Summary report. Edinburgh: Heriot-Watt-University (Dept. of Building Engineering and Surveying), 1999

6 Pekkarinnen, E.; Viljanen, V.: Acoustic conditions for speech communication in classrooms. Scand. Audiol. 20 (1991), 257–263

7 DIN 18041: Hörsamkeit in kleinen bis mittelgroßen Räumen. Berlin: Beuth Verlag, 2004

Syllable intelligibility in % as a function of the reverberation time and the signal-to-noise ratio according to Finitzo-Heiber and Tillman

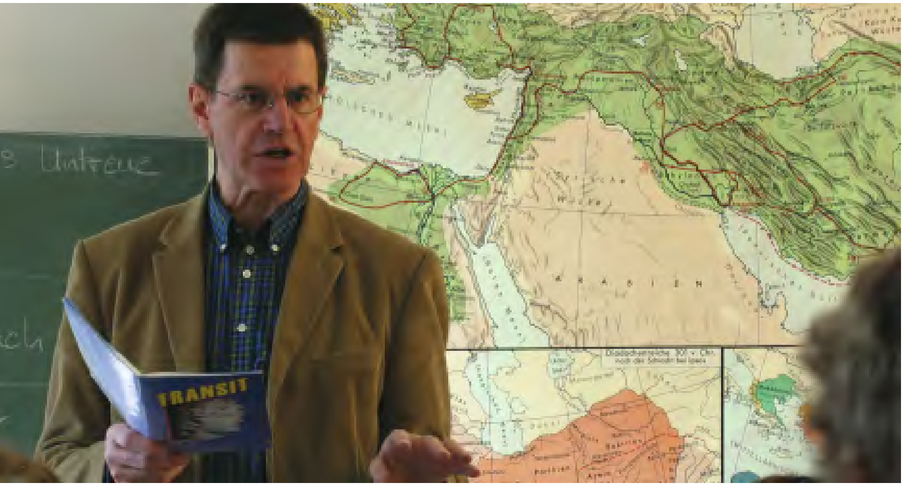
	RT = 0 s		RT = 0.4 s		RT = 1.2 s	
SNR in dB(A)	Normal hearing	Hearing-impaired	Normal hearing	Hearing-impaired	Normal hearing	Hearing-impaired
> 45	94.5	83.0	92.5	74.0	76.5	45.0
12	89.2	70.0	82.8	60.2	68.8	41.2
6	79.7	59.5	71.3	47.7	54.2	27.0
0	60.2	39.0	47.7	27.8	29.7	11.2

tion times of substantially less than 0.6 s achieve "very good" (STI > 0.75) speech intelligibility throughout. Scientists at the Heriot Watt University in Edinburgh demanded in 1999, as the result of the world's largest study to date of school acoustics[4], reverberation times in classrooms of less than 0.5 s. The new version of DIN 18041 "Acoustic Quality in Small to Medium-sized Rooms" (2004)[7] lays down reverberation times for classrooms of around 0.5 s and deals explicitly at the same time with important pedagogical problems, such as foreign language teaching, school students who are not native speakers of German or school students with impaired attention and concentration.

Speech signals

Acoustically the sibilants and plosives contain in their spectrum mainly high-frequency signal fractions (1 kHz – 8 kHz). The basic tones and vowels which lend the voice its volume are, on the other hand, mainly low-frequency (125 Hz – 250 Hz or 250 Hz – 1 kHz). While the latter give the voice its sonority, the consonants determine the articulation. The varying importance for speech intelligibility can be demonstrated effectively by whispering. Although the speech signal lacks the vocal chords' vibration when the subject is whispering, in other words it only consists of breath, sibilants and plosives, the content can easily be understood provided the signal is sufficiently loud in relation to the interfering noise. But many interfering noises contain large high-frequency fractions. The logical conclusion for room acoustics is to dampen the high-frequency fractions of the interfering noise to a corresponding degree.

