

A RESEARCH
SUMMARY

IMPACT OF NOISE IN EDUCATION



Ecophon
SAINT-GOBAIN

NOISE IMPACT IN EDUCATION

Noise in schools can reach extremely high levels. This can negatively influence on teachers and students. But by how much and to what extent? And what can we do to improve learning spaces so that they really facilitate the sharing of knowledge instead of hindering it?



Discover in this summary what research definitively reveals:

- Recommended healthy noise levels and how they compare with today's average school environment levels
- What it takes to ensure beneficial sound levels in schools
- How noise impacts on students' learning capacity and behaviour
- How noise affects teachers and the health risks involved, physically and mentally
- The effect of perceived sound on concentration and annoyance levels in teachers and students
- Optimising acoustics for inclusive learning
- Noise levels and open plan classrooms
- How noise affects the vulnerable the most

This information is based on a comprehensive literature review conducted over many years by Professor Bridget Shield, without whose work this summary would not have been possible.

NOISE IMPACT ON TEACHERS AND STUDENTS

We know that good teaching* is the single largest influence on student learning. We want to help teachers to teach even more effectively by providing evidence linking good acoustics with a healthy indoor environment. We have sourced a number of findings indicating the importance of reducing the adverse impact of acoustics on teachers:

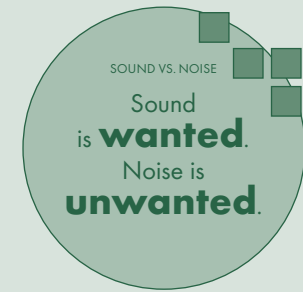
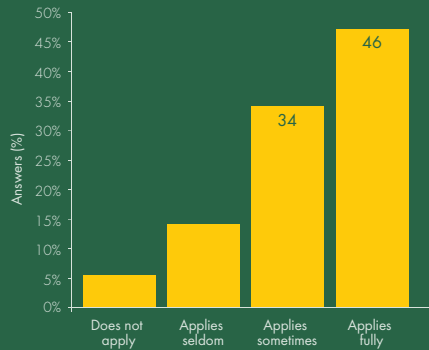
- Over 65% of teachers surveyed have experienced voice problems during their career²
- 32% of teachers stated that they had had voice problems, compared with 1% of non-teachers³

We must support students in a more diverse range of activities to help them adapt optimally in our rapidly changing societies. Students now need 21st Century Skills, including collaboration, communication, creativity and critical thinking skills. These skills demand that students actively engage in their learning process. But the increase in communication brings additional noise to the classroom. This has made the acoustic environment much more important.

With the benefit of good acoustics:

- The number of children achieving government targets in their test scores increased by up to 13%⁴
- Students work more inclusively and better together⁵
- The sound level in collaborative group work decreased by 13 dB (theoretically, only 3 dB would be expected)
- Students had increased focus and less tiredness

80% of teachers are stressed by classroom noise¹



SOUND AND NOISE LEVELS

COMMON VS. RECOMMENDED

Measuring sound

Noise is measured in a logarithmic unit called a decibel (dB)*. Doubling the sound energy, by adding twice the number of speakers to a room for example, results in an increase in the sound level of 3 dB. Raising the level by 10 dB results in a sound that is twice as loud.

Appropriate noise levels and typical acoustic guidelines for schools

Research-based guidelines provide a suitable acoustic range in classrooms for both the average listener and those with additional learning and hearing needs. Maximum noise levels to ensure sufficient speech intelligibility and good communication are outlined below. Levels include unoccupied

background noise and the difference required to hear clear speech.

- Maximum ambient noise levels for unoccupied rooms of 30-35 dB^{7,8}
- For good speech communication there should be a clear difference in the signal to noise ratio (SNR) of at least 15-20 dB⁹
- Reverberation time (RT) should be approximately 0.5 seconds for learning spaces in which verbal communication is important (a range of 0.3-0.6 seconds is recommended according to classroom acoustic standards for various Nordic countries)

Typical sound levels in decibels

Four-engine jet aircraft at 100 m	120 dB
Riveting of steel plate at 10 m	105 dB
Pneumatic drill at 10 m	90 dB
Circular wood saw at 10 m	80 dB
Heavy road traffic at 10 m	75 dB
Telephone bell at 10 m	65 dB
Male speech, average, at 10 m	50 dB
Whisper at 10 m	25 dB

*Whenever dB is mentioned in this brochure, it refers to dB(A)

AVERAGE CLASSROOM NOISE LEVELS

Noise in schools is dominated by three factors:

- External environmental noise (planes, trains and cars)
- Noise generated by students in their learning activities
- Mechanical sound sources from within the room (ventilation, projectors, computers)

A recent study¹⁰ documented noise levels in hundreds of school classrooms while students were having lessons. They discovered that students in noisier classrooms had poorer learning outcomes and behaviour.

NOISE LEVELS IN LESSONS AFFECTS STUDENTS' ACADEMIC PERFORMANCE:

Results of the research revealed that classrooms in which there were high noise levels performed worse in reading tasks than learning in classrooms with lower noise levels. This suggests that acoustic treatments that reduce noise will benefit children's reading in many schools.

