Proceedings of the Institute of Acoustics & Belgium Acoustical Society
Noise in the Built Environment, Ghent, 29-30 April 2010

A PRELIMINARY SURVEY OF NOISE LEVELS IN UK SECONDARY SCHOOLS

Robert Conetta, London South Bank University, London, UK
Bridget Shield, London South Bank University, London, UK
Trevor Cox, University of Salford, Salford, UK
Julie Dockrell, Institute of Education, University of London, London, UK
Daniel Connolly, Institute of Education, University of London, London, UK

1 INTRODUCTION

Research over the past 40 years, has shown that noise and poor acoustics have a detrimental effect upon teaching, learning and teachers' health[1-3]. However, most of this research has focused on primary schools. Far less is known about the acoustic quality of secondary schools and the impact of noise and poor acoustics upon children of secondary school age. The evidence from primary schools is that the effect of noise on pupils' behaviour and attainment is complex, depending not only on classroom conditions and individual factors concerning the child, but also on the learning task being undertaken. Noise has more of an impact upon the older children in the primary school age range, although the reasons for this are not fully understood. Demands on pupils' cognitive abilities and behaviours increase significantly in secondary schools. Pupils are taught by subject specialists, move classrooms, have less opportunity for individual support and are exposed to different pedagogic approaches. Consequently, the evidence from primary schools suggests that secondary school children will be more disadvantaged by poor acoustic environments.

A research project is currently being undertaken which aims to investigate the current acoustic environment and its effect on pupils and teachers in secondary schools in the UK. Noise and acoustic surveys of schools are being carried out in order to determine typical acoustic conditions and to provide data for subsequent investigation of the effects of the acoustic environment on students. This paper presents some preliminary noise level and room acoustic data from an initial pilot study conducted in four secondary schools in the south east of England.

2 ACOUSTIC DESIGN SPECIFICATIONS FOR SCHOOLS

Since 2003 the acoustic design of schools in the UK has been regulated under the Building Regulations. The acoustic performance standards which must be met by new and refurbished schools are specified in Building Bulletin 93 (BB 93)[4]. BB 93 includes specifications for indoor ambient noise levels ($L_{Aeq,30min}$), reverberation times and sound insulation in many different areas in unoccupied and unfurnished schools. The criteria have been selected in order to facilitate clear communication of speech between students and teachers, and to avoid interference with study activities.

Table 1 shows the specifications for indoor ambient noise levels and reverberation times for school spaces relevant to this study. The reverberation time is specified as the mid-frequency (the average value of the three octave bands, 500 Hz, 1 kHz, and 2 kHz) reverberation time.

BB 93 also specifies a minimum Speech Transmission Index (STI) of 0.6 for open plan classrooms.

Table 1. Building Bulletin 93 performance specifications

Type of room	Indoor ambient noise level $L_{Aeq,30min}$ (dB)	Reverberation time (T_{mf})
Secondary school classroom	≤ 35	< 0.8
Science laboratories	≤ 40	< 0.8
Design and technology	≤ 40	< 0.8
Indoor sports hall	≤ 40	< 1.5

3 THE PILOT STUDY

The pilot study has been carried out in four schools in suburban areas of Surrey and Kent in south-east England. Each school was visited and monitored for five days. In each school detailed noise measurements were made in unoccupied spaces and in classrooms and other spaces during lessons; room acoustic data for the measured spaces was also obtained.

3.1 The schools

Summary information concerning the four schools in the survey is shown in Table 2. Most of the schools had a range of buildings of varying ages. All were in suburban locations; none were affected by significant levels of environmental noise such as road traffic or aircraft noise.

Table 2. Description of schools surveyed

School	Gender	Age range	No. of pupils	Dates of building
1	Female (mixed 6th form)	11-18	1000	1940 - 2009
2	Mixed	11-16	1100	1950 - 2000
3	Mixed	11-18	1000	1960 - 1990
4	Mixed	11-16	500	1960

3.2 The noise and acoustic surveys

Five days of noise and acoustic measurements were undertaken at each school. This involved one day of noise measurements during lessons in each of the following subject areas: Maths, English, Science, Design and Technology, and PE.

In most cases one room was selected for each subject area and lessons during the day were monitored in that room. In total 76 lessons were measured in 22 rooms. Throughout the day, the researcher was present during each lesson to observe the lesson activities and noise sources, to note any occurrences of high noise levels and identify the sources, and to record the numbers of pupils and adults present.