7 “Acoustic Ergonomics of School” The interplay of room-acoustic factors, pedagogical trends and teacher health

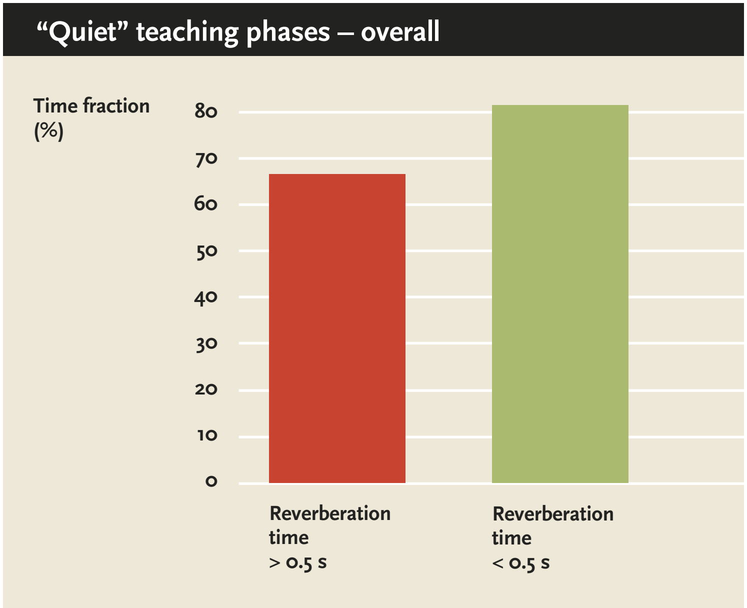


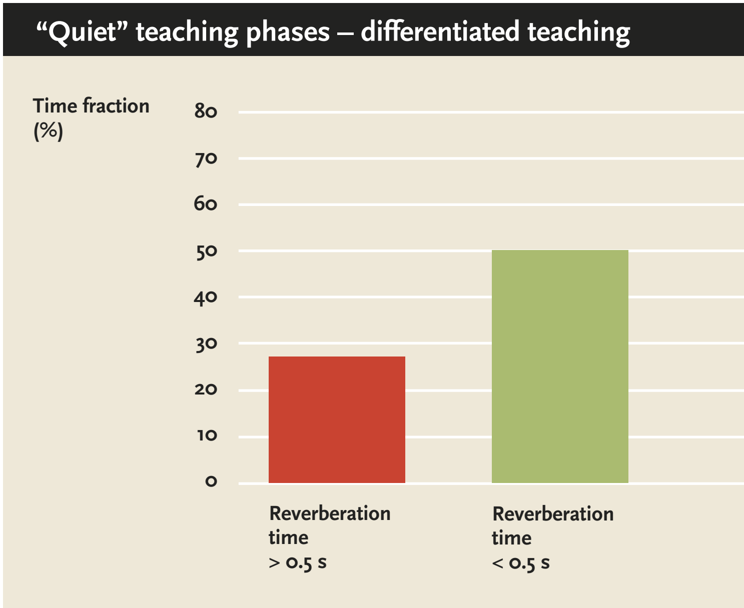
To highlight the special significance of room acoustics for modern teaching, the to date most recent study was conducted in 2005 by the ISF of the University of Bremen on the “Acoustic Ergonomics of School”[3]: On the basis of 175 lessons in different primary schools, the effects of the different forms of working (frontal teaching v. differentiated teaching) on the basic and work noise levels in the classroom were investigated as a first step. As a second step it was examined how modified room acoustics affect this level in the context of the respective form of work. By means of an extended data record description it was possible for the first time not only to evaluate average hourly values, but also to look directly into teaching phases dominated by certain pedagogical features.

On this basis the final third stage involved examination of the question as to what effects the “noise” arising during teaching as natural working noise had on the teacher concerned. How great is the influence of acoustic conditions on the measurable physiological strain on teachers as a function of what was actually going on during the teaching? Such an “ergonomic” question, linked with the current pedagogical trends, may appear surprising at first glance. But it gave astonishing insights into the phenomenon of “school noise”, its causes and effects and on the relevant room-acoustic parameters of reverberation time and speech intelligibility.