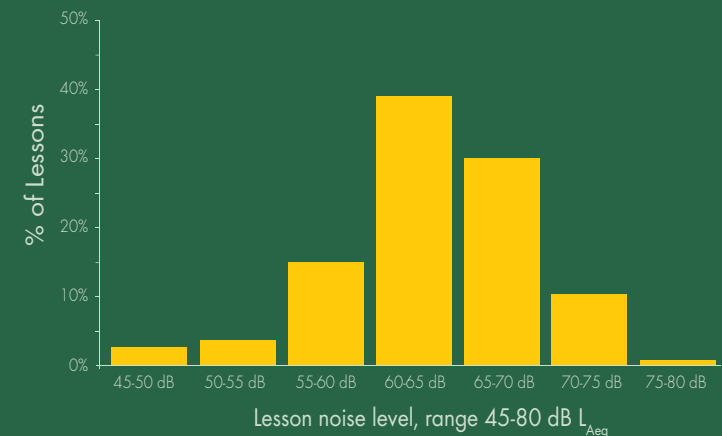
LEGISLATION LEADS TO REAL IMPROVEMENTS:

When legislation for school acoustics was introduced in England and Wales in 2003, it doubled the number of schools with optimal sound environments for their learners. This shows that, worldwide, schools stand to benefit greatly from acoustic standardisation and legislation.

ACOUSTIC CONDITIONS AFFECT STUDENT COGNITION AND BEHAVIOUR:

The time taken for students to recover from auditory disruptions (e.g. students talking or shouting) shows that having high noise levels can impact adversely on students' ability to concentrate^{4,10}. These levels have also been linked to lower scores in tests of reading, spelling and related tasks⁴. These impacts are even greater for children with special educational needs¹¹.

Noise survey of 274 lessons¹⁰





ACHIEVING GOOD ACOUSTICS

FOR OPTIMAL VERBAL COMMUNICATION

There are two clearly identified aspects that influence a school's acoustic environment: noise and reverberation time*. In classrooms, noise may have many sources: air and vehicle traffic coming from outside, building services (heating, lighting, ventilation systems), technology (projectors, computers) as well as noise from the students themselves.

The quality and intelligibility of speech depends on both the level of noise and on the amount of reflected sound. Sound reflects off, and is amplified by, surfaces in the room, including walls, ceilings, floors, tables and whiteboards. Too much reflected sound from hard and flat reflecting surfaces degrades the quality of speech and increases the noise level.

Achieving the best acoustics for verbal communication is essential. To support all facets of communication, from speaking to hearing and listening, it is necessary to look at building and acoustic design from a range of perspectives.

Key factors for adequate sound reduction from internal sources include:

- Lowering internal noise levels (e.g. from installations and activities)
- Shortening reverberation times to minimise unwanted sound reflections
- Optimising speech intelligibility by reducing reverb time and increasing the signal to noise ratio (SNR)

Designing for external noise reduction

Sound insulation from external sources, minimal service noise and intrusion from other spaces.



*The reverberation time (RT) in a room quantifies sound reflections from surfaces. RT measures the time taken for a sound to decay by 60 dB, and is directly influenced by the amount of sound-absorbent materials in a room. Optimal RT for speech is shorter, around 0.5 seconds, whereas longer times of up to 2 seconds are acceptable in rooms where speech has less primacy, such as music auditoriums.

EFFECTS ON LEARNER PERFORMANCE

This study⁴ compared different levels of background noise in order to assess the impact they had on learning. When comparing the effect on common educational tasks of “quiet” versus “average” levels of background noise, researchers found major differences in performance.

They found that lower noise levels allow students to process information more quickly, and to respond with a higher level of accuracy. This study also demonstrates that adolescents’ reading comprehension is vulnerable to unfavourable levels of classroom noise. Children that were not functioning optimally to start with, due to colds or tiredness for example, were also more severely affected by the babble noise.

Typical classroom babble at an average of 65 dB has a significant impact on arithmetic, as well as verbal and cognitive tasks.

Effects of classroom babble on performance of primary school children



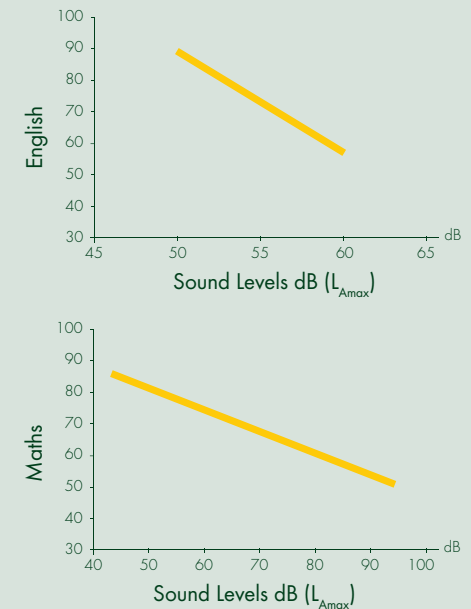
NOISE INTERFERES WITH THE PROCESSING OF LANGUAGE

This study⁴ demonstrates that the impact of noise is detrimental to students’ academic attainment.

Comparing standardised school assessment test scores of young students with internal noise levels found significant negative relationships between the ambient background sound levels in classrooms and test scores for several subjects.