All measurements were made using a Norsonics N140 sound analyzer, with the microphone at seated head height (~1.2 m). Indoor ambient noise levels, reverberation times and STI were measured in each room when it was unoccupied. To measure the indoor ambient noise level the equivalent continuous noise level was measured for a period of between 1 and 5 minutes. Although the BB 93 performance specifications are in terms of $L_{Aeq,30min}$, as the noise was constant it was judged that the shorter measurement periods were sufficient to give an indication of the $L_{Aeq,30min}$. Unoccupied reverberation time and STI were measured in each room at two receiver positions with three source positions, using balloon bursts to generate the room impulse response.

Other information collected included physical measurements of each room (for example volume, floor, surface and glazing areas), and details of the furnishings and acoustic treatments.

3.3 Lesson and activity noise

Lesson noise measurements were made at a location in the room chosen so as to minimise disruption to teaching (usually at the back or to one side of the room). Several lessons were measured in each room. The equivalent continuous noise level was measured for the 50 minute duration of each lesson. Each lesson noise level is the noise level generated by the dominant activity of the lesson, excluding any activities unrelated to the lesson itself, such as pupils entering or leaving the classroom.

During the observations over 20 different classroom activities were identified as occurring during lessons. The noise levels associated with the different activities were measured, in addition to overall lesson noise (see section 5). The most commonly occurring activities have been grouped into six main categories as shown in Table 3.

Table 3. Lesson activity categories

	Activity	**Description**
1	Individual work	Pupils working individually either from information on the board or from books, in quiet study, exam. This is often accompanied by low level discussion.
2	Instruction/Discussion	Teacher led Q&A, reading out loud, class room discussion
3	Group Work	Pupils working in groups around a table. Higher level discussion and more movement.
4	Science experiment	Practical work in a science lesson. High level of discussion and more movement.
5	Design and Technology (practical)	Practical work using machines. Lots of pupil movement. Machines are the dominant noise sources.
6	Sports	Competitive team game – lots of pupil movement, often shouting.

4 RESULTS

This section presents the results of the noise and acoustic surveys in the four schools.

4.1 Indoor ambient noise levels

Table 4 shows the indoor ambient noise levels (that is the $L_{Aeq,30min}$ in unoccupied rooms) for the measured rooms, estimated from short period (1 to 5 minutes) L_{Aeq} measurements. The relevant BB 93 performance specification levels are also shown. (Note that in school 1 two Science and in school 2 two PE spaces were measured, and that no Design and Technology space was measured in school 2.)

It can be seen that all the Maths and English rooms comply with BB 93 although they were built before Building Bulletin was published and schools came within the Building Regulations. Four of the remaining 13 rooms do not comply with the current standard, these are highlighted in Table 4.

Table 4. Indoor ambient noise levels (estimated), L_{Aeq} (dB)

	School				BB 93 specification
	1	2	3	4	
Maths	26	35	34	28	<35
English	27	31	31	33	<35
Science	30 43	44	39	39	<40
Design and Technology	30	-	35	34	<40
PE	26	32 43	42	34	<40

4.2 Lesson noise levels

The noise levels presented are the L_{Aeq} levels for the lesson period ignoring those times when untoward noise events (such as a door banging or pupils entering or leaving the classroom at the start and end of a lesson) occurred. They thus represent the L_{Aeq} level for the actual teaching time within the lesson.

The mean lesson noise L_{Aeq} levels for each subject in each school are shown in Table 5. Table 5 also shows the level for each subject, averaged over all schools, and the corresponding standard deviations (sd).

Table 5. Lesson noise levels, L_{Aeq} (dB)

	School								Overall average		
	1		2		3		4				
	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	sd
Maths	58	4	56	5	59	4	58	5	57	18	4.9
English	53	5	61	5	57	3	66	5	60	18	7.2
Science	61	5	67	5	62	5	58	3	63	18	4.8
Design and Technology	70	3	-		67	4	75	2	70	9	4.2
PE	73	3	81	4	76	3	76	3	77	13	6.6

It can be seen that the quietest lessons are Maths and English. Table 5 also shows that the average levels for Maths, Science and Design and Technology lessons across the four schools are very consistent.