In classrooms with acoustically good conditions, the time-based fraction of “quiet” teaching units was greater than 80 % (given comparable teaching), and under poor acoustic conditions it was approximately 67 % (related in each case to the average speech level of an adult (approx. 62 dB(A)) as the normal case in the teaching situation).

3 Oberdörster, M.; Tiesler, G.: Acoustic Ergonomics of School. BAuA Publication Series Fb 1071, Dortmund, 2006



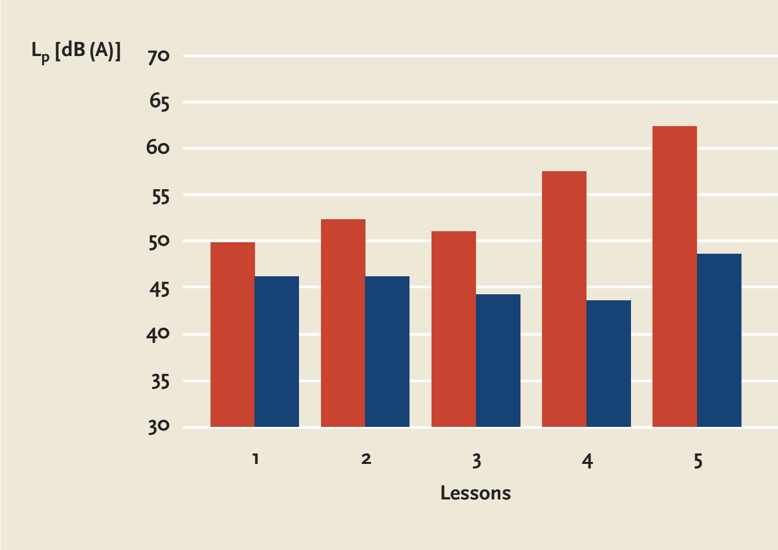


Clearer still was the change when the class worked with differentiated forms of teaching: here the fraction of quiet phases doubled!

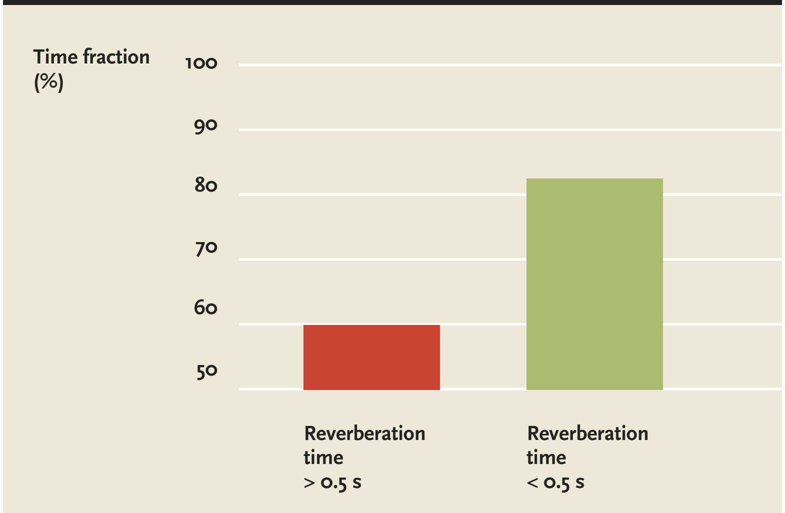
A clear indication of the lack of Lombard effect in co-operative, group or project work. The level differential between the acoustically good and the acoustically poor rooms was 13 dB with these forms of working!

When an exact comparison was made of the teaching situations, a further important aspect became evident. The usual rise in the basic noise level over the school day (red) did not occur in the classrooms with short reverberation times (< 0.5 s) (blue). This has an enormous impact on the teaching process and provides an initial indication of the physiological dimension of the acoustic working environment.

