The Essex Study

Optimised classroom acoustics for all

The Essex Study

Optimised classroom acoustics for all

By

David Canning

&

Adrian James

Published by
The Association of Noise Consultants
The Old Pump House, 1A Stonecross,
St Albans AL1 4AA
telephone: 020 8253 4518
email: info@theanc.co.uk

The authors of this document confirm that they do not intend to claim or implement any copyright on the basis that this document will be freely available for download as well as being distributed in print.

This publication is available by downloading it from the following web sites: -
Association of Noise Consultants www.theanc.co.uk;
Federation of Property Societies www.fedps.org.uk;
National Deaf Children's Society www.ndcs.org.uk.

ISBN 978-0-9572543-1-2
Published May 2012

CONTENTS

1 FOREWORD BY PROFESSOR BRIDGET SHIELD 2

2 EXECUTIVE SUMMARY 3

3 INTRODUCTION 4
3.1 Background 4
3.2 Acknowledgements and thanks 5
3.3 Nomenclature 6

4 ACOUSTIC CRITERIA FOR CLASSROOMS 7
4.1 Basics of room acoustics 7
4.2 DfES Building Bulletin 93 9
4.3 Special requirements for pupils with hearing impairments 10
4.4 The BATOD standard 11

5 METHODOLOGY FOR THE STUDY 12
5.1 General principles 12
5.2 Room Acoustic Treatments 12
5.3 Room acoustic measurements 13
5.4 Sound level measurements 13
5.5 Subjective assessment methodology 14

6 RESULTS 16
6.1 Reverberation Times 16
6.2 Discussion of Reverberation Time results 19
6.3 Sound levels and signal-to-noise ratios 20
6.4 Interviews with teaching staff 21
6.5 Semantic Differential Questionnaires 22
6.6 Costs 23

7 CONCLUSIONS, RECOMMENDATIONS AND FURTHER WORK 24
7.1 Conclusions 24
7.2 Recommendations 24
7.3 Further work 25

8 ADDITIONAL RESOURCES 26
8.1 References and Bibliography 26
8.2 Audio and video resources and other websites 27

9 APPENDIX A – REVERBERATION TIME DATA 28
9.1 Room reverberation times 28

10 APPENDIX B – SPECIFIC COMMENTS FROM INTERVIEWS 29

11 APPENDIX C - COST OF THE 3 DIFFERENT CLASS BASE STANDARDS 30

1 FOREWORD by Professor Bridget Shield

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.

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

2 EXECUTIVE SUMMARY

Studies have shown that pupils' academic performance suffers when they are taught in classrooms where communication is compromised by high noise levels or 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, with more stringent standards for classrooms designed specifically for use by pupils with hearing impairment. These are, however, minimum acceptable standards rather than criteria for excellence. Essex County Council, the Federation of Property Societies and the National Deaf Children's Society have therefore jointly funded a research project investigating the effect of improved standards for room acoustics.

The six-month experimental study used four similar classrooms in the Mathematics department of Sweyne Park School, a comprehensive school with a large resource base for students with hearing impairment. Three of the classrooms were modified acoustically, each on three separate occasions, while minimising visual clues to the changes. The fourth classroom was used as a control. This was as far as possible a blind study; staff and pupils did not know when changes were made to the modified classrooms. The four reverberation time conditions were:

- "Untreated" – slightly outside the BB93 minimum standard;
- "BB93", the requirement in BB93 for secondary classrooms.
- "BB93 HI", the BB93 requirement for classrooms specifically for use by pupils with hearing impairment.
- "BATOD", the standard recommended by the British Association of Teachers of the Deaf.

Class teachers and the Communication Support Workers, who assisted hearing-impaired pupils during lessons, were interviewed at each stage. The overall conclusion was of a significant improvement in working conditions for both staff and pupils in the "BB93 HI" and "BATOD" conditions. Teachers and Communication Support Workers commented that the improved acoustics allowed hearing-impaired children to participate better in classes. Some staff reported a reduction in stress levels, and all teachers commented on the improved teaching environment and noted better classroom behaviour and comprehension.

The interview results were consistent with the results of measurements of overall sound levels during classes. The LAeq, which we expect to be dominated by the teacher's voice, decreased by around 5 dB per halving of mid-frequency reverberation time, and the LA90 , which represents the underlying noise generated by the pupils, decreased by 9 dB per halving of RT as against the 3 dB reduction that we would expect. This indicates that in acoustically "dead" classrooms pupils generate less noise, which implies better behaviour and more attentive listening; and that this allows the teacher to speak less loudly, reducing vocal stress while still achieving a marked improvement in signal-to-noise ratio.

Finally, an invited panel of teachers, acousticians and other professionals experienced short presentations in each of the classrooms and completed semantic differential questionnaires. The results show a remarkably clear ranking, with the perceived quality improving consistently as the reverberation time decreased.

It is therefore concluded that all staff and pupils, with or without hearing impairment, would benefit if all classrooms were designed to the more stringent room acoustics standards intended for teaching pupils with hearing impairment.

3 INTRODUCTION

3.1 Background

Essex has three mainstream secondary schools which include resource bases for students with hearing impairment. In recent years, some parents of deaf children have claimed that these units were not able to provide the necessary resources and teaching environment and have requested that their children should be educated either in independent schools or in specialist schools outside Essex. At the ensuing SEND (Special Educational Needs and Disability) Tribunals, poor classroom acoustics were cited as one of the issues contributing to this problem.

The cost of educating children outside mainstream schools is high and Essex County Council therefore allocated £150,000 for the acoustic refurbishment of a number of classrooms. This gave an opportunity to assess the effect of the changes in acoustics on staff and pupils using these rooms. Essex County Council in conjunction with the National Deaf Children's Society and Federation of Property Societies therefore funded a study, taking an evidence-based approach to the relationship between acoustic parameters, performance of pupils both academically and in hearing tests, and responses to questionnaires.

Sweyne Park School, a secondary school with a large resource base for deaf students, was selected for the study. The research work was carried out by David Canning of Hear2Learn Ltd over the period March to July 2009. An interim report was issued in September 2009 and since that time David Canning has undertaken further analysis of the data.

In October 2011 David Canning and Essex County Council requested Adrian James Acoustics to assist with the production of a final report summarising the results of the work, documenting linked references and data, and setting up a central web-based resource for supporting information. This compilation and editing work was carried out by Adrian James, with the assistance of other staff at AJA.

This report is not intended to be an academic paper for specialists in acoustics; is it designed to be read by anyone who has an interest in the acoustics of classrooms. Inevitably the need to present the information in a compressed and non-technical form means that not all of the results can be presented, and it is likely that this does not do justice to the very large amount of work invested in the study by David Canning and others. Any credit for this work should go to David Canning and to those who supported the study and are listed in the acknowledgements. Any errors, inconsistencies or omissions can safely be attributed to the editor.

For background reading on the subject and for more technical information, readers should refer to the resources listed in Section 8. It is intended that these resources will be maintained and updated to keep track of more work in this and related fields.

3.2 Acknowledgements and thanks

As with most research projects, many people other than the researcher have contributed in one way or another. Special thanks are due to the following people who helped with the original investigations and the on-going reviews.

◊ At Sweyne Park School, Head Teacher Andy Hodgkinson who allowed it all to take place; the staff of the 'resource base for the hearing impaired' and teachers of the Maths department; and in particular Facilities Manager Simon Smith, whose tremendous efforts ensured the success of the study and whose appearances at subsequent conferences and interviews have done much to convince others of the benefits of improved acoustics in schools.

◊ At Essex County Council, Alan Waters, Project Manager from Essex County Council Capital Programme & Building Development Group; Greg Keeling, the Environmental Performance and Technical Standards Manager; and Construction Services Senior Engineer Alan Knibb, without whose patience, persistence and understanding this report would not have been issued in this form.

◊ Professor Bridget Shield of London South Bank University who provided great support and encouragement throughout the project. This final report has benefited enormously from her expert and painstaking review of the draft. Over the years she and Professor Julie Dockrell of the Institute of Education have published many important research papers which have influenced the acoustic design of schools worldwide, and we are honoured that she agreed to write the foreword to this document.

◊ Shane Cryer, Erling Nilsson, Colin Campbell and their colleagues in Ecophon's EDUnet group, who gave practical advice and valuable support both during the study and at subsequent conferences including their own Ecophon International Acousticians' Seminar. They also designed the front cover and arranged the seminar at which the report was launched.

◊ John Campbell of Campbell Associates who generously loaned equipment throughout the data collection phase. Joe Bear, Michael Woods and Jennifer Wilkin at Adrian James Acoustics who undertook subsequent acoustic measurements, computer modelling and presentation of results. Richard Daniels of Partnerships for Schools for seeing the importance of the study and contributing to the critical support that it has received throughout the duration of the project.

Most importantly thanks to the main sponsors of this study; the National Deaf Children's Society, the Federation of Property Societies and Essex County Council, led by Greg Keeling who has been the principal project sponsor within Essex County Council and the Federation of Property Societies.

3.3 Nomenclature

During the course of this study the terms "Hearing-impaired" and "Deaf" have been used interchangeably in a large number of papers, standards and guidelines This report therefore uses both terms without distinction. There are varying degrees of deafness and the term "Deaf" does not imply the total absence of hearing any more than does the term "Hearing Impaired".

Other terms and abbreviations used in this report are as follows:

- AJA – Adrian James Acoustics Ltd
- BATOD – British Association of Teachers of the Deaf
- BB93 - Building Bulletin 93 (Acoustic Design of Schools).
- BB93 HI – the standard set out in BB93 for room acoustics in classrooms designed specifically for use by hearing-impaired children.
- CSW – Communication Support Workers – staff who assist hearing-impaired children with communication during lessons.
- ECC – Essex County Council
- FPS - Federation of Property Societies
- H2L – Hear 2 Learn
- NDCS - National Deaf Children's Society
- RT – Reverberation Time
- SEND - Special Educational Needs and Disability Act
- SPRs – School Premises Regulations.
- T BATOD – The reverberation time measured in octave bands across the range 125 – 4000 Hz, referred to in the BATOD acoustic guidelines.
- Tmf - The reverberation time averaged over the 500 - 2000 Hz Octave band ranges, referred to in BB93

4 ACOUSTIC CRITERIA FOR CLASSROOMS

4.1 Basics of room acoustics

This study addresses only the effect in the change of room acoustics, as measured in terms of reverberation time. There are also acoustic standards for ambient noise levels and sound insulation between teaching areas, but these are not discussed here.