As would be expected, and as found in a previous survey of noise in primary school classrooms[5], the lesson noise depended on the activities being undertaken. The activity noise levels and percentages of time spent in the different activities are discussed in the following section.

4.3 Activity noise levels

Table 6 shows the average noise level for each of the six activities listed in Table 3, plus the percentage of time on average that each activity was observed to occur in each subject and over all subjects.

It can be seen that the most commonly occurring activity was Activity 2 (Instruction/discussion) which occurred for 47% of the observed lesson time.

Table 6. Average activity noise levels and percentage of time on activities

	Activity	Activity L_{Aeq} (dB)		Time spent in each subject (%)					
		Mean	sd	Maths	English	Science	DT	Sports	Overall
1	Individual work	56	5.9	28	6	11			11
2	Instruction/ Discussion	59	5.0	72	61	66			47
3	Group Work	65	5.2		33	6			9
4	Science experiment	68	6.9			17			4
5	Design Tech (practical)	70	4.2				100		12
6	Sports	77	6.6					100	17

Maths and English consist predominantly of the quieter activities, which explains why the lesson noise levels are the lowest for those subjects. It can be seen that Maths lessons in general involve only the quietest two subjects. Science lessons also have a high percentage of quiet activities but experimental work involves a higher level of inter-pupil discussion and movement which raises the overall lesson noise levels. The only activity in PE lessons is sports, which consists mainly of pupil movement and loud discussion, leading to the highest lesson noise levels, as would be expected. The main sources of noise in Design and Technology are machines being used for practical work; there is also a considerable amount of pupil movement.

The levels shown for the individual activities in Table 6 are consistent with those found in a previous study of noise levels in primary schools[5], where the L_{Aeq} for the quietest activity was 56 dBA and for the noisiest (group work and movement) was 77 dBA. 56 dBA is also the level found when pupils/students are quiet in other surveys of primary schools[6] and university classrooms[7].

4.4 Reverberation times

The measured mid-frequency reverberations times for the 21 surveyed classrooms while they were unoccupied are shown in Figure 1.

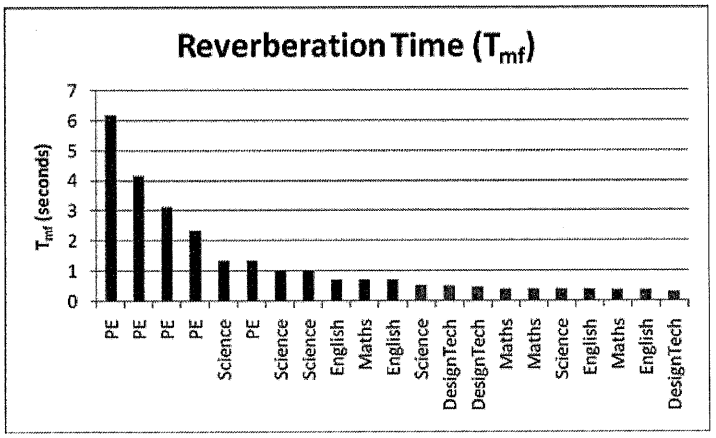

Figure 1. Measured reverberation times (T_{mf}) for each classroom

The PE sports halls and gyms have the longest reverberation times of all the rooms, ranging from 1.4 to 6.2 seconds. These rooms have the largest room volume and typically very little or no acoustic treatment. The other rooms had much shorter reverberation times, ranging from 0.4 to 1.4 seconds. These rooms typically have a smaller room volume and acoustic treatment, most commonly a suspended ceiling with acoustically absorbing panels.

With one exception, all PE rooms exceed the BB 93 performance specification for indoor sports halls (1.5 s). The room that met the performance specification was a sports gym which had acoustically absorbing panels in the ceiling. Three science laboratories exceeded the BB 93 performance specifications for science laboratories (0.8 s), with a reverberation time longer than 1 second. Of the surveyed laboratories these rooms had the largest room volumes and no acoustic treatment. The classrooms for all other subjects (Maths, English and Design and Technology) met BB 93 performance specifications.

4.5 Speech Transmission Index

The speech transmission index is an objective measure of speech intelligibility[8]. STI is a single figure rating between 0 and 1, the higher the value, the better the speech intelligibility. The correspondence between STI and subjective speech intelligibility is shown in Table 7.