Interestingly, the test that displayed the strongest association with noise was the language test. These findings suggest that background noise in the classroom interferes with general processing of language.

Increasing noise levels clearly lowers the scores in two fundamental subjects, with a more dramatic impact in English.



GOOD ACOUSTICS IMPROVE SPEECH INTELLIGIBILITY BY MORE THAN 35%

Researchers made groundbreaking findings¹¹ that most of the noise in school classrooms was not caused by the what was assumed to be noise from planes, trains and cars, but by the students themselves during learning activities.

They also found that by introducing a high performing "Class A" absorption ceiling:

- Students' word recognition improved by 35%
- Perceived sound level was reduced by half

Reducing noise levels has a physical and behavioural impact

The theoretical effect of installing a Class A sound absorbing ceiling was predicted to be a 3 dB sound level reduction for an unoccupied classroom. However, the real change was in the behaviour of the people in the classroom. Since everyone could be heard and understood without raised voices, students and teachers immediately spoke more quietly, in fact 7 dB more quietly, with a reduction of 10 dB overall.

Better for group learning

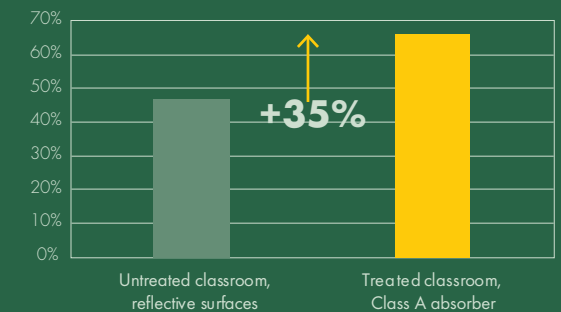
The acoustic treatment reduced the background noise levels and shortened the reverberation time, resulting in better student performance in word intelligibility tests. The improvement was particularly positive when there were a lot of students talking simultaneously in the classrooms.



Staff working in the treated classrooms report that there is a huge difference. Not only do they not have to shout to be heard, but there is generally a calmer, quieter and more relaxed atmosphere in the classroom. We're all delighted.

HEAD TEACHER MISS CATHERINE DOUGLAS OF BALGREEN PRIMARY SCHOOL

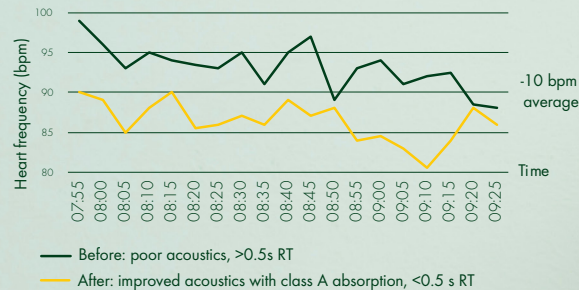
Percentage of correctly identified words



GOOD ACOUSTICS LOWER HEART RATES

Once it was realised that 80% of teachers experienced stress as result of noise, researchers decided to find out if stress levels could be reduced by improving the sound environment. They also sought to discover how classroom noise actually affects teachers and students during activities¹.

Comparing teachers' heart rates in poor vs. good sound environments (with Class A acoustic absorbers) showed that heart rates calmed down by up to 10 beats per minute (bpm) when acoustics were improved



How it is possible

If a classroom has poor acoustics, sound is amplified as it bounces off the reflective ceiling and walls. This creates background noise, which distorts speech. Sound levels then escalate because instructors and learners have to raise their voices to be heard. This is called the Lombard effect¹⁵. As a result, the environment will often feel progressively more stressful as the class (or day) continues. (Please also refer to the study described on page 20 concerning how the Lombard effect influences students' behaviour.)

Reducing noise and reverberation time reduces stress

Acoustically treated classrooms transform the space into a more relaxed environment where everyone feels calmer, reducing teachers' heart rates. Teachers experience considerably less stress in classrooms when reverberation time is less than 0.5 seconds.



*Heart rate
is a medically
recognised
stressor.*

DR GERHART
TIESLER



Teachers have **more than twice** as many days off work as those in other occupations.

VOICE PROBLEMS

VOICE PROBLEMS SHOW THAT TEACHERS' HEALTH IS AT RISK

Sadly, it has been consistently shown that teachers develop more voice problems than other occupations.

Threats to teachers' vocal health

Based on numerous studies of teachers' vocal health, teachers are at least twice as likely as other occupations to have voice-related problems.

- Over 65% of teachers surveyed experienced voice problems during their career²
- Teachers represented 16.4% of those diagnosed with voice disorders while constituting just 2% of the working population tested¹²
- 32% of teachers stated that they had had voice problems, compared with 1% of non-teachers³

CONSEQUENCES OF VOICE PROBLEMS

ON TEACHERS' WORKING LIVES

This large-scale study¹³ compared voice-related work problems and absence from work in 2,400 workers from different professions over the course of one year. The findings show that teachers are more likely than any other group of workers to restrict their activities at work and have more days off work due to voice-related problems.

Comparison of work-related problems in the past year among teachers and non-teachers

	Prevalence (%)	
	Teachers	Non-teachers
Reduced activities on at least one day	43	16
Missed at least one day of work	18,3	7,2
Missed more than 5 days of work	3	1,3
Voice not functioning as usual for more than 5 days	35	22
May need to change job because of voice	2.0	0.78

NOISE IMPACT ON STUDENT

CONCENTRATION AND BEHAVIOUR

Improving acoustic conditions has implications for the number of dysfunctional activities

This study¹⁴ investigated whether changes in classroom noise level have a direct relation to student behaviour. During five morning lessons, ‘dysfunctional’ activities increased in classrooms with inferior acoustics (RT 0.6 to 0.75 s), while dysfunctional activities in rooms with superior acoustics (RT 0.4 to 0.5 s) remained about the same throughout the morning.

Lombard effect¹⁵

As the day progresses, classrooms with poor acoustics experience more dysfunctional and disruptive behaviour following the progressive rise in noise levels¹⁵.

Acoustic improvement changes students’ behaviour

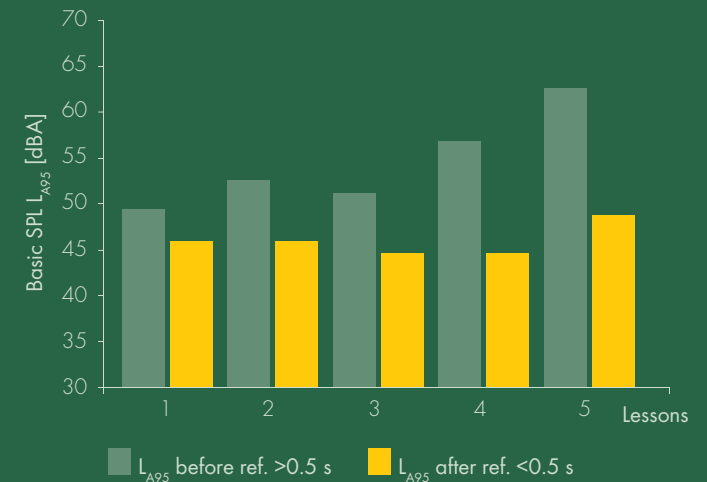
A sound-absorbing ceiling reduces the overall sound level in the classroom as well as the noise from activities, altering students’ behaviour in a very positive way.

Ease of listening encourages better behaviour

This study also monitored “dysfunctional activities” during lessons¹⁴. This included interruptions or disruptions from activities not relating to the lesson. As the sound levels were reduced, so were the dysfunctional activities, resulting in increased concentration during the lesson.

When noise levels are controlled, the levels of student concentration remained the same across the lessons. This consistency with improved acoustics negates a major source of fatigue and stress in the classroom.

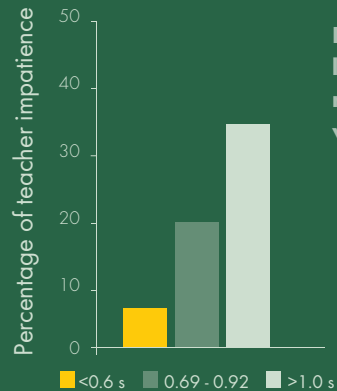
Increase in activity sound levels (L_{A95}) before and after refurbishment



POOR ACOUSTICS CAUSE ANNOYANCE

While investigating the effects of classroom acoustics on children and teachers, researchers found a direct correlation between reverberation time and annoyance for both groups¹⁶.

Children from the more reverberant classrooms had lower ratings for motivation and quality of interaction with peers and teachers. (Typical classroom acoustic recommendations are for reverberation times to be around 0.5 s.)



Excessive reverberation lowers motivation & reduces student rapport with teachers

Parents were also asked this question: “My child suffers from the noise produced by his or her classmates in school.” Results showed that the least amount of annoyance was reported for children being educated in rooms that had been treated to reduce reverberation time.

Classroom acoustics (RT)	% annoyance
<0.6 s	44%
0.7-0.9 s	51%
>1.0 s	61%

Lowering RT reduces children’s level of annoyance



NOISE SOURCES,

ACOUSTIC CONDITIONS AND CLARITY OF SPEECH

The effects of noise and reverberation on the intelligibility of speech in a classroom have been extensively investigated. Both objective and subjective measurements point to the fact that there can be a huge impact on speech reception.

One way of measuring speech intelligibility is the Speech Transmission Index (STI). The higher the STI, the better the quality of speech communication for all students.

Research¹⁷ shows that STI values are related to the quality of speech intelligibility* for all students. However, the impact is greater for younger children. Certain types of noise also have a greater effect on STI, with babble noise generated by other students having more of an impact on ineligibility than non-human sounds such as ventilation.

This means that it is essential to make acoustic improvements, such as lowering reverberation time, that reduce the impact of speech-based noise in the classroom environment.

STI descriptor	STI
Bad - poor	0.30
Poor - fair	0.45
Fair - good	0.60
Good - excellent	0.75

The Speech Transmission Index (STI) demonstrates the degree of speech intelligibility from low to high using values between 0 and 1

* Speech intelligibility is also influenced by the signal to noise (S/N) ratio, which is the difference between the signal (in this case, speech) and background noise in a room.