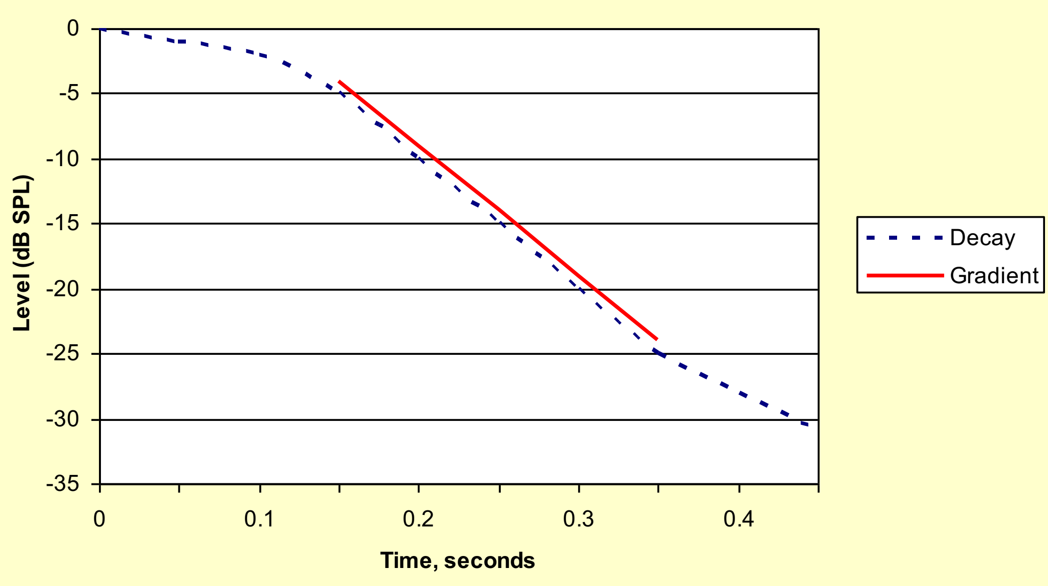
4.1.1 Reverberation time

All of the standards referred to in this study set criteria for room acoustics in terms of *Reverberation Time (RT)*. This is defined as the time taken for the sound pressure level in the space to decrease by 60 dB. RT is traditionally measured using an impulsive source such as a gunshot or balloon burst, although it is now common to use a loudspeaker source emitting interrupted broadband noise or swept sine waves.

Figure 1 shows schematically the decay of a sound signal at a specific frequency in a typical classroom, along with the gradient from which the RT is calculated.

The decay is very rarely linear over 60 dB because of the effects of background noise, so the RT is calculated by extrapolating the best straight line fit over the upper part of the decay. In this case the time for the sound to decay by 20 dB is 0.20 seconds, so the time to decay by 60 dB would be 0.60 seconds. This is the reverberation time at that frequency. RT varies with frequency and therefore has to be measured at a range of frequencies; there are different ways of averaging measurements at different frequencies to give a single-figure descriptor, as discussed later in this report.

Figure 1 - Reverberation time measurement



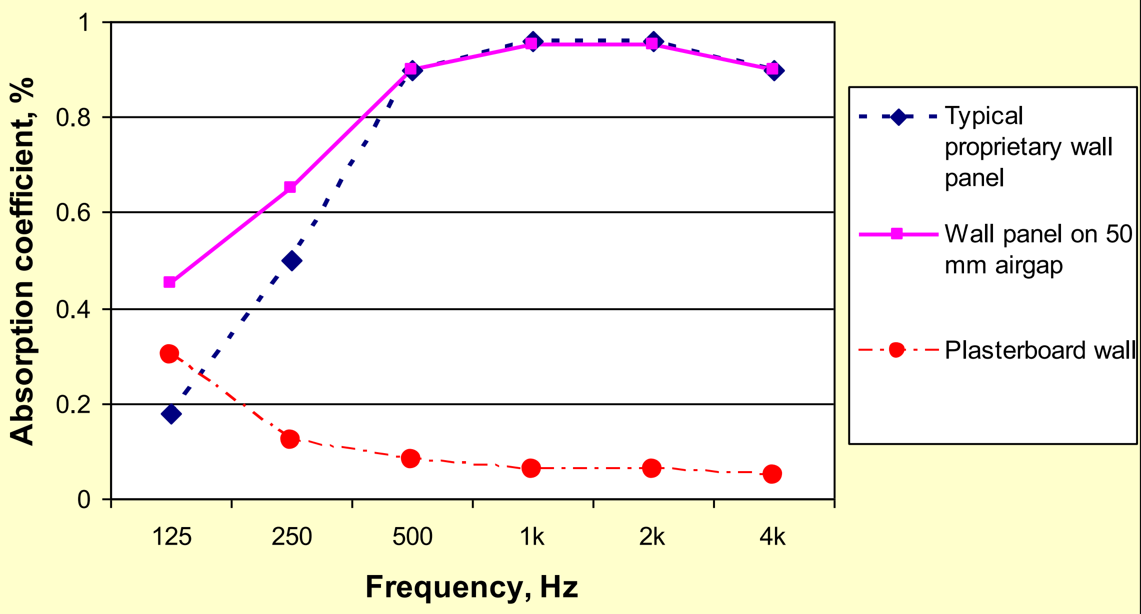
Subjectively, a long reverberation time gives a "live" acoustic while rooms with short reverberation times are "dry" or "dead". As well as causing problems with speech intelligibility, long RTs can result in increased activity noise both directly and indirectly through the "Lombard effect" as people speak more loudly to overcome the reverberant noise. This is a common problem in restaurants and dining halls but also occurs to a lesser extent in other spaces. The opposite is the "library effect"; in a quiet room with little reverberation people tend to keep their voices down. These are psycho-acoustic effects and so are not easily predictable.

4.1.2 Acoustic absorption

Reverberation times vary with frequency, and in most rooms the RT at low frequencies is longer than at mid and high frequencies. This is because most commonly encountered materials such as carpets and curtains are least acoustically absorptive at low frequencies. The exceptions are large areas of panels or boards over airspaces, which tend to act as "Panel absorbers" at low frequencies. Figure 2 shows typical absorption coefficients for a standard wall-mounted absorber, for the same absorber over an air gap, and for the same area of plasterboard partition.

While even the low-frequency absorption coefficients of plasterboard walls are not very high, the areas of the walls are large and so the total low-frequency absorption rapidly becomes significant. For this reason, classrooms with dry-lined walls have the advantage of naturally shorter low-frequency reverberation times which often helps in the acoustic design.

Figure 2 - Typical absorption co-efficients



Rooms with masonry walls are naturally more reverberant at low frequencies and reducing this low-frequency reverberation can require large areas of low-frequency absorptive treatment, which typically requires a material over a substantial airgap. With acoustically absorbent ceilings this airgap can be anything up to 200 mm, while with wall panels airgaps of 50 mm are the most that can normally be accommodated.

The main disadvantage of dry-lined partitions is that they are intrinsically less robust than masonry walls. In fact, many primary and secondary schools are largely fitted out in standard plasterboard, but more robust impact-resistant proprietary boards are commonly used in areas where damage is more likely. The same result can be achieved using a single skin of plasterboard with an internal skin of 12mm plywood or Sterling board on each side of the timber or metal studwork. This then has the joint effect of proving a more robust wall and the ability to get good fixing to the wall. In some cases, however, masonry is preferred as the ultimate impact-resistant material, and it is in precisely these cases that acoustic absorption will be most needed. In recent years several manufacturers have developed impact-resistant absorbent panels and these are widely used in sports halls.

4.1.3 Effect of volume

The reverberation time of a space increases as a direct linear function of that space's volume. Hence classrooms with high ceilings generally need more acoustic absorption than those with lower ceilings. This is a problem when treating classrooms in traditional Victorian schools with high ceilings and tall windows. We tend to design new classrooms with ceiling heights around 2.4 metres; at that height, a room with a good-quality acoustically absorbent ceiling may not need any additional absorption on the walls.

4.1.4 *Effect of furniture*

All of the standards described in this document refer to the RT in unfurnished, unoccupied rooms. That is for the purpose of reproducible measurement, especially when testing for compliance with building standards in recently completed schools.

Furniture, fittings and indeed people provide some acoustic absorption and this is of course always present in the rooms when they are in use. It is also impracticable to remove all of the furniture from a room so as to measure the RT. All of the measurements described in this document were taken in furnished rooms, but with no pupils present. In general the effect of furniture is relatively small although it does serve a useful secondary "scattering" effect. To assess the acoustic suitability of classrooms for hearing-impaired children we tend to consider the acoustics of the space when furnished and fitted out for the intended use.

4.2 DfES Building Bulletin 93

Since 1 July 2003, acoustics of school buildings have been required to comply with Part E of the Building Regulations. The criteria for this are set out in Section 1 of Building Bulletin 93, "Acoustic Design of Schools". These regulations are not retrospective, and any refurbishment work which is not classified as a change of use under the building regulations is not strictly required to conform to them. However, BB93 states that "….such work should consider acoustics and incorporate upgrading as appropriate".

BB93 defines acceptable RTs in terms of the mid-frequency reverberation time Tmf which is the average of the values at 500, 1000 and 2000 Hz for unoccupied and unfurnished rooms. The criteria for classrooms are as follows:

Table 1 – Reverberation time criteria in teaching rooms

Room / area type	Tmf, seconds
Primary school classrooms	< 0.6
Secondary school classrooms	< 0.8
Classrooms designed specifically for use by hearing impaired students (including speech therapy rooms)	< 0.4

These are mandatory requirements for new schools and must be met to comply with building regulations (although enforcement of these regulations is by no means consistent across England and Wales). While they are not mandatory standards for classrooms built before 2003, they are generally considered to set a standard for acceptable acoustics and, for example, a SEND tribunal would tend to consider that a room failing to meet the BB93 requirement for hearing-impaired use was not suitable for such use.

Before 2003, building regulations for acoustics did not apply to schools. Similar standards were set out in Building Bulletin 87, and were nominally a requirement under the Education Premises Act, but in the absence of an enforcement process these were widely ignored and many schools built before 2003 had, and continue to have, acoustics which would be considered inadequate in new schools.