Table 7. Subjective rating scale for STI

STI	Subjective intelligibility rating
< 0.30	Bad
0.30 to 0.45	Poor
0.45 to 0.60	Fair
0.6 to 0.75	Good
> 0.75	Excellent

For occupied open plan classrooms, BB 93 requires a performance standard for STI of at least 0.6, which corresponds to 'good' or 'excellent' conditions.

Figure 2 shows the calculated STI ratings for each surveyed classroom in an unoccupied state. (Note that STI ratings were not calculated for School 4).

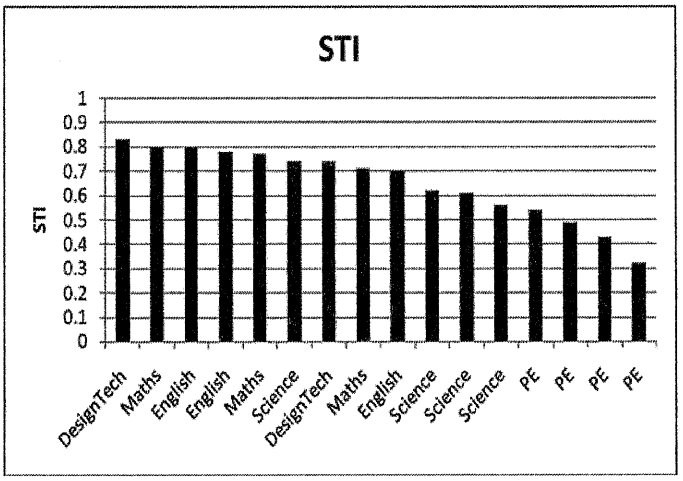

Figure 2. STI ratings for each classroom.

The PE halls, which had the longest reveberation times, have the lowest STI ratings, indicating that the speech intelligibility is 'poor'. The classrooms used for other subjects have a calculated STI rating of 'good' or 'excellent', with one exception, a Science laboratory, which was rated as 'fair'. This room had the longest reverberation time of the surveyed labs and no acoustic treatment. Of the smaller cellular rooms those used for Science have the lowest STI ratings. It must also be remembered that the STI ratings for all rooms will worsen when they are occupied during lessons.

5 FACTORS AFFECTING NOISE LEVELS

At present the data set is too small for meaningful statistical analysis to be carried out. However, the data has been examined in an attempt to identify any trends in relationships between noise levels and various class and room based factors. When more data has been obtained full statistical analysis will be undertaken. In the following section relationships between lesson noise levels and indoor ambient noise level, reverberation time and STI are examined. The effects of numbers and ages of pupils on noise levels are also discussed.

5.1 Indoor ambient noise level

Figure 3 compares measured lesson noise levels for each subject with the indoor ambient noise levels of each classroom. (Note that stacked data points represent lesson noise levels measured in the same room).