SPEECH MUST BE HEARD CLEARLY

ABOVE BACKGROUND NOISE

Hearing and understanding what is said in classrooms requires good speech intelligibility at an audible level. Speech needs to be heard above the ambient background noise. This is called the signal-to-noise ratio (SNR).

The younger the listener, the greater the SNR needs to be in order to hear spoken language clearly above the noise. One important study⁹ indicated that while 15 dB could be considered a satisfactory SNR for older children (age 11), the youngest children (age 6) required an SNR of up to 20 dB to provide adequate speech intelligibility.

Younger learners need larger signal-to-noise ratios (SNRs) to hear speech

Age	SNR required for 75% to achieve 90% intelligibility score
6 year olds	+20 dB
8 year olds	+18 dB
11 year olds	+15 dB

In a later study¹⁸, researchers investigated speech perception in the presence of noise in order to find maximum acceptable levels of ambient classroom noise. They found that younger children needed a higher SNR than older children in order to achieve the same speech intelligibility score of 95% when there was a background noise level of 35 dB.

OPTIMISING ACOUSTICS

TO INCLUDE ALL STUDENTS

Researchers tested how successive changes in acoustic treatment affected noise levels in the classroom once they were upgraded according to recommendations for children with hearing loss⁵. They found that for every upgrade that improved acoustics for children with special hearing needs, both students and teachers became quieter and calmer.

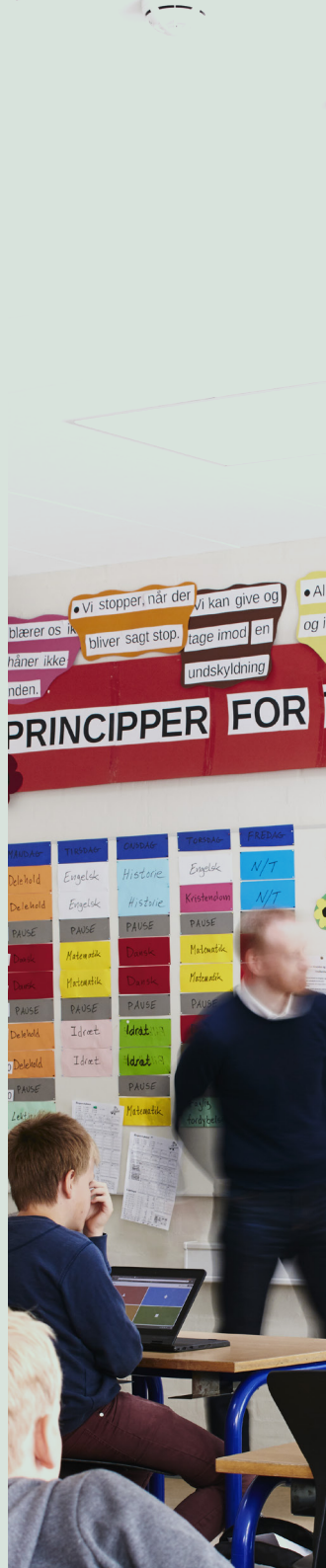
Results showed that following these recommendations produced a sound environment that was both inclusive and beneficial for everyone else in the room. Learners generated less noise and instructors did not have to speak as loudly or strain their voices.

Acoustic improvement resulted in:

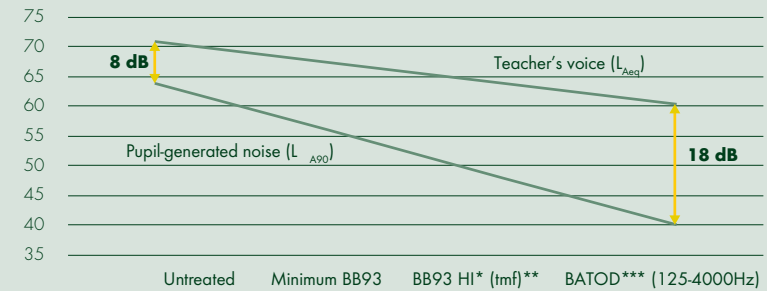
- More classroom discussions and group work
- More effective teaching and fewer repetitions
- Reduced teacher stress levels

Increasing sound absorption lowered occupied sound levels

A sound-absorbing ceiling reduces the overall sound level. Adding additional low-frequency absorbers reduces background noise and improves speech clarity.



Classroom noise and signal to noise ratios showed remarkable improvements as the acoustics were adjusted to meet inclusive standards



Theoretically, these improvements in RT should have produced a reduction of only 3 dB in sound levels in the classroom. However, the data showed that the teacher was able to speak over 10 dB more quietly after refurbishment because the underlying noise generated by the students was so much lower.

Additionally, it was also possible for the signal-to-noise ratio (SNR) between the teacher's voice and the noise generated by the pupils to increase beneficially by up to 10 dB (from 8-18 dB). This means that following acoustic recommendations allowed

the critical SNR of 15-20 dB to be reached, making listening conditions in noisy conditions ideal for those with hearing loss as well as for younger children¹⁷.

Improved acoustic treatment increases the SNR and pupils were found to require less effort to understand the teacher, simultaneously reducing vocal effort and stress for the teacher.

Classrooms with the highest-performing acoustic treatment including additional low-frequency absorption were consistently rated as providing the best conditions for both speaking and listening.