Development of basic noise over the morning



Teaching phases involving little work strain



In fact the positive effects of acoustically good rooms reduce the workload on the teacher. After an acoustic improvement, for example, substantially more teaching phases took place with comparatively little working strain for one and the same teacher. The pulse rate serves as an objective indicator of the psychophysical working strain; the reference point here is the test subject's average pulse rate of 90 per minute. Other studies have also testified to a lower sensitivity on the part of the teacher to the stressor of "noise", and hence to a considerably more relaxed working atmosphere. There is therefore no doubt that the acoustic design of classrooms has an ergonomic dimension.

Room-acoustic interventions

In the classroom of a 2nd year primary class a reverberation time of RT = 0.8 s was measured. With a speech transmission index = 0.7, teaching was not conducted under "very good" acoustic conditions, but also not under disastrous ones. By means of a room-acoustic intervention (ceiling and wall cladding) the reverberation time was lowered considerably to about 0.4 s and the speech intelligibility was substantially improved (STI = 0.85). The effects of this intervention on the noise level during teaching were surprising – especially since the school had already been a decidedly quiet and disciplined place before the "conversion" thanks to a pedagogical anti-noise approach and the consistent practice of quiet forms of working. Overall the basic noise level was suddenly about 8 dB lower than prior to the intervention! But this level reduction cannot be explained by the physical absorption of the sound energy of approx. 4–3 dB alone. Rather the children – although unusually quiet and disciplined anyway – reacted directly in terms of their behaviour to the modified learning environment, which led to a further substantial reduction in level of on average 4–5 dB.

What goes on in the classroom had changed fundamentally over the past few years. "Modern", "differentiated" and "non-teacher-centred" forms of working (e.g. co-operative, group or project work phases) generate completely changed communication scenarios as compared to classic frontal teaching: the teacher recedes as the conveyor of subject matter, the presenter of pre-specified stocks of knowledge. The students on the other hand have to try things out for themselves more, consider things, discuss them between themselves and they are expected to acquire knowledge and problem-solving skills themselves. Modern teaching therefore goes for communal learning and deliberately allows for a number of individuals speaking simultaneously in the classroom.

8 Measures of acoustic-ergonomic classroom design

1. Very highly absorbent elements on the ceiling to reduce the reverberation time

The present research shows that optimised room acoustics combined with excellent speech intelligibility lead to substantially reduced sound levels and a quieter behaviour on the part of the school students, especially in the case of open forms of working. **A reduction in the reverberation time to less than 0.5 s and an STI > 0.75 are to be aimed at.** Small differences are often of great importance for the listener's experience!

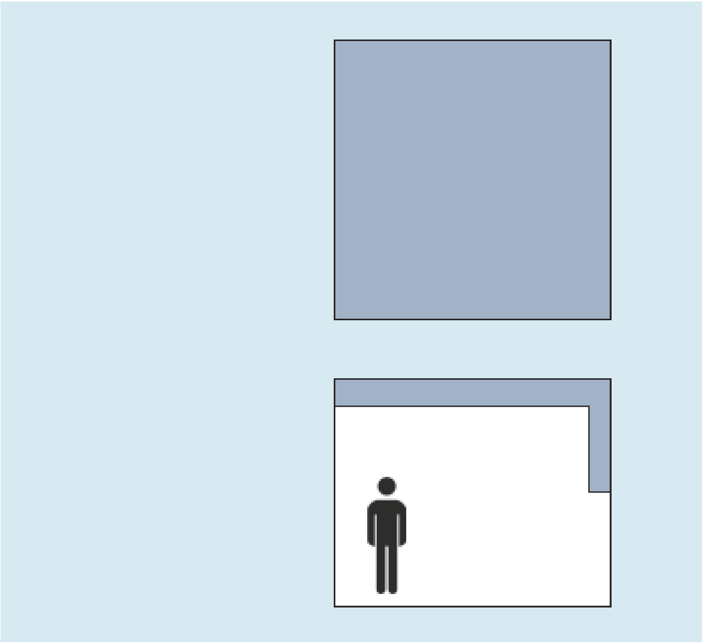
Insulation which is stronger than previously may have the effect of being unfamiliar at the beginning, but it yields significant results; it was rated by the teachers and students involved in the "Noise in Educational Institutions"[2] project as very beneficial and their reaction was favourable.