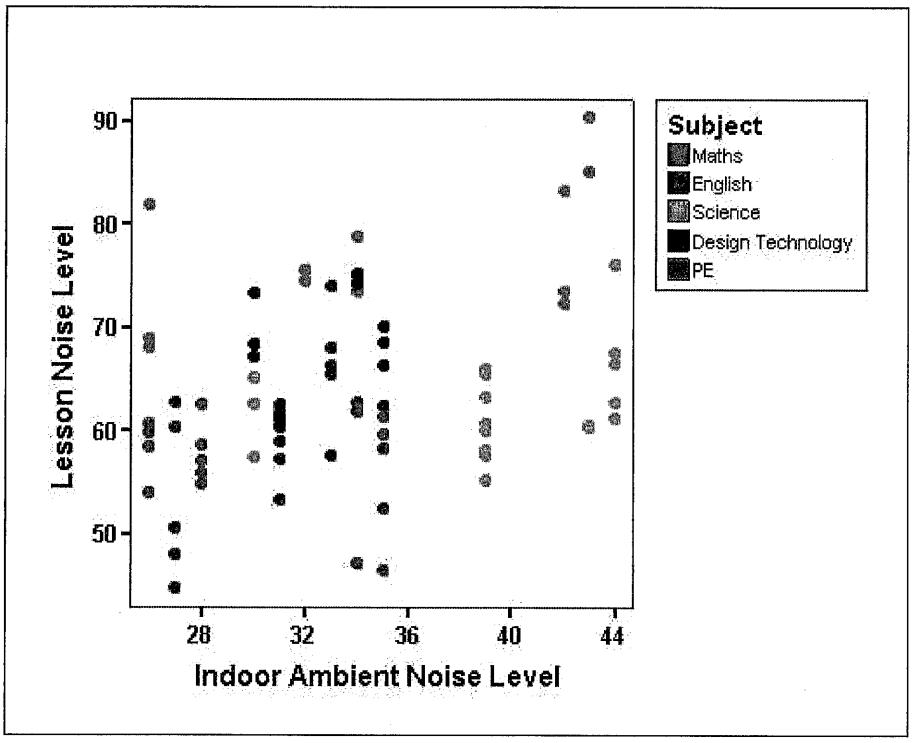

Figure 3. Comparison of lesson and indoor ambient noise levels.

It can be seen that there is a general positive trend for lesson noise levels to increase with increasing indoor ambient noise level within some subjects. From Figure 3 it appears that this trend

is particularly strong for English lessons. Further analysis is required to investigate these trends further.

5.2 Reverberation time

Figure 4 compares measured lesson noise levels for each subject with the measured reverberation times of each classroom. The comparison again shows that there is a positive trend, indicating that lesson noise levels are higher in classrooms with longer reverberation times.

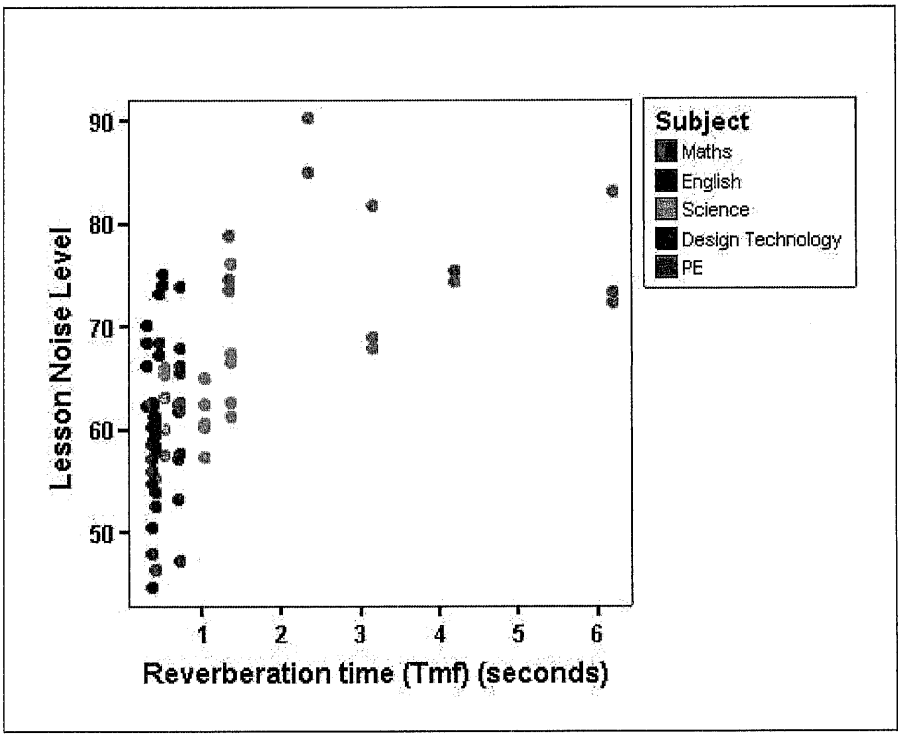

Figure 4. Comparison of lesson noise levels and reverberation times

Lesson noise levels might be louder in the more reverberant rooms because the Lombard effect is more pronounced, and noise levels increase quickly, making speech communication between the occupants without voice levels rising and the control of incidental noise harder. The trend is most pronounced for PE sports halls and gyms, where the highest lesson and activity noise levels occur, and the longest reverberation times were measured. However it is also observed for the classrooms used in the other subjects. The trend for rooms with shorter reverberation times will be examined in more detail when more data is available.

5.3 Speech Transmission Index

STI is dependent on reverberation time so it is to be expected from the discussion above that trends would also be observed when comparing lesson noise levels and STI. This can be seen in Figure 5 which plots lesson noise against STI rating. The figure shows that there is a negative trend, with lesson noise levels being higher in classrooms with a lower STI, and lower in rooms with a higher STI. Thus lessons are quieter in classrooms with better speech intelligibility. The trend is most

pronounced for PE sports halls and gyms, where the highest lesson noise levels were observed and longest reverberation times measured. However it is also observed for some classrooms used for other subjects. Again these effects will be examined in more detail with more data in future.

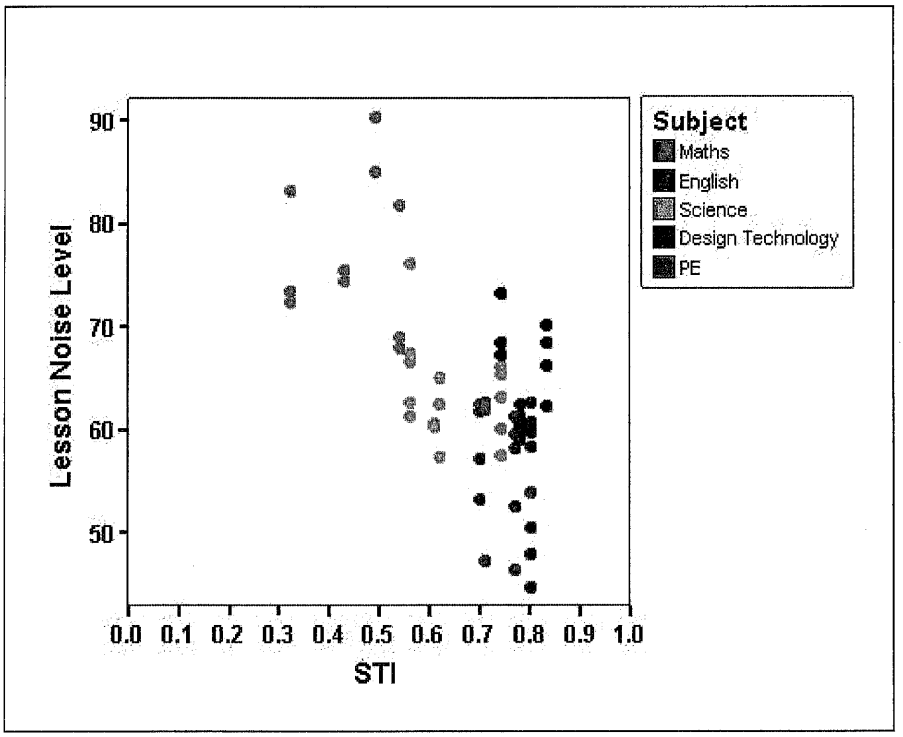

Figure 5. Comparison of lesson noise levels and STI

5.4 Age and number of pupils

The UK school curriculum is divided into a number of 'Key Stages' which represent different levels of educational knowledge that each pupil progresses through. In secondary schools there are three Key Stages for pupils in the age range of 11 to 18 years (Key Stage 3: 11 – 14 years; Key Stage 4: 15 – 16 years; Key Stage 5: 17 – 18 years). In this section these three Key Stages are used as an indicator of pupil age. Figure 6 shows the mean lesson noise level for each Key Stage (n = number of samples). The figure shows that there is little difference between the levels for Key Stages 3 and 4, but that the lesson noise level decreases at Key Stage 5. This could be due to a number of factors.