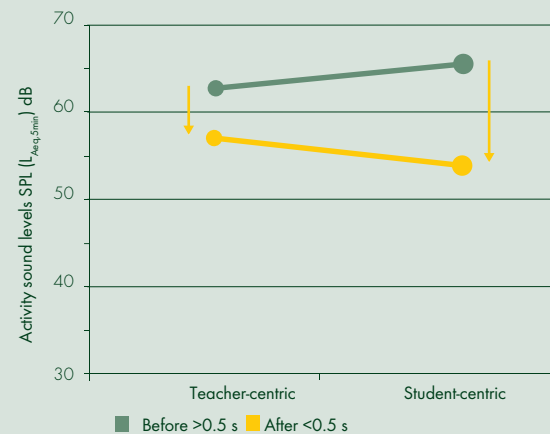
IMPROVED ACOUSTICS SUPPORT

COLLABORATIVE GROUP WORK

A study in Germany compared classrooms with long and short reverberation times (RT). They discovered a significant reduction in noise levels between them when the classrooms were occupied and the students were engaged in different learning activities. Sound levels in the treated room were reduced dramatically with shorter RT, enabling:

- collaborative group work, because learning activities can be carried out with much lower sound levels
- the teacher to speak at a lower level, reducing voice strain
- reduction in workload stress due to the noise reduction

Activity sound levels before (green) and after (yellow) refurbishment: the treated rooms reduced noise levels by 6 dB for traditional teaching and 13 dB for group work



A room that is acoustically treated is especially beneficial for group work because a number of people can speak at the same time, though more quietly, and without needing to compete in the volume of their speech.

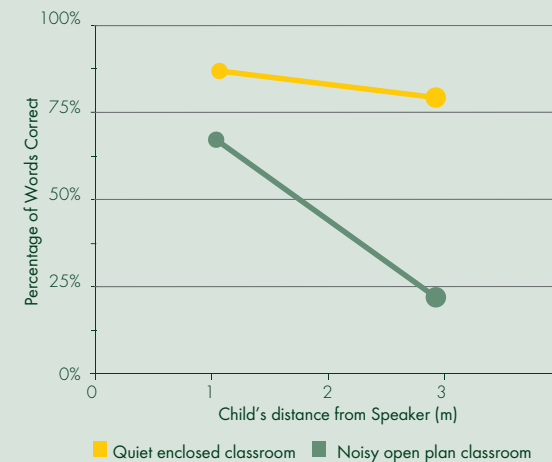
You buy a 3 dB sound reduction and you get 10 for free!

DR G. TIESLER

OPEN PLAN CLASSROOMS

Researchers compared noise levels in four types of preschools with different spatial designs: one enclosed and three open plan designs of different sizes¹⁹.

Intrusive noise was measured for quiet activities (whole class teaching) and noisy activities (group work) in all the classrooms. Intrusive noise levels increased with the size of classroom and number of class groups, both for adjacent quiet activities and for noisy activities.



In open plan classrooms, the further away listeners are from the speaker, the greater the number of incorrect answers are given.

Even when surrounding open classes were engaged in quiet activities, children at the back of the large open classrooms were disadvantaged due to higher noise levels. The above diagram shows that in a quiet, enclosed classroom, with an absence of outside noise distraction and disturbance, it is possible to hear at the back of the class.

In open plan spaces, another factor that contributes to reducing speech intelligibility is that the listener is often further away from the speaker. In order to maintain speech intelligibility in open plan designs, one technique could be to cluster listeners closer to the speaker in order to reduce the distraction caused by intrusive sounds from adjacent spaces and learner groups.

RESPONSES TO NOISE IN OPEN PLAN CLASSROOMS

Having reviewed extensive studies²⁰ researchers have concluded that sound levels during activities are not conclusively higher between open plan and enclosed classrooms.

Despite the common perception that noise levels are higher in open plan spaces, noise levels appear to be quite similar to closed classrooms.

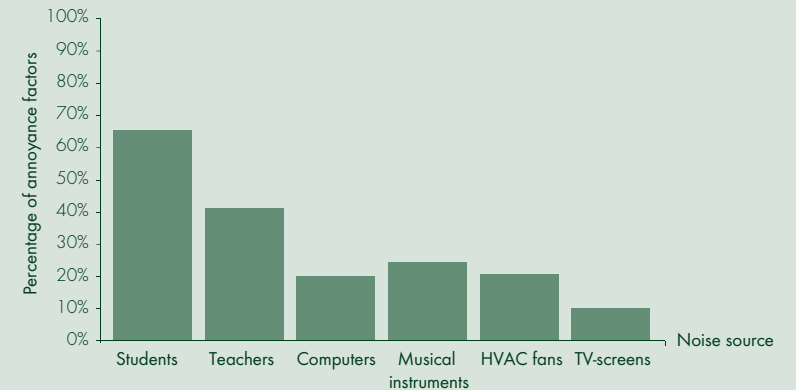


In some, levels were higher in an open plan environment, however, in some cases they were lower. This is possibly due to low reverb times as a result of increased absorption and/or appropriate classroom management.

However, noise from other students outside the classroom is frequently cited as a source of annoyance and disturbance for open plan classrooms in both primary and secondary schools. Children taught in open plan classrooms are particularly susceptible to hearing irrelevant speech and, indeed, speech from adjacent teaching areas has been cited in surveys of open plan schools as the most common form of disturbance²¹.

When asked to rate sounds that were the most annoying in open plan classrooms, 65% were fellow students from other classes, followed by teachers from other classrooms.

Sounds which annoy students in open plan primary school classes



THE VULNERABLE SUFFER THE MOST

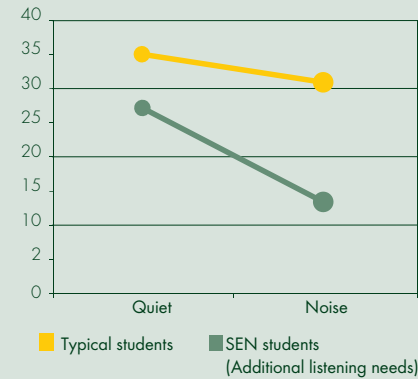
In any classroom there are a number of learners with special educational needs (SEN) that influence their ability to hear speech and cope with noise. This not only includes hearing loss but also those with attention problems and those learning in a second language. Interestingly, it applies to anyone who is not in optimal condition, for example, those experiencing lack of sleep or feeling run down.

Hearing impairment increases the risk of stress and fatigue and requires more effort when listening, which may jeopardise a child's ability to learn in a noisy environment and thus compromise their performance.

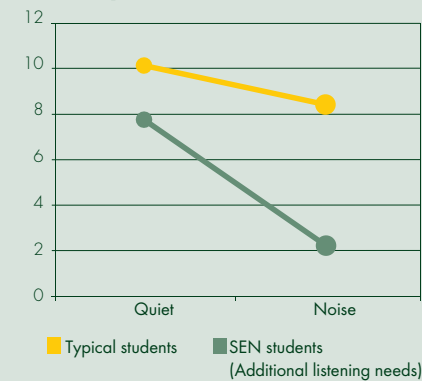
To find out more, researchers compared performance between primary school children with SEN and those without in a series of tasks including literacy and speed of processing. The tasks were undertaken in quiet conditions as well as when babble noise of 65 dB was introduced – a background noise level common to most classrooms evaluated.

The results showed that children with SEN were most negatively affected, especially in the babble condition. They also revealed that test scores from learners with additional needs plummeted when the environment became noisy, whereas typically-developing learners were much less impacted.

Maths scores in noisy vs. quiet conditions



English scores in noisy vs. quiet conditions



HEARING IMPAIRMENT STANDARDS

SET THE CRITERIA FOR INCLUSION

Students with additional listening needs/SEN are vulnerable to challenging sound environments but also attend mainstream schools which are often not optimised for them. Inclusion policies and recommendations are therefore designed to support their learning in these environments.

Students that fall into the additional listening needs group commonly include those with hearing loss and cognitive problems, but also those that are not being educated in their first language. Children on the autistic spectrum are also vulnerable, showing increased instances of disturbing behaviour as environmental noise increases²².

A comprehensive list of groups with additional listening needs includes:

- Permanent sensorineural/conductive hearing impairment
- Fluctuating conductive hearing impairment (caused by colds, ear infections, etc.)
- Speech, language and communication difficulties
- Attention Deficit Hyperactivity Disorder (ADHD)
- Auditory Processing Disorder (APD)
- Being on the autism spectrum (ASD)
- Learning in an additional language

Inclusive learning environments require that students have increased speech intelligibility. Standards that recognise the importance of controlling reverberation at low frequencies for sensitive listeners deliver precisely that.

All recommendations for students with additional listening needs also benefit typically-developing students as well as teachers because they create a better sound environment for everyone in the room as well.

In addition to the SEN groups mentioned, it is important to

remember that the classroom also consists of younger children with developing auditory systems. They need a higher signal to noise ratio (SNR) in order to hear the teacher's voice above the background noise^{9,18}. And that is exactly what following these recommendations has been shown to provide⁵.

Below is a summary of UK standards (BB93⁷ & BATOD⁸) for noise and reverberation in SEN classrooms

Acoustic criteria - additional listening needs	BB93 (2015)* BATOD**	
	New build	Refurbishment
Indoor ambient noise level*	≤ 30 dBA	≤ 35 dBA
Reverberation time*	≤ 0.4s, average 125 Hz to 4000 Hz octave bands	
Signal to noise ratio**	>20 dB, 125 Hz to 750 Hz	
	>15 dB, 750 Hz to 4000 Hz	



CONCLUSION

In order to provide suitable working and learning environments that support the development of education – including critical 21st century skills – a good sound environment is a fundamental necessity.

We believe this research summary can provide much-needed knowledge and awareness of the positive impact of improving acoustic environments. We believe acoustics is a key component for teachers and students in ensuring their overall health and well-being during teaching and learning activities. Good acoustics can support critical aspects of a positive culture in education. The result is enhanced participation and engagement for everyone.

Schools designed with good acoustics enable everyone to communicate more easily. The practice of sharing knowledge and ideas becomes a more productive experience. Imagine the exponential impact if teachers were able to remain focused on teaching instead of having to control noise and disruptions, while students could spend longer periods engaged in more in-depth learning.