With reference to the **new version of DIN 18041**[7] the intention was to pay special attention to a balanced reverberation time curve in the frequency range of between 100 Hz and 5 kHz.

As an aid to orientation, these specifications can be fulfilled in classrooms of usual size and cubature by installing, for example, a ceiling covering over the whole surface with very highly absorbent materials of absorption class A to DIN EN ISO 11654. Under normal conditions it is possible in this way to ensure the values given largely regardless of the other room fittings and the occupation of the room.

2 Schönwälder, H.-G.; Berndt, J.; Ströver, F.; Tiesler, G.: Lärm in Bildungsstätten – Ursachen und Minderung. BAuA Publication Series Fb 1030, Dortmund, 2004

7 DIN 18041: Hörsamkeit in kleinen bis mittelgroßen Räumen. Berlin: Beuth Verlag, 2004

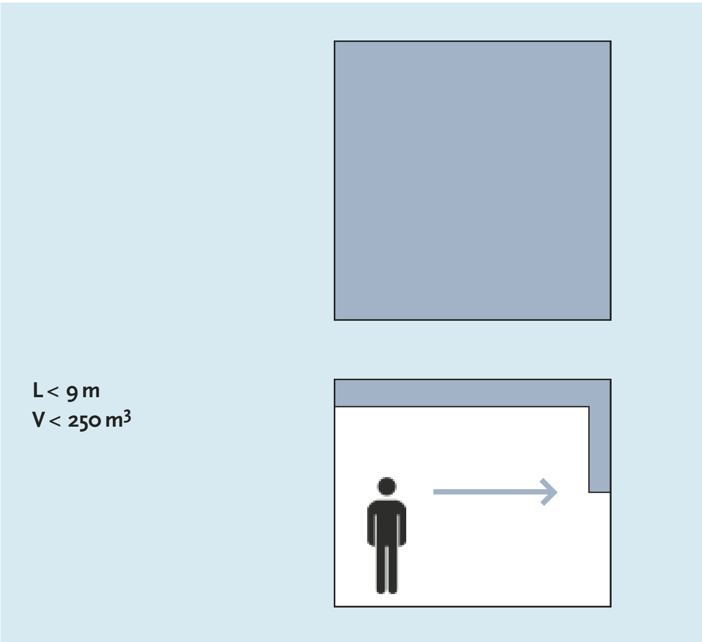


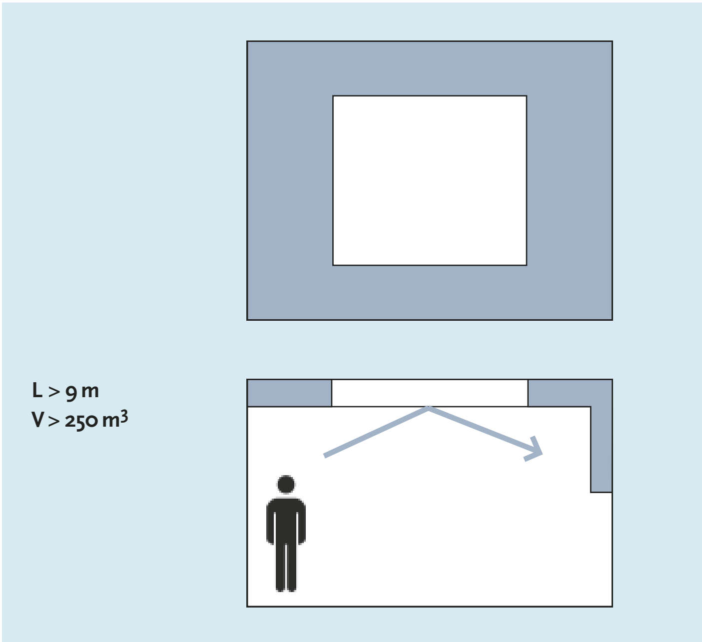
2. Dispensing with the classic ceiling reflector