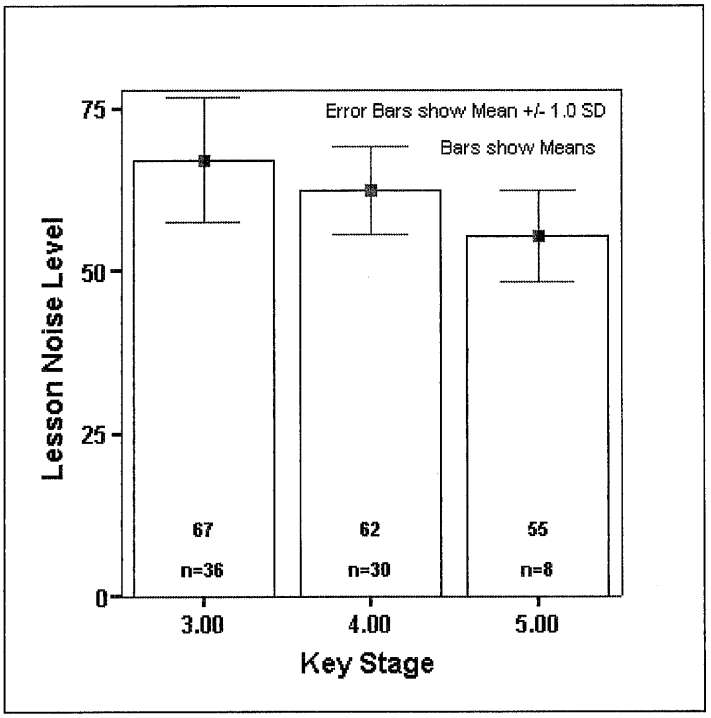

Figure 6. Average lesson noise levels for Key Stages 3, 4 and 5

As the number of pupils in a lesson increases the lesson noise levels increase. Figure 7 shows the effect of the number of pupils on the lesson noise level. The scatter of the data in Figure 7 is currently quite diffuse however a general positive trend is shown. It is expected that as more data are collected this relationship will become more apparent. The data in this plot have been categorised to show the number of pupils present in lessons at different Key Stages. It can be seen that the number of pupils in lessons at Key Stages 3 and 4 ranges from less than 10 to approximately 30, whereas the number at Key Stage 5 is less than 20. This suggests that a possible reason for lower lesson noise levels at Key Stage 5 is that there are fewer pupils in each lesson. It is also likely that the lessons at this stage involved quieter activities than those at the earlier stages.

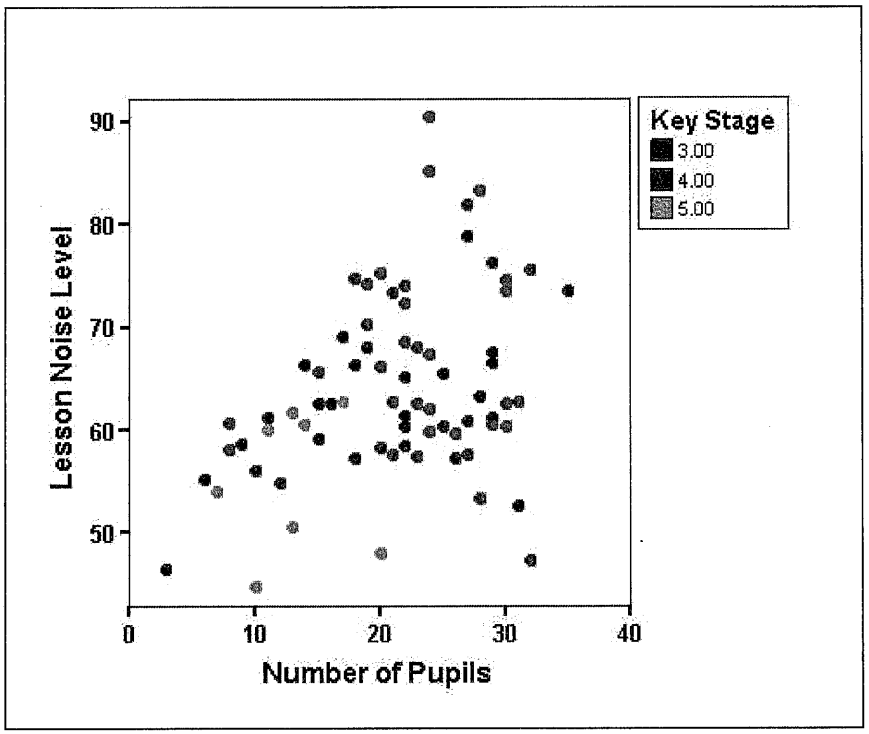

Figure 7. Lesson noise levels at Key Stages 3, 4 and 5 compared with numbers of students.

6 SUMMARY AND CONCLUSIONS

This paper has presented some preliminary noise level and room acoustic data collected from classrooms in four schools in the south east of England. Seventy six lessons were observed in 22 classrooms. The effects on occupied noise levels of a range of classroom based and room acoustic factors were examined.

The quietest lesson noise levels were observed in Maths and English lessons. The highest lesson noise levels were observed in PE lessons. Lesson noise levels were shown to be influenced by the lesson activity, relationships were also revealed that suggest that a classroom's indoor ambient noise level, reverberation time and STI have an effect the lesson noise level. The number and age of pupils in the classroom also appears to have an effect on noise levels.