Building Bulletin 93 was still in force at the time of writing of this report (March 2012) and in the 2012 consultation on the School Premises Regulations the Department for Education has expressed a commitment to maintaining acoustic standards in schools through a revised version of BB93. This is likely to retain many or all of the criteria in the current building bulletin, along with mandatory standards for refurbished teaching areas. It is intended that these criteria will become mandatory under the revised Schools Premises Regulations and Independent School Standards. The net effect is that these acoustic standards would be triggered not only for new school buildings and for building works amounting to a change of use under building regulations, but for all refurbishments and adaptations to create teaching spaces in schools including academies, free schools and independent schools.

4.3 SPECIAL REQUIREMENTS FOR PUPILS WITH HEARING IMPAIRMENTS

Building Bulletin 102 "Designing for disabled children and children with special educational needs" provides some outline advice but does not provide any specific design criteria or guidance on appropriate criteria, instead referring back the requirements set out in BB93. The introduction to BB93 states:

"The Disability Discrimination Act 1995[1], as amended by the Special Educational Needs and Disability Act 2001, places a duty on all schools and LEAs to plan to increase over time the accessibility of schools for disabled pupils and to implement their plans. Schools and LEAs are required to provide:

- *Increased access for disabled pupils to the school curriculum. This covers teaching and learning and the wider curriculum of the school such as afterschool clubs, leisure and cultural activities.*
- *Improved access to the physical environment of schools, including physical aids to assist education. This includes acoustic improvements and aids for hearing impaired pupils. When alterations affect the acoustics of a space then improvement of the acoustics to promote better access for children with special needs, including hearing impairments, should be considered.*

As well as setting acoustic criteria for compliance with building regulations, BB93 sets out recommendations and guidance (but not mandatory requirements) on other aspects of school acoustics. Section 6: "Acoustic Design and Equipment for Pupils with Special Hearing Requirements" discusses design appropriate for pupils with hearing impairments. It discusses the necessary acoustic performance of spaces and describes the range of aids available to help these pupils.

The acoustic environment can be the most important factor in allowing children with hearing impairments to participate within mainstream classes. Section 6.5 of Building Bulletin 93 identifies the following communication activities in classes:

- listening to the teacher when s/he is facing away from the listener.
- listening when the class is engaged in activities.
- listening to the teacher while s/he is moving around the classroom.
- listening when other children are answering questions.
- listening when other adults are talking within the same room.
- listening to peers when working in groups.
- listening with competing background noise from multimedia equipment.

BB93 goes on to state:

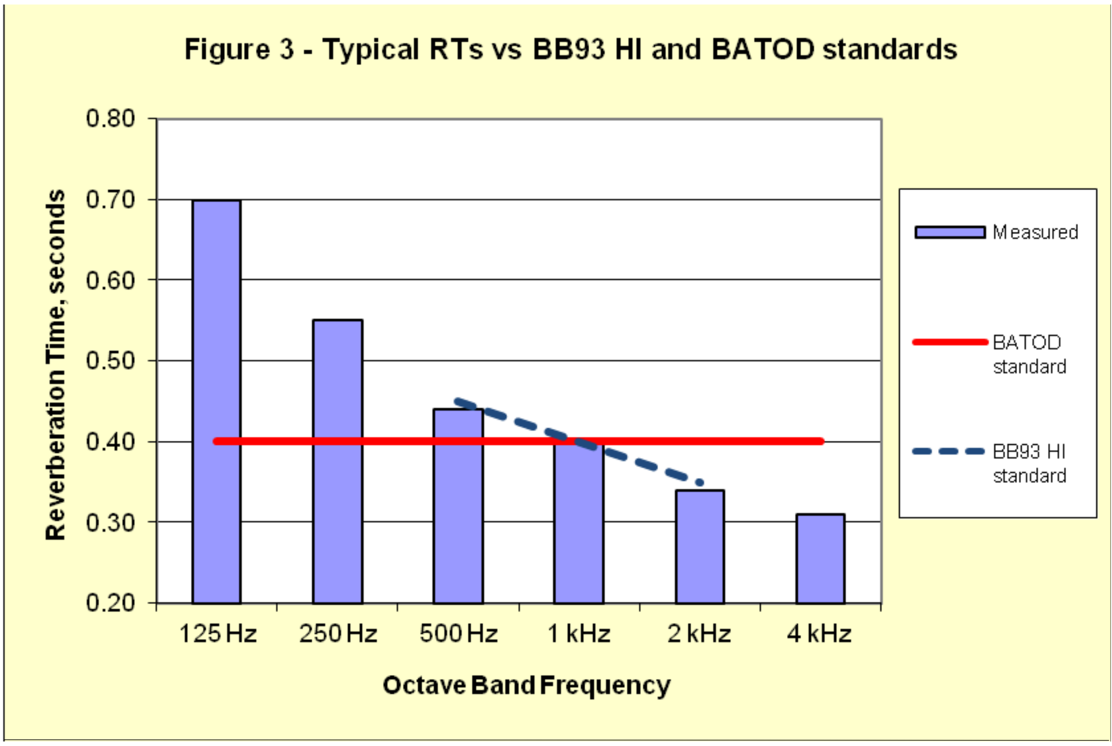
> *A teacher should manage teaching in such a way as to ameliorate the challenges faced by a student with hearing difficulties. However, the better the acoustic conditions, the less challenging will be the situations described above.*

This is important; it means that the use of Soundfield systems or other aids is not a substitute for adequate room acoustics.

For the purposes of regulation, as shown in Table 1, BB93 requires that new classrooms designed for use by deaf children should have a mid-frequency reverberation time less than 0.4 seconds ($T_{mf} < 0.4$ s). In this report we denote this as the "BB93 HI standard". It is considerably more stringent than the requirements for "normal" primary classrooms ($T_{mf} < 0.6$ s) or secondary classrooms (($T_{mf} < 0.8$ s) but is still only defined over a relatively narrow range of frequencies.

4.4 THE BATOD STANDARD

Section 6 of BB93 also refers to the recommendations of the British Association of Teachers of the Deaf (BATOD) for classrooms designed for use by hearing impaired students. The BATOD criterion is also <0.4 seconds but this is a figure not to be exceeded in any octave band from 125 Hz to 4 kHz. This is a much more demanding requirement than the BB93 HI standard because of the need to control the RT at low frequencies, at which many absorbers are less efficient. Figure 3 shows the RT in octave bands for a typical classroom which complies with the BB93 HI standard use but not with the BATOD standard.



A SEND tribunal would normally consider that a room meeting the BATOD standard would have suitable room acoustics for teaching deaf pupils. It would be debatable whether a room complying with the BB93 HI standard but not the BATOD standard, as shown in Figure 3, would be suitable for this purpose. While the BATOD standard is not enshrined in regulations or national standards, it is considered to set a demonstrably good standard while BB93 HI is the lowest standard that would comply with building regulations for this purpose.

5 METHODOLOGY FOR THE STUDY

5.1 General principles

The study was designed around an experimental approach that would be useful in determining causality between changes to the acoustics and the impact on pupils and teachers. The approach was therefore to change one variable (the room acoustic) only, with the staff and pupils being as far as possible blind to the condition and with analysis of the acoustic data also blind to the condition of this variable.

5.2 Room Acoustic Treatments

Four classrooms similar in physical size in the Maths department of Sweyne Park School were chosen for the study. These were cellular classrooms, typical of the majority of secondary school classrooms in the UK. Three of these were refurbished, applying acoustic finishes in order to comply with one of three published acoustic standards. The fourth untreated room was used as a control. The acoustic standards for the treated rooms were as follows:

- Type 1: "BB93 standard". This is for a Building Bulletin 93 (BB93) compliant secondary school classroom. This requires a mid-frequency reverberation time not exceeding 0.8 seconds (Tmf < 0.8 s)
- Type 2: "BB93 HI". This is the BB93 requirement for classrooms specifically for use by deaf pupils This requires a mid-frequency reverberation time not exceeding 0.4 seconds (Tmf < 0.4 s)
- Type 3: "BATOD". This is the standard recommended by the British Association of Teachers of the Deaf. This also requires a reverberation time not exceeding 0.4 seconds, but over a much wider larger frequency range than the BB93 Enhanced standard. (T125-4kHz < 0.4 s)

Before the rooms were treated they had hard walls and a hard ceiling, as well as windows on two sides, as shown in Figure 4 below.

Figure 4 - Classroom before treatment

The acoustic treatment involved installing a suspended acoustic ceiling and acoustic wall panels. In addition to this the rooms was freshly painted and new lights were installed, as shown in Figure 5 below.

Figure 5 - Classroom after treatment

Each treatment was installed for a minimum of four weeks. All changes were made over week-ends, and the rooms remained visually similar each time. This meant that staff and students were unaware of when a change between different types of treatment had taken place, although obviously there was a clear visual difference between the treated classrooms and the untreated room which was used as a control. The study was carried out in three phases:

Table 2 – Process of treatments in teaching rooms

	Pre-test	Stage 1 (post 14th March)	Stage 2 (post 6th June)	Stage 3 (post 29th June)
Classroom A (ma2)	*Untreated*	BATOD	BB93 (Enhanced)	BB93 (Standard)
Classroom B (ma1)	*Untreated*	BB93 (Enhanced)	BB93 (Standard)	BATOD
Classroom C (ma3)	*Untreated*	BB93 (Standard)	BATOD	BB93 (Enhanced)
Classroom D (ma5)	*Untreated*	*Untreated*	*Untreated*	*Untreated*

5.3 Room acoustic measurements

Reverberation times were measured using the WinMLS system. This is a proprietary computer-based system which calculates the room impulse response and reverberation time from a logarithmic swept sine measurement. The advantage of this system is that it is very much less sensitive to background noise than measurements using impulsive noise sources (gunshots or bursting balloons) or interrupted noise techniques (pink noise through loudspeakers). Previous studies have shown good agreement between WinMLS and impulse noise techniques but during the study some measurements were also taken using impulsive noise for comparison with the WinMLS measurements

5.4 Sound level measurements

Sound levels were measured in the classrooms during lessons. The aim was to determine whether there was a significant difference in sound noise levels as a function of reverberation time. In reverberant rooms, sound levels tend to be higher both because of the direct effect of the reverberation on the overall sound level and, more significantly, because speakers feel the need to raise their voice to be heard over the noise level. Where several people are talking at once this can lead to a sharp escalation in the noise level as people compete to be heard over each other; this is known as the Lombard Effect.