Thanks to the increasingly decentralised communication in the classroom and the decrease in frontal teaching, the classic reflector in the middle of the ceiling has declined in importance. In group or project work phases in particular, which generates the highest work noise level anyway, it tends to act as a disturbance factor in the noise development. The benefit of a reinforced initial reflection from the blackboard position is not particularly significant, on the other hand, for general speech intelligibility in normal-sized classrooms: neither the teachers involved in the “Noise in Educational Institutions”[2] study nor the school students complained of inadequate sound input in the back rows, for example. The measured values also document that none of those involved raised their voice more than prior to the refurbishment. Clearly the reduction in signal level due to the absorbent ceiling is cancelled out by the drastic reduction in the basic noise level, and so even at remote listener locations there is a sufficient, for the most part even improved signal-to-noise ratio.

At the same time a reflector-free room design comes up against its limits as the size of the room increases. We should recall here the remarks in DIN 18041, according to which full-coverage absorber cladding can only be recommended up to a room size of about 250 m³. A tried and tested guide figure here is also a room length of up to about 9 m. In shorter rooms absorbent ceiling claddings which have full coverage generally present no problems because the direct sound supply is then sufficient.

In longer or larger rooms it is essential for a firm of acoustics engineers to conduct a specific calculation!



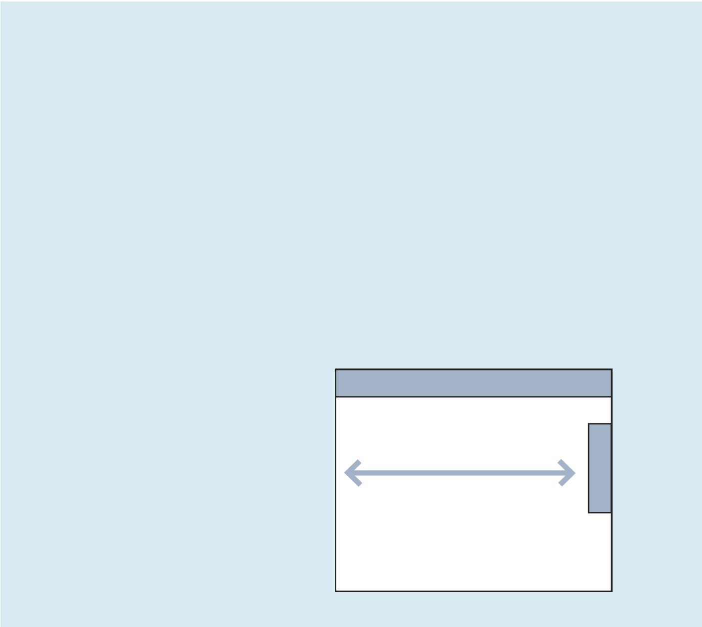


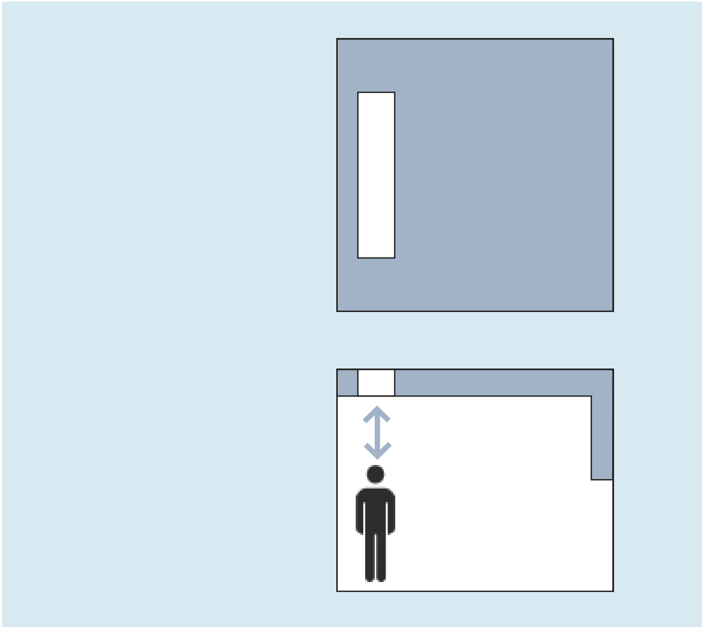
3. Design of individual functional surfaces

The heavy insulation of a room on only one surface may have undesirable consequences, especially in the case of only slightly diffuse rooms:

a) To avoid audible flutter echoes it is therefore urgently recommended that at least one wall surface be of absorbent design in the normally sparsely furnished classrooms (e.g. by means of open furniture, absorbent pin walls etc.).

b) It is easier for the teacher to be used to a heavily insulated room characteristic if a small reflector is fitted above a defined speaker's position (e.g. in the area of the board), which will provide the speaker with acoustic feedback concerning his own voice and volume (without the feedback extending to the students' workplaces; see 2.). This measure only makes sense, however, in the case of predominantly frontal teaching and requires in the planning phase that such a position can be specified as permanent.





