The Essex Study

Optimised classroom acoustics for all

Foreward

This report is a very welcome and important addition to the literature on the need for good acoustic design of schools, providing conclusive evidence of the beneficial effects of improving the acoustic environment in classrooms.

Problems caused by noise and poor acoustic design in educational settings have been recognised for over 100 years. If noise levels are too high or rooms are too reverberant pupils find it difficult to hear and understand their teachers, while teachers find it difficult to speak and often suffer from voice disorders as a result of continually raising their voice. Despite the introduction of various guidelines over the years aimed at ensuring good speaking and listening conditions in schools, many schools continue to be built which are acoustically 'unfit for purpose' with high noise levels and reverberant conditions creating difficulties for both pupils and teachers.

There have been many studies in the past 50 years which have shown that noise at school – both external noise from sources such as road traffic or aircraft, and internal noise such as classroom babble - has a detrimental effect upon pupils' learning and academic performance, as well as causing problems with hearing, speaking and understanding in the classroom. It is also known that pupils with additional needs, such as hearing impaired children, are particularly vulnerable to the effects of noise. There have, however, been far fewer studies examining the consequences of different degrees of reverberation in the classroom. The study presented here is the most extensive, systematic study to examine the impact of reducing reverberation in a working school environment. By installing varying acoustic treatments in three similar classrooms it has been possible to investigate the true effects of different acoustics in occupied schoolrooms. The three classrooms, plus an untreated room, were compared both objectively through acoustic measurements and subjectively through surveying the opinions of pupils, teachers and other adults. The results demonstrate conclusively the benefits to all of improving the acoustic environment.

Classroom noise levels.

If noise levels are too high or rooms are too reverberant pupils find it difficult to hear and understand their teachers

Essex County Council is to be congratulated for having the vision to recognise the importance of such a study, and to have enabled it to be carried out as part of the refurbishment of Sweyne Park School. The other sponsors of the study – the National Deaf Children's Society, the Federation of Property Societies and Ecophon – must also be acknowledged for their contribution to such a valuable and much needed project. The tireless work of David Canning who designed the study and who rigorously organised the measurement programme, questionnaire surveys and analysis is to be applauded, together with the efforts of Adrian James in working with David to produce this excellent report. And not least, of course, the contribution of the staff and students of Sweyne Park School, without whom this important project would not have been possible, must be recognised.

Currently the provision of new school buildings in the UK has diminished in favour of refurbishments of existing buildings. In addition many other types of building are being converted to provide accommodation for 'free schools'. The publication of this study is thus particularly timely and pertinent. This report will be of interest to many people involved in designing, working and learning in schools including acoustics consultants and researchers, architects, teachers, and pupils. It demonstrates the improvements that can be achieved by using acoustically suitable materials which provide efficient and sustainable solutions to problems of poor acoustics in classrooms. It is to be hoped that the results of this study will be used to influence the acoustic design of new and refurbished classrooms so that every school in the future will have an acoustic environment which enhances, rather than hinders, teaching and learning.

Bridget Shield
Professor of Acoustics, London South Bank University

Background

Teaching is all about communication between teachers and pupils. The vast majority of this communication is through speech, whether in a traditional "talk and chalk" classroom or in less formal group teaching. Previous studies have shown that pupils' academic performance suffers when they are taught in classrooms where communication is compromised by high noise levels and poor room acoustics. It has also been established that pupils using hearing aids and cochlear implants are more sensitive than most other pupils to poor room acoustics.

Building Bulletin 93 "Acoustic Design of Schools" sets minimum acoustic design standards for primary and secondary school mainstream classrooms. It also sets more stringent standards for classrooms designed specifically for use by pupils with hearing impairment. These are all however minimum acceptable standards rather than criteria for excellence. Essex County Council (ECC), the Federation of Property Services (FPS) and the National Deaf Children's Society have therefore jointly funded a research project investigating the effect of classroom acoustics, and in particular of reducing reverberation times from the BB93 "Mainstream" standard to those for hearing-impaired pupils.

Methodology

This was a six-month experimental study using four similar classrooms in the Maths department of Sweyne Park School. Sweyne Park is a comprehensive school with a large resource base for students with hearing impairment, who are also taught in mainstream classes. Three of the classrooms were modified and re-modified to achieve the three acoustic standards reported in BB93. The fourth classroom was used as a control and so was left untreated throughout.

As far as possible, only the room acoustics were changed, the changes being made at weekends without the knowledge of pupils and teachers. Each treatment was installed for at least four weeks. The four reverberation time conditions were as follows:

→ **"Untreated" - typically the Tmf before treatment was between 1.0 and 1.2 seconds**

→ **"BB93" - the minimum standard in BB93 for secondary mainstream classrooms. Tmf < 0.8 seconds.**

→ **"BB93 HI" - the BB93 requirement for classrooms specifically for use by pupils with hearing impairment. Tmf < 0.4 s**

→ **"BATOD" - this is the standard recommended by the British Association of Teachers of the Deaf. T125-4000 Hz <0.4 seconds, but over a much wider larger frequency range than the BB93 Enhanced standard. (T125-4kHz < 0.4 s)**

Classroom after treatment.