As found in a previous survey of noise in primary school classrooms, the lesson noise depended on the activities being undertaken. The quietest activity was individual work, where pupils are engaged in near silent study. The noise level observed for this activity were similar to the levels reported by other researchers for similar activities. The most common, Activity 2 (and second quietest), was instruction/discussion, where typically one person is speaking at a time, for example the teacher instructing the class or the class are engaged in a teacher led discussion. This activity occurred in 47% of the observed lessons. These activities were most often observed in Maths and English classrooms. The loudest activities were Sports and Design and Technology (practical). Sports activities typically involve a great deal of pupil movement and loud inter-pupil communication. Design and Technology (practical) lessons also involve pupil movement and also the use of machinery, such as belt sanders and lathes. Both of these activities occurred only in PE and Design and Technology lessons and explain why the noise levels in these lessons were the highest.

When the indoor ambient noise level for individual classrooms was compared with lesson noise level a general positive trend was found, indicating that lesson noise levels are louder in classrooms with a higher indoor ambient noise level. The majority of classrooms comply with BB 93 performance specifications for indoor ambient noise levels, in particular all of the Maths, English and Design and Technology classrooms surveyed. Only four rooms did not comply with the current standard: two science laboratories and two PE halls.

A positive trend was observed when the measured reverberation time for each classroom was compared with lesson noise levels, hence indicating that lesson noise levels are louder in classrooms with longer reverberation times. The PE sports halls and gyms had the longest reverberation times of all the rooms, ranging from 1.35 to 6.19 seconds. These rooms have the largest room volumes and typically had very little or no acoustic treatment. With one exception, all PE rooms exceeded the BB 93 performance specifications for indoor sports halls. The other subjects had much shorter reverberation times, ranging from 0.38 to 1.36 seconds. The rooms used for these subjects typically had a smaller room volume and acoustic treatment, most commonly a suspended ceiling with acoustically absorbing panels. The majority of these classrooms met the BB 93 performance specifications.

A negative trend was observed when the calculated STI for each classroom was compared with lesson noise levels, indicating that lesson noise levels are louder in classrooms with a lower STI and quieter in rooms with a higher STI. The PE halls, which had the longest reveberation times, had the lowest STI ratings, indicating that the speech intelligibility is 'poor'. The classrooms used for other subjects had STI ratings of 'good' or 'excellent'.

It was shown that lessons at involving the older pupils are quieter than those of the younger pupils. A positive trend was observed when the number of pupils in each lesson was compared with the lesson noise levels, suggesting that as the number of pupils in a lesson increases the lesson noise levels increase. It was shown that the number pupils in lessons at Key Stages 3 and 4 ranges from less than 10 to approximately 30, whereas the number at Key Stage 5 is less than 20. This suggests that a possible reason for lower lesson noise levels at Key Stage 5 is that there are fewer pupils in each lesson. It is also likely that the lessons of the older students will involve the quieter activities.

The work presented here will be expanded upon by collecting further data from a larger number of secondary schools. From this it is hoped that reliable statistical assumptions can be made of the influence on lesson noise levels of these and other factors present in UK secondary school classrooms.

7 REFERENCES

1. Sheild, B.M. and Dockrell, J.E. (2003) The effects of noise on children at school: a review. Journal of Building Acoustics, 10(2), 97-106.

2. Evans, G.W. and Lepore, S.J. (1993) Nonauditory effects of noise on children: a critical review. Children's Environments, 10(1), 31-51.

3. Shield, B.M. and Dockrell, J.E. (2008) The effects of environmental and classroom noise on the academic attainments of primary school children. Journal of the Acoustical Society of America 123(1), 133-144.

4. Department for Education and Skills (2003), Building Bulletin 93 Acoustic Design of Schools, www.teachernet.gov/acoustics

5. Shield, B.M. and Dockrell, J.E. (2004) External and internal noise surveys of London primary schools. Journal of the Acoustical Society of America 115(2), 730-738.

6. MacKenzie, D. (2000) Noise sources and levels in UK schools. Proc. International symposium on Noise Control and Acoustics for Educational Buildings, Proc Turkish Acoustical Society, Istanbul, May 2000, 97-106.

7. Hodgson, M. (1994) UBC-classroom acoustical survey. Canadian Acoustics, 22(4), 3-10.

8. BS EN 60268-16 (2003): 'Objective rating of speech intelligibility by speech transmission index'.