The sound level during a lesson is affected by several factors :

- Speech from the teacher and from pupils addressing the teacher. This is effectively the signal which the pupils are expected to understand over the noise from other sources. It varies both with the loudness of the speaker's voice and with the amount of speech during the measurement period.
- "Class noise" - This can be considered as the noise from pupils moving, whispering among themselves etc. This varies with the type of activity during a class and so is time-variant over both long and short periods. It can generally be considered as the noise over which the teacher has to project his or her voice.
- Ambient noise due to other sources : traffic noise, heating systems, computers, whiteboard projectors etc. These were on average invariant across the study and in any case were very much lower than the sound levels from speech and class noise. For the purposes of this study, therefore, this was included in class noise.

It is of course impossible to measure speech and class noise separately with a simple measurement as the two occur at the same time. If measuring a signal-to-noise ratio it is in fact necessary to measure the two separately.

As the hypothesis is that the speech signal increases with the noise, however, even this approach is unlikely to work and we can only determine approximate signal-to-noise ratios by using different aspects of time average

Most sounds are not steady, so that the sound pressure level fluctuates with time. A measurement is therefore meaningless unless we know whether it represents a minimum, maximum or some kind of time-averaged level. Various parameters have been derived to measure sounds of differing characters, and the most relevant to this report are shown schematically in Figure 6, which shows how different parameters compare on a time-varying sound signal :

- **Leq,T** The "Equivalent continuous noise level" is used widely to measure noise that varies with time. It is defined as the notional steady noise level that would contain the same acoustic energy as the varying noise. Because the averaging process used is logarithmic, the Leq,T level tends to be dominated by the higher noise levels measured.
- **L90,T** This is the sound pressure level exceeded for 90% of the measurement period T. It is an indication of noise levels during the quieter periods of measurement, and is widely used to measure background noise.
- **LMax, T** This is the maximum level measured, but because it tends to be influenced by individual unpredictable noise events (such as doors slamming) it has not been used in this study.

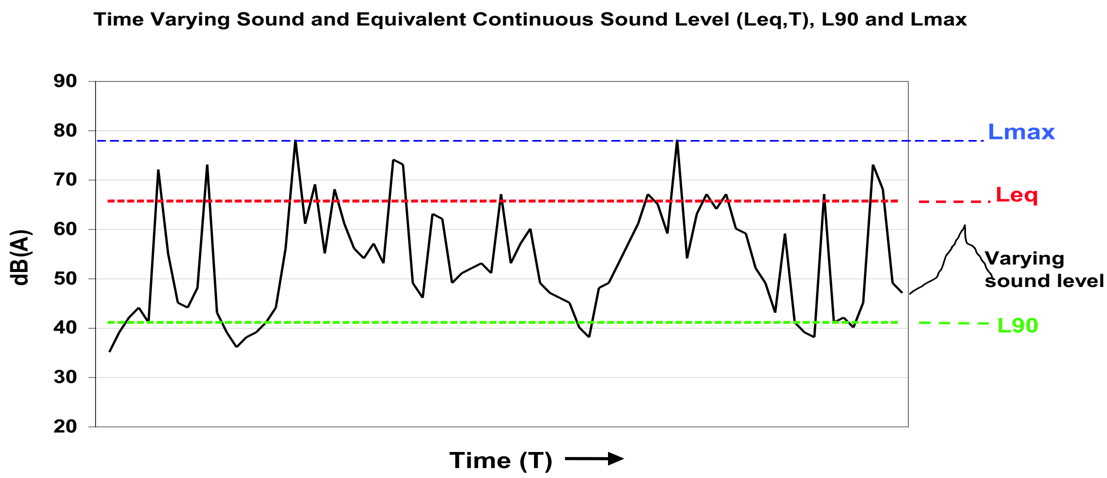


Figure 6 - Time varying sound pressure level

Use of the suffix "A" in any of these descriptors (e.g. LAeq,T) denotes that the measurements were taken using the A-weighting, which is a widely-used frequency weighting which mimics the ear's response to sound at different frequencies.

LAeq and LA90 levels were measured at the back of the classroom (at the same position each time) with an integrating sound level meter. They were averaged over the duration of an entire lesson in each case. Considerable effort was given to obtaining objective data of this type ; more than 120 hours of lessons were measured and in addition 78 hours of detailed acoustic data were recorded for possible later analysis.

5.5 Subjective assessment methodology

5.5.1 Scope and sample size

The data collection methodology included acoustic performance, teacher and pupil questionnaires and interviews, and pupil assessments. Data from both deaf and hearing pupils was collected. All data was collected without staff or pupil knowledge of the acoustic standard to which each classroom was treated. More than 400 children were involved directly in the study, including 17 children with hearing impairment

Ten teacher and class combinations were included in the study. Groups included grades 7 (11yrs) to 10 (14yrs) with top, middle and bottom ability sets. Eight classes were taught exclusively in one of the rooms, while three of the four classrooms were predominantly used by the same teacher.

The trial has sought to use more than one approach to the question under investigation. This is referred to as triangulation and is an approach that seeks to enhance confidence in the findings. This approach uses both quantitative and qualitative research methods:

- Children completed questionnaires specifically looking at the ease of hearing for each of the communication activities.
- Teachers completed questionnaires regarding the acoustic environment and the auditory behaviour of a specific deaf child in their class (where possible).
- Teachers were interviewed about their experience by an external consultant who had no knowledge of the rooms and was independent of the school and county council.
- A range of hearing assessments using speech material were carried out with deaf and matched hearing children. The children were matched in terms of academic ability and performance.

5.5.2 Speech in noise tests

Speech in noise tests were conducted using the Paediatric Audiovisual Speech in Noise Test (PAVT), which is based on the E2L word recognition test. Each test lasted between 3-5 minutes per child and assessed how dependant each of the children was on lip reading to be able to understand what was being said. A test consists of the child being presented with a list of random words and them having to choose a toy or picture which corresponds to the word which was said. Tests were conducted with and without lip reading and the signal-to-noise ratio could be controlled and changed by the tester.

Tests for speech discrimination were also carried out. In these tests hearing children were matched academically with hearing-impaired children to see how their sentence recognition scores compared.

These tests were to investigate the relative sensitivities to noise of hearing and hearing-impaired children, rather than to assess the effect of changes in the acoustics ; in fact the variation between individual children was, as expected from the literature, very large so that correlation with room acoustics would not be practicable.

5.5.3 Interviews

Interviews were conducted by an external consultant with members of staff who taught in the rooms during the study. Use of an external consultant for the interviews was to give an unbiased, professional view of the outcomes. When interviews were carried out neither the interviewer nor the interviewee knew which treatment had been applied in which room.

Children were also asked their opinions, some of which were featured in the BBC 'See Hear' Educational Acoustics programme which can be seen on http://youtu.be/DIJJkxuWk3E.

5.5.4 Questionnaires

Teachers, students and a panel of visitors were asked to complete semantic questionnaires regarding the acoustic performance of each of the classrooms at various stages of the study. They were given a questionnaire similar to that in Table 3, and for each room they were asked to identify the descriptor which best rated the specific criteria in that particular room. Each member of staff or student who completed one of these questionnaires completed one for all of the rooms. This ensured that the results of the questionnaires showed a subjective view of the treatments applied in all rooms.

Table 3 – Semantic differential questionnaire

	Extremely	Very	Fairly	Partly	Fairly	Very	Extremely	
Distinct								Indistinct
Booming								Clear
Pleasant								Unpleasant
Reverberant								Dry
Strenuous								Effortless
Clashing								Insulated
Best possible listening environment								Worst possible listening environment
Worst possible speaking environment								Best possible speaking environment
Any other comments about rooms								

6 RESULTS

6.1 Reverberation Times

6.1.1 Room MA1

The measured reverberation times at the different stages are shown in Figure 7.

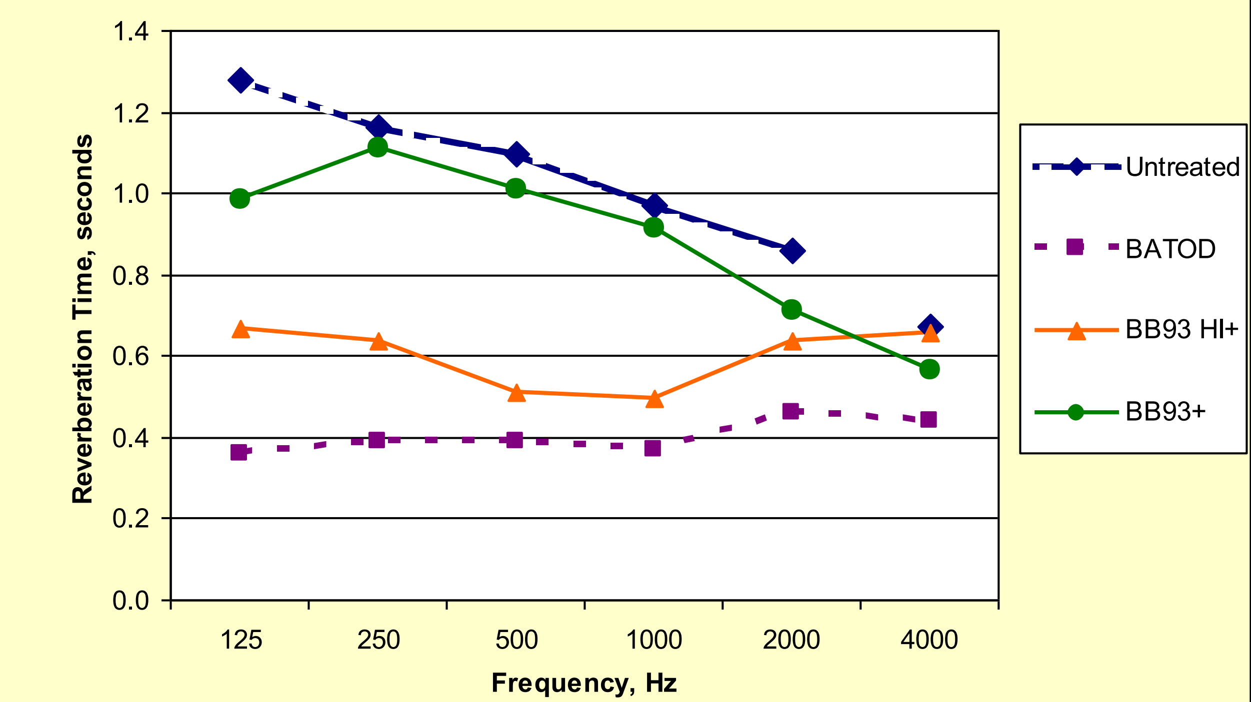


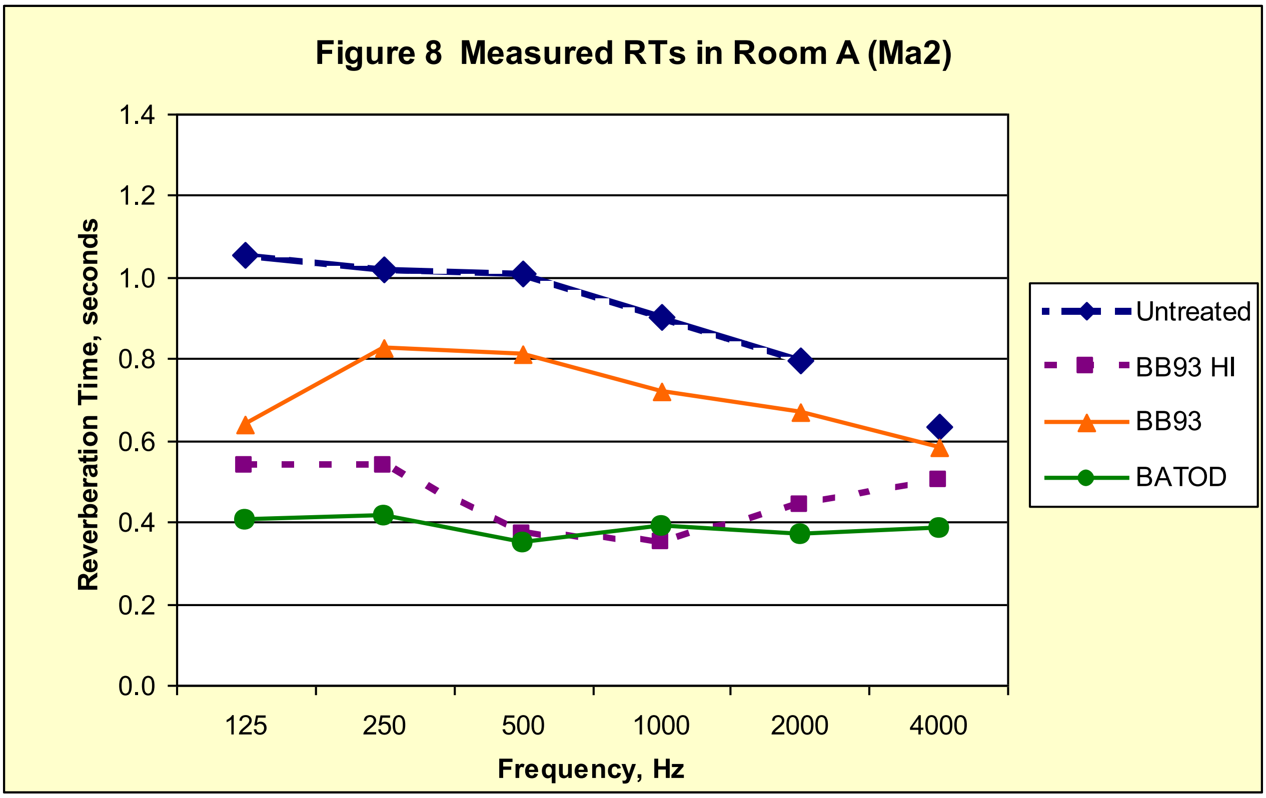
Figure 7 Measured RTs in Room B (Ma1)

It is not possible to design acoustic absorption in a room to match a reverberation time curve exactly, especially given the need to minimise visual changes to the room and to undertake the changes at weekends. In this case the measured reverberation times in the conditions designed to comply with the BB93 and BB93 HI criteria in fact exceeded those criteria and are therefore denoted BB93+ and BB93HI+ on the graph. The results are summarised below.

Condition	T mf (500–2000 Hz), seconds
Untreated	0.98
BATOD	0.41
BB93 HI+	0.55
BB93+	0.88

6.1.2 Room MA2

The measured reverberation times at the different stages are shown in Figure 8.

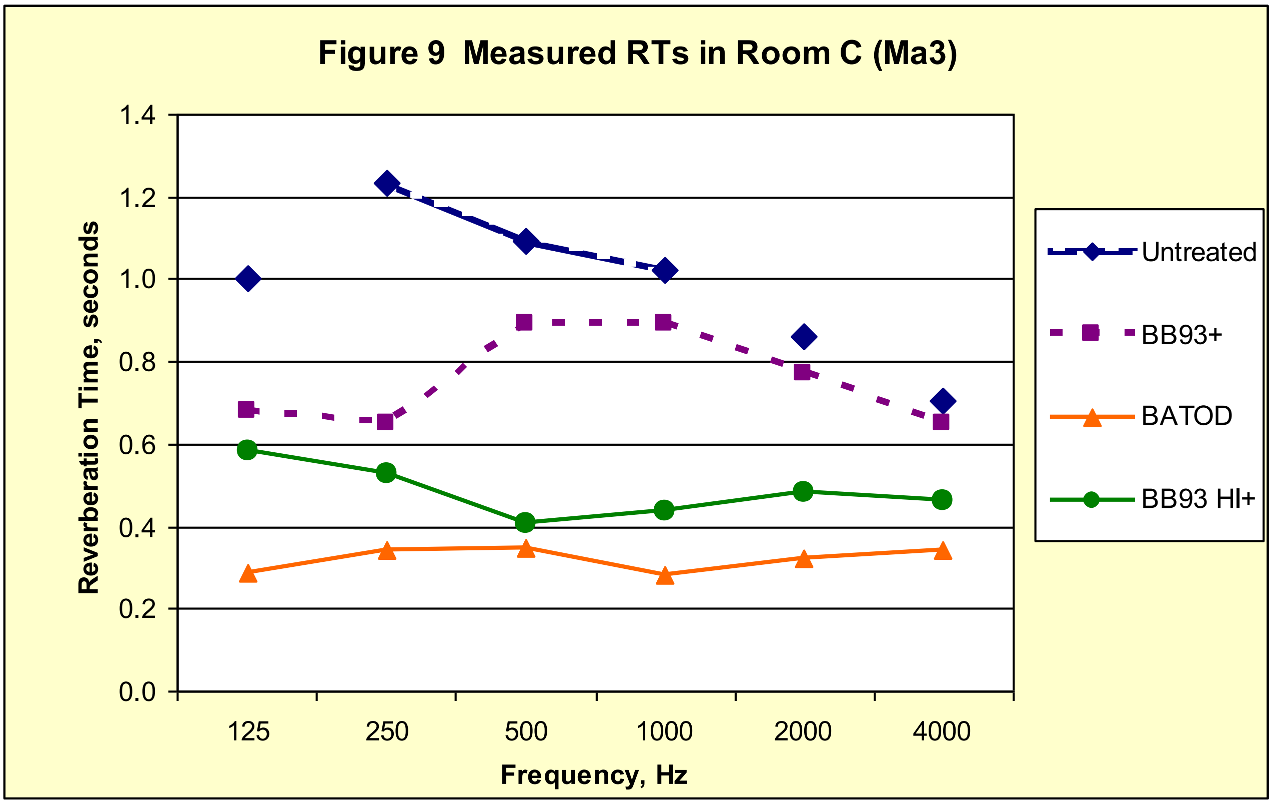


In this room the measured reverberation time in each condition complied with the targets. The results are summarised below.

Condition	T mf (500–2000 Hz), seconds
Untreated	0.90
BB93 HI	0.39
BB93	0.73
BATOD	0.37

6.1.3 Room MA3

The measured reverberation times at the different stages are shown in Figure 9.

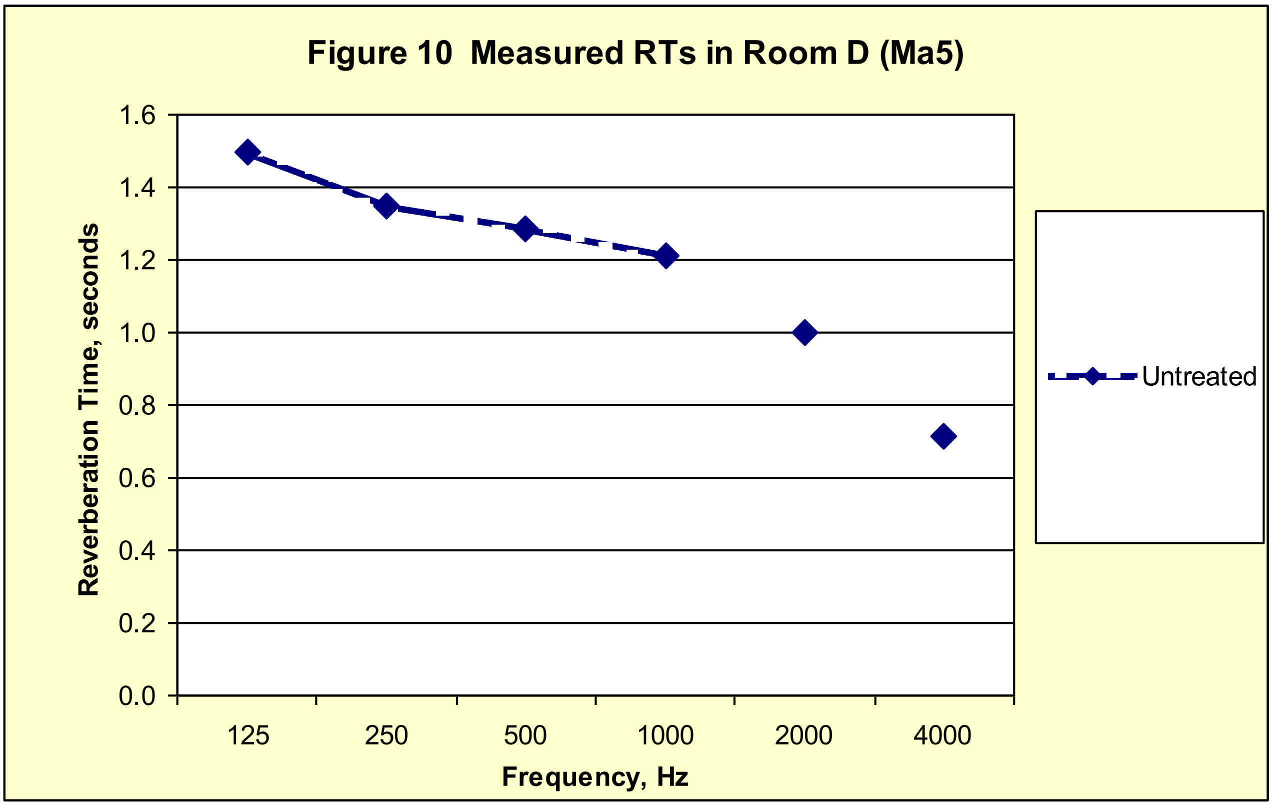


In this room the measured reverberation times in the conditions designed to comply with the BB93 and BB93 HI criteria exceeded those criteria, although to a lesser extent than in Room Ma1. The curves are therefore denoted BB93+ and BB93HI+ on the graph. The results are summarised below.

Condition	T mf (500–2000 Hz), seconds
Untreated	0.99
BB93+	0.85
BATOD	0.32
BB93 HI+	0.44

6.1.4 Room MA5

The measured reverberation times at the different stages are shown in Figure 10.



This was the control room for the experiment and was untreated throughout, so the reverberation time did not change. The results are summarised below.

Condition	T mf (500–2000 Hz), seconds
Untreated	1.17

6.2 Discussion of Reverberation Time results

Although the BB93 criterion was exceeded by the treatments intended to achieve those criteria in rooms Ma1 and Ma3, in all rooms there was a significant difference between the RTs with the different treatments. The BATOD condition was met in all three of the treated rooms and there was a substantial difference between the BB93 HI and BATOD conditions in each case.

The basic construction of the rooms Ma1, Ma2 and Ma3 included a certain amount of plasterboard which provided significant absorption at low frequencies, particularly 125 Hz. In rooms built exclusively using masonry walls a larger difference would have been achieved at low frequencies. The low-frequency RT in the control room Ma5 was longer and this may have increased the perceived difference between this and the treated rooms. On the whole, however, the reverberation times in each condition were reasonably consistent while also achieving a large enough difference between conditions to make subjective differences apparent to pupils and teachers.

6.3 Sound levels and signal-to-noise ratios

Figure 11 shows both the LAeq and the LA90 sound levels (these terms are explained in section 5.4 of this report) plotted as a function of reverberation time This is a much-simplified graph summarising measurements over a very large number of measurements in the four classrooms. There are a number of immediately obvious conclusions :

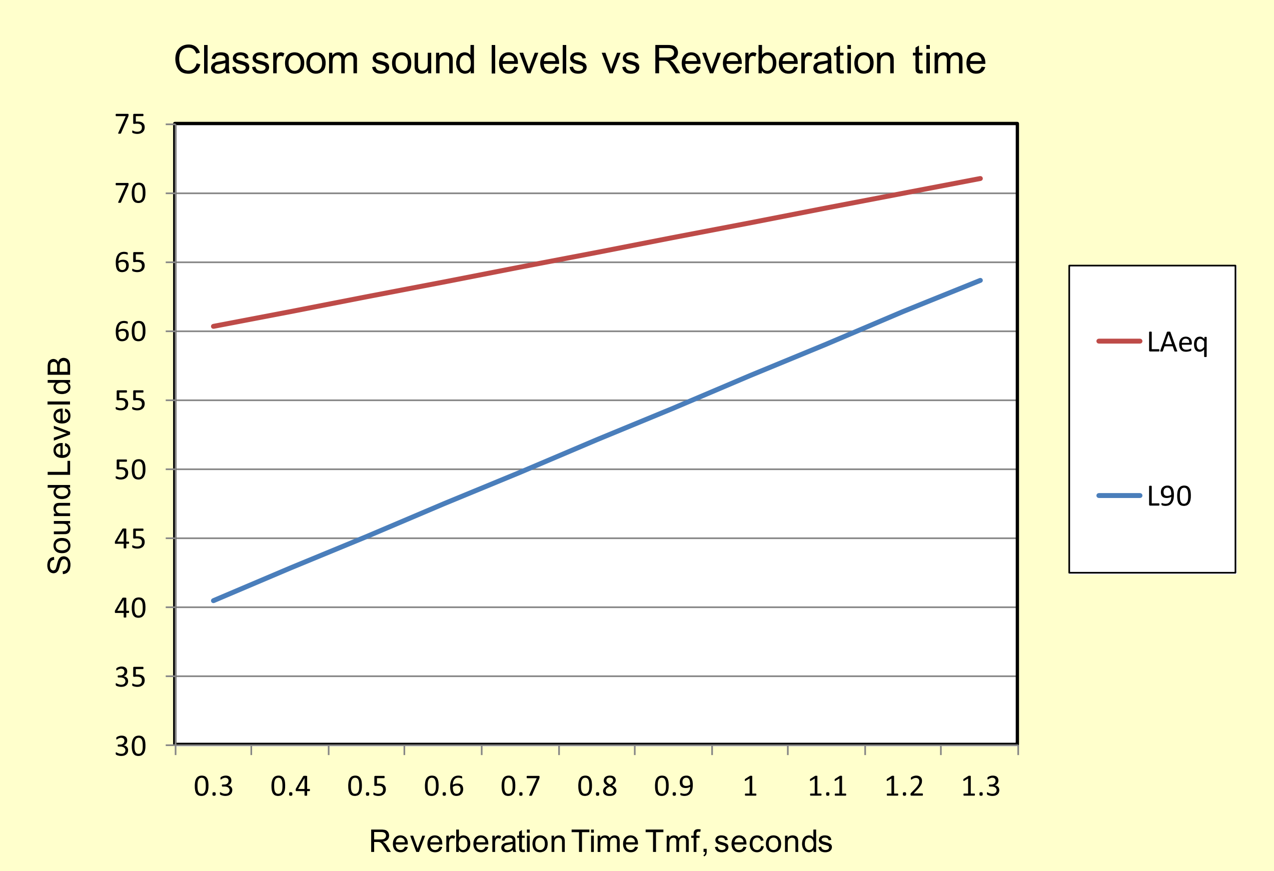


Figure 11 – sound levels as a function of RT

The background noise level LA90 decreased very significantly as the reverberation time reduced. A reduction in reverberation time from 1.2 to 0.8 seconds (that is, from an untreated classroom to one which just complies with the BB93 standard for mainstream secondary classrooms) corresponded to a decrease of 9 dBA in LA90. A further decrease from 0.8 to 0.4 seconds corresponded to a further decrease of 9 dBA. A 9 dBA decrease is very significant, and an 18 dBA decrease is very significant indeed.

As the LA90 corresponds roughly to the lowest constant noise level in the classroom it may be deduced that the underlying noise generated by the pupils decreased sharply as the reverberation time decreased. Theoretically, if the pupils were emitting the same level of sound power, we would expect the LA90 to decrease by 3 dBA for a halving in RT. The remaining 6 dBA of reduction may be attributed to the Lombard effect discussed in Section 4.1.1 of this report. This effect is consistent with the results of a previous study by David McKenzie of Heriot-Watt University.

The LAeq level also decreased significantly, but at a lesser rate, as the reverberation time decreased. A reduction in reverberation time from 0.8 to 0.4 seconds corresponded to a decrease of 4 dBA in LAeq. As the LAeq is generally dominated by the speech from the teacher it can be seen that as the RT reduces, the underlying noise level over which the teacher has to be heard reduces and so the teacher simply has to speak less loudly. That the LAeq reduces less than the LA90 is attributable to the fact that there is only a limited range of loudness over which the teacher can speak for an extended period – the difference is effectively that between the teacher speaking normally and in a raised voice.

We can consider the difference between LAeq and LA90 to be representative of a signal-to-noise ratio[1]. It can be seen that as the RT decreases, so the signal-to-noise ratio increases and hence the pupils need less effort to understand the teacher. This effect is particularly marked for pupils with hearing impairment.

Hence reducing the RT from 0.8 to 0.4 seconds has two separate but linked beneficial effects – it reduces the vocal effort and stress required of the teacher, and it makes it easier for the pupils to understand what is being said.

6.4 Interviews with teaching staff

Thirteen class teachers and Specialist Communication Support Workers (CSWs) were involved in the study although the majority of classes included were taught by just five teachers. Teaching and support staff were asked to comment on the auditory behaviour of specific children in their classes at each stage of the trial. Just before the final acoustic retreatment of the classrooms, key staff were invited to talk about their experiences of the rooms with a senior independent external interviewer from the National College of School leadership.

In summary, the consultant reported as follows:

- The overall impression from the data was of an overwhelming improvement in working conditions for both staff and pupils.
- Staff commonly used the terms “Quieter” and “Calmer” to describe the changes.
- Teachers involved in the interviews varied in seniority and length of experience, but even the most experienced of teachers found the changes a big improvement.
- Less experienced staff reported a large reduction in stress levels.

The consultant noted many other positive comments and views. Improvements were reported in the behaviour of all students including hearing-impaired children.

One of the accounts described as ‘powerful’ by the consultant was that of a teacher who worked with a particularly challenging group of children. The consultant’s report of the interview with the teacher is included in Appendix B. The teacher’s experiences of the classroom suggested that changes in the acoustic environment had a very profound effect on his pupils and their educational experience. He found that improvement in the pupils’ behaviour followed changes in the acoustic environment. When using a treated room with groups that were not normally taught in a treated room their behaviour also improved. He felt that improving the acoustic environment allowed him to “teach with less stress and more effectively”. Another experienced teacher reflected that he was able to do group work in the treated room, whereas before he would not take that risk.

All teachers commented on the improved working environment, noting improvements in classroom behaviour. Teachers reported that pupils were better at following class directions, and that they could concentrate more on task behaviour and less on repair behaviour (asking for clarification or repetition).

Teachers also commented that the improved acoustics allowed hearing-impaired children to participate more equally in classes with the other children. Some hearing-impaired pupils included within the mainstream classes had support from communication support workers. The CSWs’ comments were often detailed and related directly to the experience of the children within the classes: One CSW who acted as the ‘ears’ for a child with a cochlear implant, by providing speech to text services, reported:

> “This pupil is using the speech to text equipment to access the lesson. The reduced noise levels enable a much higher level of captioning, giving (the student) a much higher level of access to the lesson. The stenographic equipment operates much more effectively in the new environment allowing a much greater level of access for hearing impaired pupils.”

[1] Technically this is not a true signal-to-noise ratio but it is an indication of the difference in level between the speech signal and the underlying noise.

6.5 Semantic Differential Questionnaires

In addition to the teaching staff, an invited panel of 25 teachers, acousticians, County Council personnel and other professionals and interested lay people were invited to experience the acoustic conditions of the rooms in person. The group received short presentations about the study in each of the study classrooms. At this point no one present was aware of the precise performance standards of each of the rooms.

While the group spent time in the rooms they were asked to complete the semantic differential questionnaires described in Section 5.5.4. The results are summarised in Figure 12. The "good" semantic terms are plotted horizontally and the subjects' averaged qualitative descriptors are plotted vertically. This shows that there is a 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 increases so the rating of the room decreases.

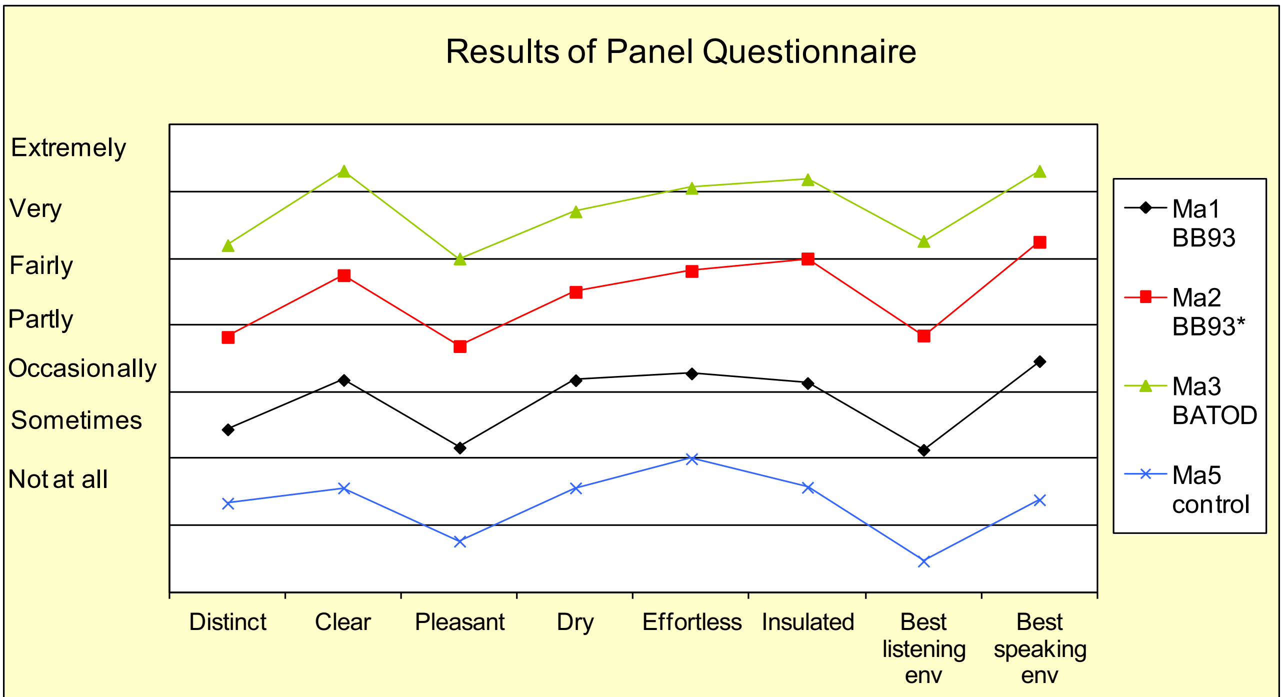


Figure 12 – X-Y plot of semantic questionnaire results

The same data is shown in a different form in the area plot of Figure 13 below. In this case 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 best perceived quality is very strongly related to the reverberation time.

It must be remembered that at this stage, while it was of course obvious that room MA5 had not been treated acoustically, the panellists did not know which of the rooms Ma1, Ma2 and Ma3 had been treated to which standard.

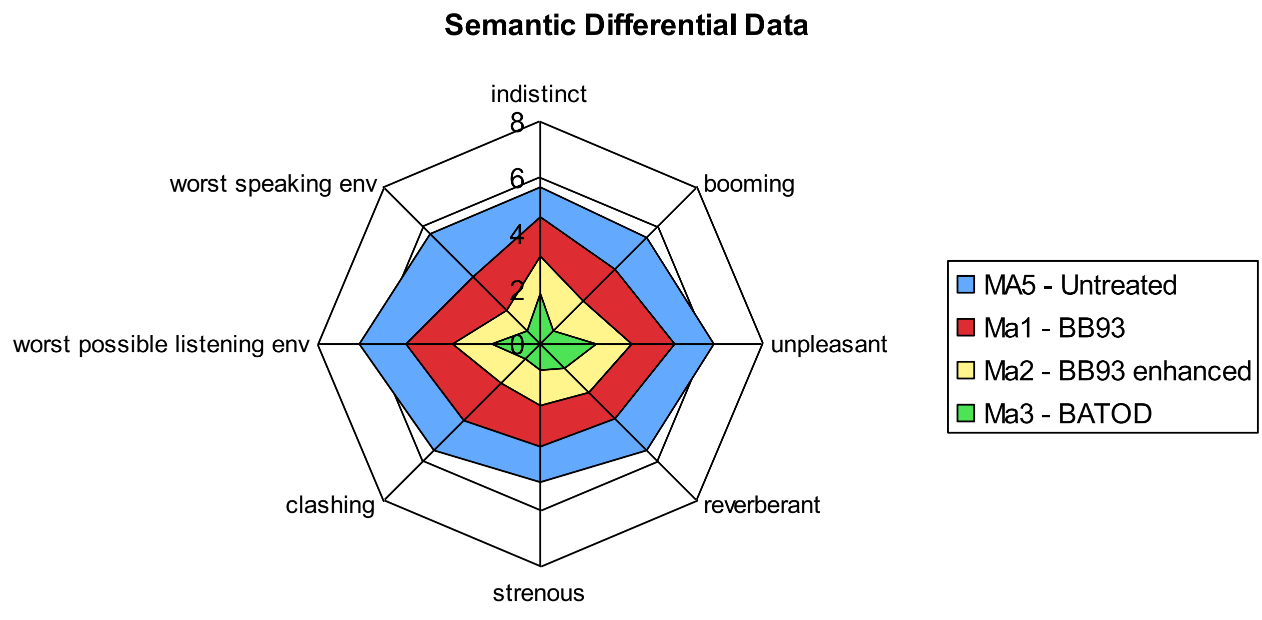


Figure 13 – Area plot of semantic differential data

6.6 Costs

The additional cost of treating a typical classroom of $50m^2$ to a higher specification from the minimum standard was £375. The additional cost of the very highest specification was £1475.

Costings of room refurbishments and the likely cost for a small new school at 2009 prices have been included in Appendix C. The costs of lighting are also included in the appendix.

7 CONCLUSIONS, RECOMMENDATIONS AND FURTHER WORK

7.1 Conclusions

The results of all of the subjective assessments, questionnaires and interviews showed a very strong correlation between reverberation time and perceived quality of the teaching environment for both speech and listening. This correlation applied a wide range of semantic descriptors across the whole range of RTs provided, such that the room treated to the BATOD standard was consistently rated better than that treated to the BB93 HI standard, which in turn was rated better than the "Normal" BB93 standard, which was rated better than the untreated classroom.

The same strong correlation applied to the measured sound / noise levels during teaching in the classrooms. In particular, the reduction in classroom noise measured in terms of LA90 was surprisingly large, at 9 dB for a reduction in RT from 0.8 to 0.4 seconds. This corresponds with the reports of teachers when interviewed, who reported very significant improvements in behaviour in the rooms with the shortest reverberation times.

These very large reductions in classroom noise allowed teachers to talk in normal rather than raised voices while apparently still achieving higher nominal signal-to-noise ratios. Again, this corresponds with the teachers' reports of lower stress levels, better behaviour and better comprehension from both hearing and hearing-impaired pupils.

7.2 Recommendations

All of the evidence from this study appears to point towards the desirability of designing all classrooms to at least the BB93 standard for hearing-impaired children (Tmf < 0.4seconds) and possibly to the BATOD standard, which requires more control of low-frequency absorption.

Taking account of the cost implications and of the desirability of providing a good acoustic environment for staff, hearing and hearing-impaired pupils, we understand that Essex County Council will seek to set the enhanced BB93 standard (0.4 second Tmf) as the desirable standard for all new and refurbished classrooms, and to achieve the BATOD standard where practicable. This can most economically be achieved by keeping room volumes, and particularly room heights, to a practical minimum ; by using robust dry-lined constructions to provide natural low-frequency absorption ; and by educating architects to consider acoustic performance as an essential part of school design. The requirements for acoustic absorption and the resulting impact on lighting and ventilation strategy should be considered from the earliest stage of any school design or refurbishment.

7.3 Further work

To the best of our knowledge this is a unique study. There has been a dearth of planned, results-based research of this type into acoustic standards in schools ; in 2003 the reverberation time criteria in BB93 were decided on the basis of historic standards and professional opinion (albeit from some very experienced acousticians) in the absence or a database of existing school acoustics related to learning outcomes. Since then there has been little publicly-funded research in the UK into whether these standards are appropriate or adequate, and the impending revision to BB93 is likely to go ahead on the same basis as its predecessor.

A number of questions have been raised fairly consistently and could be addressed by further research:

7.3.1 Room Acoustics

- Is there any justification for retaining the difference between reverberation time requirements for primary (0.6 seconds) and secondary (0.8 second) classrooms ?
- Is there any benefit in considering RTs below 0.4 seconds, particularly in hearing-impaired units ?
- Are the BB93 RT criteria for other areas appropriate – in particular dining halls, sports halls and assembly halls ? Should the desirable criteria for RTs in those areas be a function of room volume ?

7.3.2 Soundfield systems

- Under what circumstances can Soundfield systems be beneficial to hearing and / or hearing -impaired pupils ?
- Could a study similar to the Sweyne Park study be used to determine the benefits of acoustic treatment (say to reduce RTs in secondary classrooms from 0.8 to 0.4 s Tmf) compared with the use of a well-designed and properly-used Soundfield system ?

7.3.3 Ambient noise levels

- Are the BB93 and / or BATOD criteria for internal ambient noise levels in mainstream and HI classrooms appropriate ?

7.3.4 Sound insulation

- Are the BB93 criteria for sound insulation between classrooms, and particularly between classrooms and circulation spaces, appropriate ?

The Sweyne Park study has shown the value of staff interviews as a way of judging the teaching environment and any or all of these issues could be addressed by a similar approach, or by auditing existing schools and correlating acoustic measurements with well-planned surveys and interview techniques.

8 ADDITIONAL RESOURCES

8.1 References and Bibliography

- Building Bulletin 93 “Acoustic Design of Schools – a design guide.” Department for Education and Skills, 2003.
- “Classroom Acoustics – recommended standards.” British Association of Teachers of the Deaf. www.batod.org.uk
- “Acoustic testing in schools : Good Practice Guide” published online by the Association of Noise Consultants, www.theanc.co.uk
- J S Bradley and H Sato. "The intelligibility of speech in elementary school classrooms." J Acoust Soc Am 123(4): 2078-86 (2008).
- D Canning & A James “Acoustic design of special schools” Proceedings of Internoise, Lisbon (2010).
- J Dockrell and B Shield. “Acoustical barriers in classrooms: the impact of noise on performance in the classroom”. British J Educational Research 32(3), 509-525(2006).
- J Dockrell and B Shield “The impact of sound field systems on learning and attention in elementary school classrooms” J Speech Lang Hear Res, published online Jan 9, 2012
- E Greenland and B Shield. ”A survey of acoustic conditions in semi-open plan classrooms in the United Kingdom”. J. AcoustSoc Am 130(3), 1399-1410 (2011).
- A James and D Canning “When BB93 just isn’t good enough - School acoustics design for excellence”. Proceedings of the Institute of Acoustics & Belgian Acoustical Society, Ghent (2010).
- J B Larsen, A Vega et al. "The effect of room acoustics and sound-field amplification on word recognition performance in young adult listeners in suboptimal listening conditions." Am J Audiol 17(1): 50-9 (2009).
- D J McKenzie “Noise levels and sources in UK Schools”. International symposium on noise control and acoustics for educational buildings, Yildiz Technical University, Turkish Acoustical Society (2000).
- M Meis, C Nocke et al “Subjective evaluation of speech and noise in learning environments in the realm of classroom acoustics; results from laboratory and field experiments”. J Acoust Soc Am 117 (4): 2437 (????)
- M Picard and J S Bradley. "Revisiting speech interference in classrooms." Audiology 40(5): 221-44 (2001).
- H Sato and J Bradley. "Evaluation of acoustical conditions for speech communication in working elementary school classrooms." J Acoust Soc Am 123(4): 2064-77 (2008).
- B M Shield and J E Dockrell. “The effects of noise on children at school: a review. In ‘Collected papers in Building Acoustics: Room Acoustics and Environmental Noise (ed B Gibbs, J Goodchild, C Hopkins and D Oldham), 159-182 (2010).
- B Shield, E Greenland and J Dockrell. ”Noise in open plan classrooms: a review”. Noise and Health 12:49,225-34 (2010).
- Shield, B. M. and J. E. Dockrell. "The effect of amplification on children's performance in the classroom." J Acoust Soc Am 123(5): 3918 (2008).
- Tiesler, G. and M. Oberdoerster. "Noise - A stress factor? Acoustic ergonomics at schools." J Acoust Soc Am 123(5): 3918 (2008).
- Yang, W. and J. S. Bradley. "Effects of room acoustics on the intelligibility of speech in classrooms for young children." J Acoust Soc Am 125(2): 922-33 (2009).

8.2 Audio and video resources and other websites

- "See Hear Education Acoustics" – This is a 10-minute video taken from a television programme discussing the importance of acoustics in schools and describing some of the work set out in this report including interviews with David Canning, Bridget Shield, Simon Smith and several pupils. http://youtu.be/DIJJkxuWk3E
- Sound simulations – these are simulations of sound quality at the front and back of different classrooms with normal hearing, high-frequency hearing loss and cochlear implants. They can be listened to on loudspeakers but are best heard on good quality headphones. Available on http://www.hear2learn.org/ndcssim/ and http://www.ndcs.org.uk/family_support/audiology/hearing_loss_simulation/
- **The National Deaf Children's Society** (NDCS) provides information and support for families of deaf children, deaf young people and professionals working with families. NDCS supports and campaigns for improved acoustic standards in schools. www.ndcs.org.uk.
- **Essex County Council** has supported the implementation of improved acoustic standards in schools for all pupils with and without hearing impairment. The Council jointly commissioned and funded this study. www.essex.gov.uk
- **The Federation of Property Societies** (FPS) provides a consolidated voice on professional property-related matters in local government. The FPS supports research into areas of Construction and Property including this study. www.fedps.org.uk
- **The Institute of Acoustics** (IoA) is the UK's professional body for individuals working in acoustics, noise and vibration. The IoA's membership covers all areas of acoustics including building acoustics. The authors of this report are members of the IoA and the author of the foreword, Bridget Shield, is the Institute's president elect. www.ioa.org.uk
- **The Association of Noise Consultants** (ANC) represents professional acoustic consultancies in the UK. Most consultancies undertaking acoustic design of schools (including Adrian James Acoustics, which compiled this report) are member companies of the ANC. The ANC and IoA work together to encourage research, development and improvements in acoustic standard in schools. www.theanc.co.uk

9 APPENDIX A – REVERBERATION TIME DATA

Room reverberation times

T-20	F[Hz]							
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Ma1 phase 1	0.54	0.49	0.48	0.34	0.41	0.37	0.4	0.39
Ma1 phase 2	1.31	0.36	0.37	0.35	0.36	0.35	0.38	0.39
Ma1 phase3	0.5	0.37	0.4	0.36	0.4	0.39	0.38	0.36
Ma2 phase 1	1.09	0.94	1.14	1.03	0.92	0.7	0.56	0.45
Ma2 phase 2	1.02	1.02	1.04	0.97	0.92	0.71	0.57	0.47
Ma2 phase3	1.12	0.99	1.16	1.03	0.91	0.73	0.57	0.48
Ma3 phase1	0.88	0.58	0.55	0.37	0.42	0.52	0.47	0.42
Ma3 phase 2	0.62	0.54	0.5	0.42	0.45	0.45	0.47	0.45
Ma3 phase 3	0.78	0.63	0.54	0.43	0.45	0.48	0.45	0.47
Ma5 phase 1	1.65	1.53	1.39	1.18	1.06	0.91	0.71	0.59
Ma5 phase 2	1.66	1.42	1.29	1.18	1.08	0.91	0.72	0.55
Ma5 phase 3	1.52	1.41	1.31	1.23	1.12	0.98	0.72	0.55

10 APPENDIX B – SPECIFIC COMMENTS FROM INTERVIEWS

The following is a transcript of a verbal report from the External Consultant, immediately following in-depth interviews with staff about their experiences using the experimental teaching rooms. Neither the interviewer nor the staff member interviewed knew which sound treatment had been installed over the Easter holiday.

"…Before Easter it was the lesson I hated most of all I had to give loads of detentions in order to get any sense of discipline at all...umm.. I don't touch the physical environment at all i.e. the desks are in straight lines, it is a senior member of staff's room I'm only in there once a week so I don't move that....but since Easter I have had no discipline problems whatsoever and yet this rather structured straight jacketed rows of desks are exactly the same. I ask my pupils to be quiet and they are quiet, they are completely quiet, they respond immediately. I don't have the brighter lights on, I turn those off, but for the pupils it's a totally positive experience.

If we have a room change and I teach a different class which I have done in this particular classroom………again it's a completely different atmosphere, the classes are angelic in comparison which they would be if I taught them in other places in the school.

Before Easter I would have walked out stressed, high blood pressure, feeling blinkered, hearing not right with a changed altitude as if in an aeroplane, after Easter I walk out of there refreshed". ……..… I said

(In answer to the question "what difference has it made to you?)

"Well it's absolutely fantastic, the staff really have appreciated these positive changes, as a school we are incredibly lucky to be part of it all"... The real difference is I can teach, previously I could not teach, I had to structure the lesson such that I got them in, I shouted above their noise to try and get them quiet, now they come in they are calmer. I can actually teach a teacher-led formal lesson with the whole class. Previously my aim was to get them occupied and then to go around and then to teach individuals and small groups - now I can actually teach".

11 APPENDIX C - COST OF THE 3 DIFFERENT CLASS BASE STANDARDS

Room type

- *Type 1 is a regular secondary school classroom performance* standard which may not meet BB93 minimum requirement;
- Type 2 is a BB93 classroom specifically for use by deaf pupils;
- Type 3 is to British Association of Teachers of the Deaf recommendations.

Ceiling

- Type 1 is a plastic faced plasterboard tile in white exposed T bar system;
- Type 2 is a general high performance acoustically absorbent tile with a textured surface;
- Type 3 is a high performance acoustic absorber with textured surface with primed edges. To improve absorption in the low frequency range, additional absorbers are installed on top of the ceiling.

Lighting

- For a typical 8m x 7m (56sqM) class base with 350lux and good uniformity. Example fitting is a white gull wing with central louvre;
- Installation consists of 9 No. 600 x 600 recessed luminaires with 40watt lamp High Frequency control gear. Emergency control gear in 2 fittings;
- Install circuit for luminaires using PVC/PVC cables clipped within ceiling void Switched in rows with interactive board luminaire separately switched.

Room Type	Small refurbishment 2 class bases (approx 112M²)		Small New School (approx 1000M²)	
	Ceiling	Lighting	Ceiling	Lighting
1	£19.50/M²	£210/M²	£15.00/M²	£149/M²
2	£29.00/M²	£210/M²	£22.50/M²	£149/M²
3	£53.00/M²	£210/M²	£44.50/M²	£149/M²

Costs were approximate and at 2009 prices.

Published by
The Association of Noise Consultants
The Old Pump House, 1A Stonecross,
St Albans AL1 4AA
telephone: 020 8253 4518
email: info@theanc.co.uk

The authors of this document confirm that they do not intend to claim or implement any copyright on the basis that this document will be freely available for download as well as being distributed in print.

This publication is available by downloading it from the following web sites: -
Association of Noise Consultants www.theanc.co.uk;
Federation of Property Societies www.fedps.org.uk;
National Deaf Children's Society www.ndcs.org.uk.

ISBN 978-0-9572543-1-2
Published May 2012