The acoustic characteristics of ceiling tiles and wall panels were varied while as far as possible making no visible changes.

Figure 8: Measured RTs in Room A (Ma2)

Tmf is the "Mid-frequency" reverberation time used in BB93 and is the average of the reverberation times in the 500, 1000 and 2000 Hz octave bands. The BATOD standard, T125-4000 Hz <0.4 s, is not an average but a limit in any octave band, so that the reverberation time (RT) may not exceed 0.4s in any octave band from 125 to 4000 Hz. This is normally more difficult to achieve than Tmf because of the difficulty of providing so much low-frequency absorption; most materials are more absorbent at medium and high frequencies.

Of course it was not possible to match these criteria precisely and there were variations between classrooms, but reasonable approximations were achieved.

The study covered ten teacher / class combinations over a six-month period. Groups ranged from Grades 7 to 10 (11 to 14 years) with top, middle and bottom ability sets. Because these were mainstream classrooms, the study was able to investigate the effect of acoustics on both hearing-impaired and normal-hearing pupils.

Results

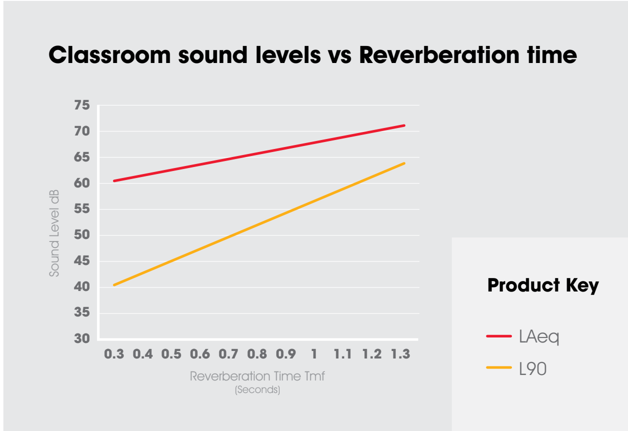
Interviews

An external consultant interviewed class teachers and Communication Support Workers, who assist hearing-impaired pupils during lessons. Neither the interviewee nor the consultant knew the acoustic condition of the room under discussion. In summary, the consultant reported the following reactions to improved acoustic conditions beyond the minimum standards:

→ **The overall impression from the interviews was of a significant improvement in working conditions for both staff and pupils. Staff commonly used the terms "Quieter" and "Calmer" to describe these conditions.**

→ **All teachers commented on the improved working environment and noted better classroom behaviour and comprehension. Less experienced staff reported a reduction in stress levels.**

→ **Teachers and CSWs commented that the improved acoustics allowed hearing-impaired children to participate in classes more equally with other children.**