It is therefore possible at manageable expense and effort to design classrooms in such a way that they meet the requirements of modern teaching with its entire methodological variety. The effects in the teaching situation documented in more recent literature are astounding and justify saying once again that optimised classroom acoustics represent a central ergonomic resource for the success of teaching and learning in our schools.

9 Consequences and prospects

Study "Noise in Educational Institutions" (2004): The proud team of "scientific collaborators" after the successful survey of their classroom

Modified pedagogy combined with a steady increase in differentiated forms of working and a corresponding reduction in frontal teaching may mean that school buildings which have "functioned" well for many decades need to be reassessed. New forms of teaching also impose different requirements regarding the ergonomic parameters.

Needless to say it would be completely ridiculous to claim that teachers exercised no influence on the noise development in their classrooms. Of course they do – and they must make use of this. In the research report on the "Noise in Educational Institutions"[2] study, these possibilities for exercising an influence are dealt with in detail. During the investigation it became evident what order of level reductions could be expected within a shorter period due to the pedagogical intervention of individual teachers: approximately 2 dB. At the same time, however, it was found that, with comparable room-acoustic conditions and comparable social structure among the students, comparatively large differences (5 to 6 dB) in the noise level were found between the individual schools. The relations were easy to identify: only those schools were really quiet where the teaching staff pursued a uniform pedagogical approach. If the same rules of conduct apply not only in all classrooms and during lessons, but also in all areas of the school, and the children – regardless of which teacher they encounter – could expect the same response if they failed to adhere to these rules, this was reflected to a notable extent in the noise levels measured. The recipe is then as simple as it promises to be successful, but it requires a teaching body which acts together and displays reciprocal solidarity.

The contributions of the individual teacher in terms of school organisation and on a personal level are invariably indispensable for efficient noise reduction in the school. The ergonomic conditions provide the necessary framework for the pedagogical activities in the school's daily routine. Neither aspect can be replaced by the other, nor can they be played off against one another – they have a reciprocal effect and must interact to ensure that teaching can work, especially in the context of a modified mode of communication.

2 Schönwälder, H.-G.; Berndt, J.; Ströver, F.; Tiesler, G.: Lärm in Bildungsstätten – Ursachen und Minderung. BAuA Publication Series Fb 1030, Dortmund, 2004

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