Stress and heart rates go down. Productivity and engagement go up. Improved acoustics = greater concentration and better student performance.

Teacher testimonials from studies^{5,14} of improved acoustics reveal:

- Significant improvement in working conditions for both staff and students, describing the improvements as a quieter and calmer sound environment
- Better classroom behaviour and comprehension
- Lower stress levels for teachers, especially those with less experience
- Students with impaired hearing participate in classes on more equal terms

For a more in-depth look into the impact of acoustics in educational environments, please see Ecophon's blog Acoustic Bulletin (www.acousticbulletin.com) where we delve more deeply into studies, standards and issues relevant to the world of education.

REFERENCES NUMBERED THROUGHOUT. BY AUTHOR(S), TITLE, DATE:

1. Schönwälder, H.-G., Berndt, J., Ströver, F., Tiesler, G. Professional stress and strain in teachers (in German), Schriftenreihe der BAuA, Fb 989, NW-Verlag, Bremerhaven, Germany. 2003.
2. Comins, D. Survey of UK voice clinics 2001/2. Voice Care Network UK. 2002.
3. Smith, E., Lemke, J., Taylor, M., Kirchner, H. L., & Hoffman, H. Frequency of voice problems among teachers and other occupations. *Journal of voice*, 12(4), 480-488. 1998.
4. Shield, B M., and J E. Dockrell. "The effects of environmental and classroom noise on the academic attainments of primary school children." *The Journal of the Acoustical Society of America* 123(1). 2008.
5. Canning & James. The Essex study –Optimising classroom acoustics for all. 2012.
6. McKenzie & Airey. Classroom acoustics, a research project – Summary report. 1999.
7. Department for Education. Building Bulletin 93 - Acoustic design of schools: performance standards. Education Funding Agency, London, 2015
8. British Association of Teachers of the Deaf (2001) Classroom acoustics - recommended standards. BATOD Magazine, January 2001.
9. Bradley, J. S., & Sato, H. The intelligibility of speech in elementary school classrooms. *The Journal of the Acoustical Society of America*, 123(4), 2078-2086. 2008.
10. Shield, B., Conetta, R., Dockrell, J., Connolly, D., Cox, T., & Mydlarz, C. A survey of acoustic conditions and noise levels in secondary school classrooms in England. *The Journal of the Acoustical Society of America*, 137(1), 177-188. 2015.
11. Shield, B., Connolly, D., Dockrell, J., Cox, T., Mydlarz, C., & Conetta, R. The impact of classroom noise on reading comprehension of secondary school pupils. In *Proceedings of the Institute of Acoustics*, 40, 236-244. 2018.
12. Smith, E., Gray, S. D., Dove, H., Kirchner, L., & Heras, H. Frequency and effects of teachers' voice problems. *Journal of voice*, 11(1), 81-87. 1997.
13. Roy, N., Merrill, R.M., Thibeault, S. Parsa, R. A., Gray, S. D., & Smith, E. M. Voice disorders in teachers and the general population: effects on work performance, attendance, and future career choices. *Journal of Speech, Lang and Hearing Research*, 47. 2004.
14. Tiesler, G. Communication Behaviour and Workload of Students and Teachers in Highly Absorbent Classrooms. In *Proceedings of Euronoise*. 2018.
15. Brumm, H., & Zollinger, S. A. The evolution of the Lombard effect: 100 years of psychoacoustic research. *Behaviour*, 148(11-13), 1173-1198. 2011.
16. Klatte, M., Hellbrück, J., Seidel, J., & Leistner, P. Effects of Classroom Acoustics on Performance and Well-Being in Elementary School Children. 2009.
17. Astolfi, A., Bottalico, P., & Barbato, G. Subjective and objective speech intelligibility investigations in primary school classrooms. *The Journal of the Acoustical Society of America*, 131(1), 247-257. 2012.
18. Yang, W., & Bradley, J. S. Effects of room acoustics on the intelligibility of speech in classrooms for young children. *The Journal of the Acoustical Society of America*, 125(2), 922-933. 2009.
19. Mealings, K. T., Demuth, K., Buchholz, J. M., & Dillon, H. The effect of different open plan and enclosed classroom acoustic conditions on speech perception in Kindergarten children. 2015.
20. Shield, B., Greenland, E., & Dockrell, J. Noise in open plan classrooms in primary schools: A review. *Noise and Health*, 12(49), 225. 2010
21. Greenland, E. E. (2009). *Acoustics of open plan classrooms in primary schools* (Doctoral dissertation, London South Bank University). 2009.
22. Kanakri, S. M., Shepley, M., Tassinary, L. G., Varni, J. W., & Fawaz, H. M. Observational study of acoustics design and repetitive behaviors on children with autism. 2017.

Ecophon is the leading supplier of indoor acoustic solutions that improve working performance and quality of life. We believe in the difference sound can make to our everyday lives, and are passionate advocates for the importance of room acoustics to people's well-being – whatever the space, activity or need.

Having a sound effect on people is the principle that guides all we do. We are proud of our Swedish heritage and the human approach on which that promise is founded. We have an uncompromising commitment to transparent sustainable practice, and as members of the Saint-Gobain Group, we are playing our part in making the world a better home.



Ecophon
SAINT-GOBAIN