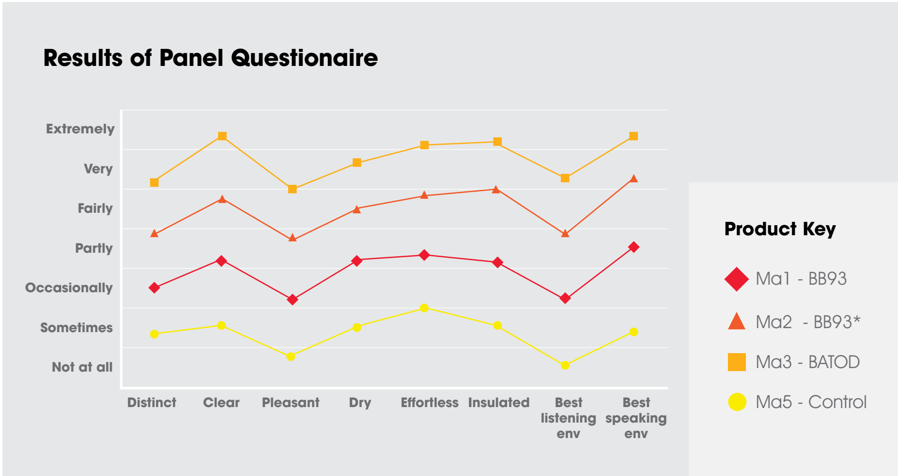


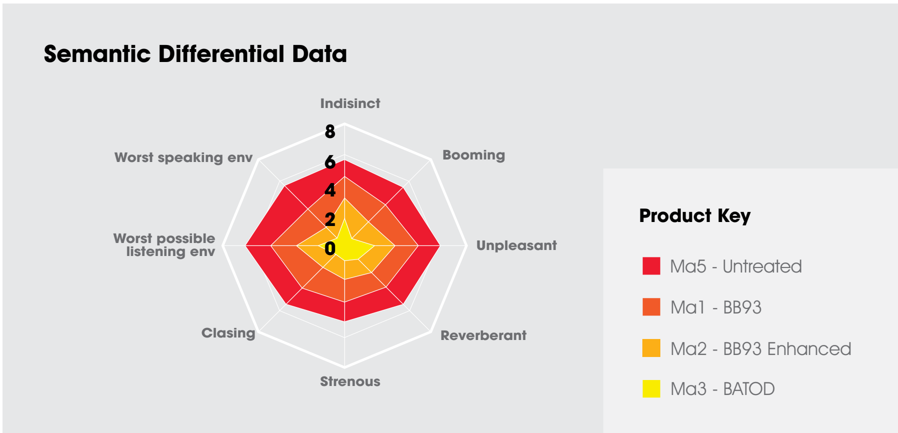
Sound levels and signal-to-noise ratios

Overall sound levels (LAeq and LA90) during lessons were measured at the back of each classroom at each stage of treatment. Levels were measured over the duration of an entire lesson in each case. Some 120 hours of lessons were measured and this graph summarises the LAeq and the LA90 sound levels plotted as a function of reverberation time over all of these measurements. Theoretically, if the pupils and teachers were emitting the same sound power levels, we would expect the sound level to decrease by 3 dBA for a halving in RT. In fact, the LAeq, which we expect to be dominated by the teacher's voice, decreased by around 5 dB and the LA90, which represents the underlying noise generated by the pupils, decreased by 9 dB per halving of RT. From this we can conclude:

→ **As RT is reduced, pupils generate less noise, which indicates better behaviour and more attentive listening.**

→ **This allows the teacher can speak less loudly, reducing vocal stress while still achieving a marked improvement in signal-to-noise ratio.**





Semantic Differential Questionnaire

An invited panel of 25 teachers, acousticians and other professionals experienced short presentations and completed a semantic differential questionnaire in each of the classrooms. The results are shown in two ways. On the line graph, the "good" semantic terms are plotted horizontally and the average of the subjects' qualitative descriptors is plotted vertically for each acoustic condition. This shows a remarkably clear ranking of the classrooms. The room with the shortest RTs (conforming to the BATOD standard) was rated as the best for both listening and speaking. In each case, as the reverberation time decreased so the rating of the room increased.

The same data is shown in a different form in the area plot below. Each classroom is represented by a colour; the area of that classroom's colour represents the subjects' response against the "Bad" semantic descriptors, so that the largest area corresponds to the worst perceived quality. Again it can be seen that the perceived quality is very strongly related to the reverberation time.

Conclusion

The questionnaire responses demonstrate a clear preference for classrooms with shorter reverberation times, with the most stringent (BATOD) standard achieving the best results.

Objective measurements of noise levels during classes show a much larger than expected reduction in LA90 as the reverberation time (RT) decreases. This leads to the conclusion that pupil behaviour and attentiveness all improve as RT decreases. This leads to a much better signal-to-noise ratio while requiring less vocal effort from teachers. This is consistent with the results of the interviews in which teachers and Communication Support Workers all reported substantial improvements in behaviour and comprehension of pupils in classrooms with a shorter RT.

Project Funded by **Essex County Council**, the **Federation of Property Services** and **National Deaf Children's Society**.
Research by **David Canning** of Hear2Learn.
Final report and summary by **Adrian James Acoustics**.

General comments and futher considerations for acoustical design in classrooms (not included in the study)

→ It's a quite well known experience that classrooms with almost the same reverberation time can subjectively be judged as acoustically different.. For a more accurate evaluation it's necessary to measure supplementary measures related to speech clarity and sound levels.. This is especially important in rooms with ceiling treatment since the non-uniform distribution of absorption leads to the low correlation between (late) reverberation time and measures related to speech clarity and intelligibility or sound levels..

→ The amount of absorption and the need for wall panel absorption very much depends on the size and furnishing of the classroom. The distance floor to ceiling is of crucial importance and often determines whether wall panels are needed or not. Rooms with floor to ceiling height larger than 2.9 metres generally need wall panels to fulfil BB93 HI demands.

→ To fulfil the requirements at low frequencies in octave bands 125 and 250Hz to meet the BATOD level for inclusion, additional low frequency absorption over and above that provided by an ordinary acoustic ceiling is needed.

*Listening test- Reducing the RT at low frequencies (125Hz) will contribute to increase the speech intelligibility. An alteration of the RT from 0.7s to 0.6s for octave band 125Hz will give a significant improvement of subjectively perceived speech intelligibility. If the speech contains a lot of energy in this octave band the improvement will be especially pronounced. (Lund Institute of Technology – Nilsson / Hammer)

Ecophon®
SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE