London South Bank University

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An Investigation into the Effects of Classroom Acoustics on Teachers' Voices

Nicholas David Durup

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First Supervisor: Dr S. Dance, London South Bank University

Second Supervisor: Professor Emerita B. Shield, London South Bank University

Third Supervisor: Dr R. Sullivan, Sharps Redmore Acoustic Consultants

http://orcid.org/0000-0002-4824-320X

Declaration

This thesis is submitted to London South Bank University in support of my application for the degree of Doctor of Philosophy.

I, Nicholas Durup, declare that the work, research and results presented within this thesis are my own, having been generated by myself as a result of my own original investigation and research and have not been submitted in any previous application for any degree at any institution.

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Nicholas Durup

Preface

I have always been fascinated with all things related to sound ever since I can remember. This has led me through the playing of musical instruments and Technics 1210s to building loudspeakers and recording, via sound engineering at concerts and conferences and finally into acoustic consultancy and research.

I have been fortunate to meet inspirational people throughout this journey who have fired my imagination and guided me to the next step. I owe a great debt to those who have helped me along this path which has taken me to places, and enabled experiences I never expected in a field which I find endlessly fascinating.

Nick Durup

Ely, December 2017

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Glossary

To assist the reader, this section includes details of technical terms, abbreviations and their definitions as used in this thesis.

Term	Abbreviation	Units	Definition
A-weighting	dBA	-	Frequency specific weightings for sound across the frequency range to mirror the ear's response.
Absorption coefficient	α	-	The ratio of sound absorbed by a material to the sound incident upon its surface, 0 is total reflection, 1 is total absorption.
Acoustic absorption	A	m^2 Sabine	The amount of sound absorption in a room.
Acoustic absorption mid-frequency	A_{mf}	m^2 Sabine	The amount of sound absorption in a room in the 500, 1 k and 2 kHz octave bands.
Approved Document E	ADE	-	The Building Regulations Resistance to the passage of sound Approved Document E (various versions).
Ambient noise level	-	Decibels	Noise levels that do not include school activity noise but include traffic, mechanical services and other environmental noise sources.
Ambulatory Phonation Monitor	APM	-	A portable device worn by a participant which is able to measure parameters of vocal behaviour.

Term	Abbreviation	Units	Definition
Association of Noise Consultants	ANC	-	UK-based organisation of companies that are engaged in the business of acoustics, noise and vibration consulting.
Aphonia	-	-	Absence of voice.
Alternative performance standards	APS	-	Alternative criteria to those in BB93 which can be proposed on a project.
Arithmetic average	-	-	The arithmetic averaging of noise data as opposed to logarithmic averaging.
A-weighted sound pressure level	dBA	Decibels	A sound pressure level which has had an A-weighting applied.
Background noise level	L_{90}/L_{A90}	Decibels	L_{90} is the sound pressure level exceeded 90% of the measurement time.
British Association of Teachers of the Deaf	BATOD	-	Professional association for teachers of the deaf in the UK.
Building Bulleting 93	BB93	-	Explains minimum performance standards for the acoustics of school buildings. Editions published in 2003 and 2015.
Building Research Establishment Environmental Assessment Method	BREEAM	-	A method of assessing, rating, and certifying the sustainability of buildings used by the Building Research Establishment.
British Standards Institute	BSI	-	The national standards body of the UK.

Term	Abbreviation	Units	Definition
Building Control Body	BCB	-	Has the role of checking that building regulations are being complied with. BCBs are either Local Authority or Approved Inspectors.
Chi-square test for independence	X^2	-	A statistical test used to determine if there is a significant relationship between two categorical variables.
Correlation coefficient	p	-	A numerical measure of a statistical relationship between two variables.
Decibel	dB	Decibels	A unit used to measure the intensity of a sound by comparing it with a given reference level using a logarithmic scale.
Degrees of freedom	df	-	Equivalent to the number of possible outcomes minus one.
Direct field	-	-	The region where the direct sound from the source is dominant.
Dysphonia	-	-	Voice disorder.
Early decay time	EDT	Seconds	A reverberation time parameter calculated from the initial decay from 0 dB to -10 dB and represents initial reflections from nearby surfaces.
Early decay time mid frequency	EDT_{mf}	Seconds	EDT values arithmetically averaged for the 500, 1 k and 2 kHz octave bands.

Term	Abbreviation	Units	Definition
Equivalent continuous sound pressure level	$L_{eq,\ T}$	Decibels	The equivalent constant sound pressure level of a time-varying signal that has the same total energy over the same time period. L_{Aeq} is the A-weighted value.
Fundamental frequency	SF_0	Hertz	The voice fundamental frequency is the lowest frequency in the periodic waveform of the voice's acoustic output.
Hertz	Hz	Hertz	SI unit of frequency, 1 Hz is equal to 1 cycle per second.
Health and Safety Executive	HSE	-	The body responsible for the encouragement, regulation and enforcement of workplace health, safety and welfare in the UK.
Impulse response	-	-	A plot of sound pressure, by time, as a result of an impulsive excitation of the room with a Dirac Delta function.
Independent-samples t-test	-	-	Compares the means of two independent groups to determine if the population means are significantly different.
Indoor ambient noise level	IANL	Decibels	The unoccupied, internal, ambient noise level (L_{Aeq}) as defined in BB93. Measured in the absence of school operational noise.
Institute of Acoustics	IoA	-	The UK's professional body for those working in acoustics, noise and vibration.

Term	Abbreviation	Units	Definition
Independent School Standards Regulations	ISS	-	Equivalent of SPR for independent schools.
Logarithmic average	Log. av.	-	Averaging of noise data by logarithmic rather than arithmetic averaging.
Lombard effect	-	-	An involuntary response whereby the speaker modifies their voice level, SF_0, speech speed and syllable duration to enhance audibility.
Maximum noise level	L_{fmax}	Decibels	The maximum sound pressure level during the measurement period. L_{Afmax} is the corresponding A-weighted value.
Mid frequency reverberation time	T_{mf}	Seconds	Arithmetic average of the RT_{60} values in the 500, 1 k and 2 kHz octave bands.
Near field	-	-	In the immediate vicinity of a sound source. Here the sound pressure level may not decrease with distance.
Octave bands	-	Hertz	The audible frequency range is divided into sets of frequencies an octave in width. The upper band frequency is twice the lower band frequency.

Term	Abbreviation	Units	Definition
Office for Standards in Education, Children's Services and Skills	Ofsted	-	Ofsted is responsible for inspecting a range of educational institutions, including state schools and some independent schools.
Phonation	-	-	The production or utterance of speech sounds.
Phonation percentage	Phonation %	%	The phonation percentage is the phonation time as a percentage of the measurement period.
Phonation time	$T_{phonation}$	Seconds	Phonation time is the length of time (seconds) for which the vocal folds are producing speech excluding gaps or pauses.
Phoniatrics	-	-	The medical speciality of voice, speech, language, hearing and swallowing disorders.
Reverberant field	-	-	In this region the sound level is constant and sound is diffused. The level does not change with distance from the source.
Reverberation time	RT_{60}	Seconds	The time in seconds for sound in an enclosed space to reduce by 60 decibels once interrupted, from -5 dB to -65 dB.
Room radius	-	Metres	The distance from a noise source when the direct component and the reverberant component of the sound are equal.

Term	Abbreviation	Units	Definition
Signal-to-noise ratio	SNR	Decibels	The difference in decibels between wanted sound such as the teacher's voice, and unwanted sound such as traffic noise.
Sound Level Meter	SLM	-	Electronic device for measuring variations in sound pressure levels.
Sound pressure level	SPL, L_p	Decibels	A logarithmic measure of the effective pressure of a sound relative to a reference value of 2 x 10^{-5} Pascal (SI unit of pressure).
Speech intelligibility	-	-	How comprehensible speech is in given conditions.
Speech Transmission Index	STI	-	A method of quantifying how a given space will affect intelligibility. STI has a value between 0 and 1, the higher the value the better the speech intelligibility.
School Premises Regulations	SPR	-	Prescribes standards for the premises of all Local Authority maintained schools in England.
Standard deviation	*SD*	-	A quantity expressing by how much the members of a group differ from the mean value for the group.
T_{20} reverberation time	T_{20}	Seconds	A measurement of reverberation time over the -5 to -25 dB decay, this is multiplied by a factor of three to give the RT_{60} value.

Term	Abbreviation	Units	Definition
T_{30} reverberation time	T_{30}	Seconds	A measurement of reverberation time over the -5 to -35 dB decay, this is multiplied by a factor of two to give the RT_{60} value.
Unoccupied ambient noise level	UANL	Decibels	Unoccupied internal noise level parameters measured in the absence of school operational noise.
Variance	-	-	Variance is a measurement of the spread between numbers in a data set.
Vocal Fold Distance	VFD	Metres	Total movement of vocal folds includes SF_0 and phonation time.
Vocal loading	-	-	Vocal loading describes additional vocal demands resulting from occupational voice use.
Vocal loading index	VLI	-	A measure of relative ‘work’ done by the voice system incorporating phonation time and SF_0.
Voice level	$L_{pZ,\ 1\ m}$	Decibels	Voice level given as a linear sound pressure level at 1 m from the mouth.
World Health Organisation	WHO	-	A specialised agency of the United Nations that is concerned with international public health.

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Abstract

The acoustic design of classrooms has traditionally focused on pupils hearing the teacher. There is a need for guidance on the consideration of voice ergonomics for teachers in classroom design.

This project undertook measurements of teachers' voices in classrooms with different acoustic properties to examine possible relationships between voice parameters and classroom acoustics. The mean voice level measured was classified as 'loud' (based on guidance values) and the participants spoke for a large proportion of the day (average 21%).

Those teaching in rooms with higher unoccupied noise levels spoke with a higher sound level. There was a significant, moderate, positive correlation between voice levels in female participants and the unoccupied noise levels in the same region of the noise spectrum as the fundamental frequency of the female voice. There were signs of a similar relationship for male participants. This indicated that the control of low frequency noise levels and reverberation times (not currently covered by schools guidance documents in England) may be important in reducing voice levels and the associated vocal risks.

An online survey was also undertaken which gathered 153 responses and included questions on voice problems, voice training, classroom acoustics and general health.

The respondents reported a number of interesting findings. 66% reported having experienced voice problems, with many continuing to work despite these problems. A relatively small proportion of respondents had received voice training (41%), and many reported shouting or raising their voice.

There were greater rates of reported voice problems in teachers of young children and those teaching in open plan classrooms. Subjectively the main acoustic issues for teachers were inadequate internal sound insulation and excessive reverberation. External noise intrusion was not reported as significant.

Chapter 1 Introduction and research objectives

The voice is an essential communication tool and an intrinsic part of an individual's personality and identity. With the change in occupations away from mass industrial and manual employment in post-industrial economies, a greater proportion of the population now depend on their voice as an essential part of their professional lives.

Teaching is one such occupation with a heavy reliance on the voice. There are indications that teaching may carry a significant risk of developing voice problems. The size of the teaching population means that such problems have the potential to affect large numbers of people.

The acoustic design of classrooms has predominantly been driven by the aim of ensuring that pupils can hear the teacher clearly. The voice ergonomics of the teacher would not normally be considered.

This project has been born out of the need for guidance for those involved with the acoustic design in schools in terms of whether classroom acoustics play a role in how the teacher's voice is used, and how the voice ergonomics of teachers can be considered in practical terms.

This thesis aims to examine the relationship between classroom acoustic conditions and voice parameters in teachers as well as exploring teachers' subjective impressions of voice problems and classroom acoustics.

The thesis has two main strands:

1) Measurements of the voice parameters of teachers speaking in various classroom types with different acoustic conditions, the aim being to understand whether classroom acoustics have a relationship with teachers' voice parameters and hence with potential voice problems.
2) An online questionnaire for teachers to gather subjective data on their experiences of voice problems, voice training and classroom acoustics in general. The motivation for this is to gain insight into the subjective impressions teachers have of the rooms they teach in, and to examine their experiences of voice problems in more detail.

The thesis begins with a brief explanation of how the human voice operates and describes the common voice parameters.

There then follows a review of voice problems in general, their prevalence among teachers, the impacts of such problems, the associated risk factors and voice training.

This is then followed by a chapter covering classroom acoustics and a further chapter on current acoustic guidance and legislation. In the final background chapter, the current literature on the effects of classroom acoustics on the teacher's voice is summarised.

The methodology developed for measuring the teacher's voice is then detailed, together with the selection of instrumentation and the pilot study. The voice and acoustic surveys carried out are described along with results and analysis of the voice measurements survey.

The second element of the thesis describes the development of the online survey for teachers (including the pilot study), presenting the results and analyses undertaken.

The outcomes of the two strands are summarised in the conclusions chapter which also includes details of further work that could be undertaken to develop and extend the research undertaken in this thesis.

The appendices include details of template health and safety checklists and further information on the ethical approval process, as well as copies of the invitation letter, participant information sheet, consent forms and participant questionnaires used in the voice measurements element of this thesis. Data on occupied and unoccupied classroom noise levels is also included as is a copy of the online questionnaire. Details of journal and conference papers which have been published, and presented, in relation to this thesis are included in an additional appendix. The penultimate appendix contains enlarged images from the APM software and the final appendix includes a copy of the presentation given by the author at the viva voce examination.

Chapter 2 The teacher's voice

The first section of this chapter will provide a brief introduction to the voice and how it operates; the second section will detail the main voice parameters used to quantify the voice.

2.1 The human voice

Speech is a complex pattern of behaviour which involves the conversion of emotions, language and concepts in the brain into sound via the control and articulation of various structures in the body. The physical mechanisms involved are shown schematically in Figure 2.1.

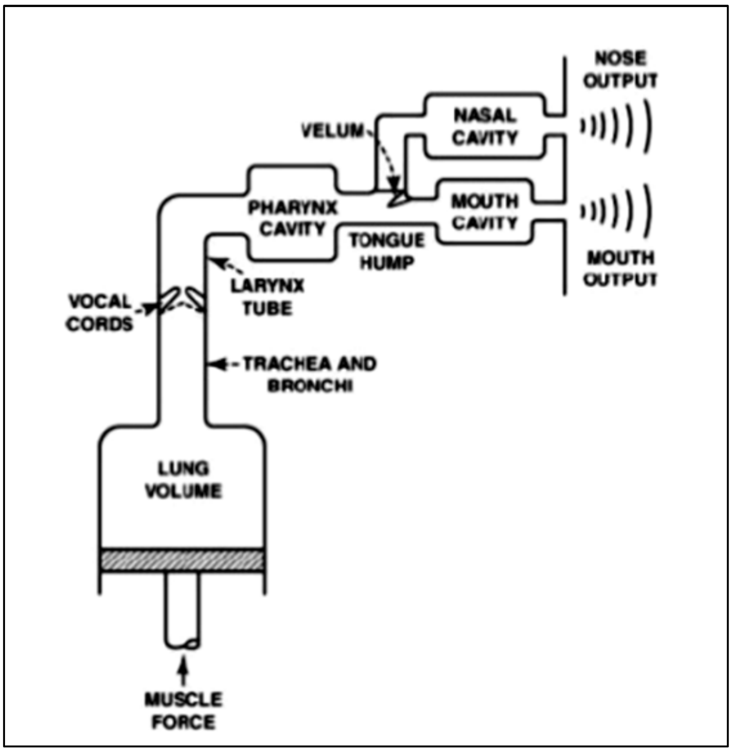


Figure 2.1: Vocal schematic [1]

Sound generation starts with air from the lungs and diaphragm passing through the larynx tube where it is modulated by the vocal folds which are able to close and open within the airflow to effectively vary the resonant qualities of the tube. This is where voice pitch and tone is controlled. Sound is further controlled by the mouth, nose and throat providing articulation for speech. The anatomy of the speech production mechanisms are shown in Figure 2.2.

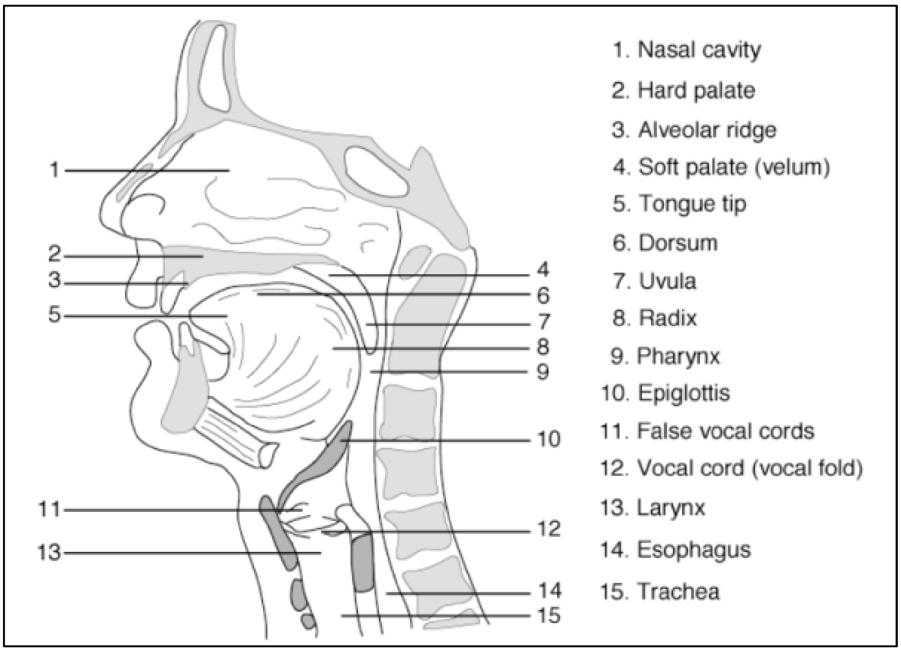


Figure 2.2: The anatomy of the speech production mechanism [2, fig. 5.2]

The larynx is shown in Figures 2.3 and 2.4 and generates sound by the vocal folds temporarily blocking (termed adduction - see Figure 2.4) and releasing (abduction) the flow of exhaled air. This generates pressure pulses which determine the speech fundamental frequency (SF_0) (see section 2.2.1) and contribute to the perceived pitch of the voice.

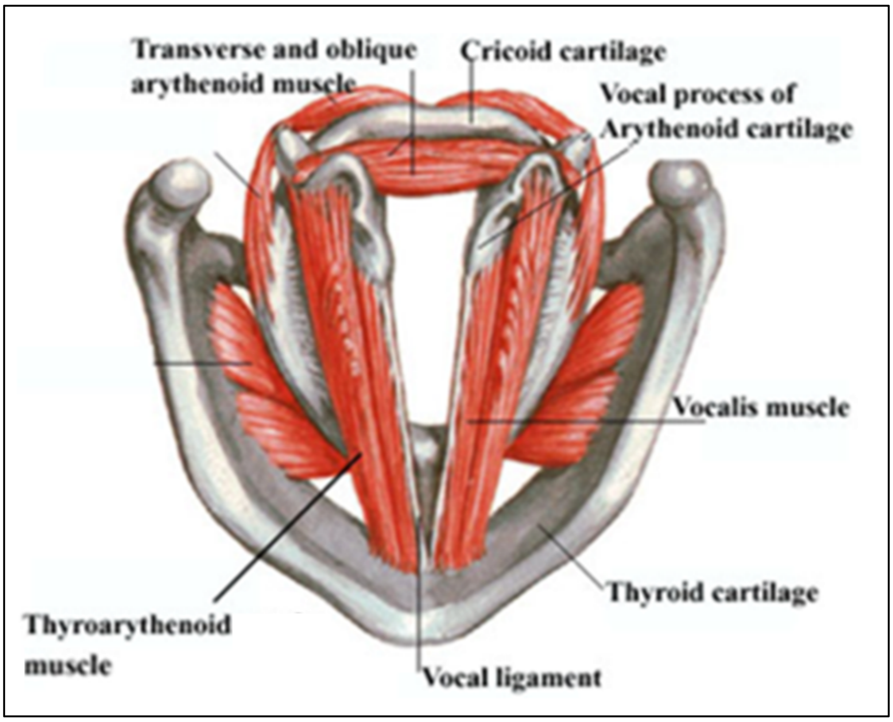


Figure 2.3: Larynx anatomy detail [3]

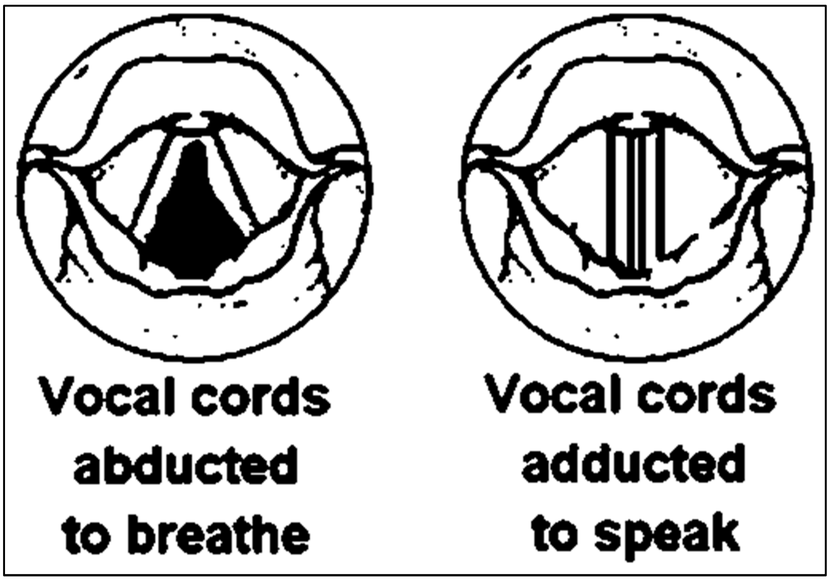


Figure 2.4: Vocal folds abducted and adducted [4]

2.2 Voice parameters

The voice can be quantified using a number of parameters which enable objective comparisons between different individuals and groups. These are fundamental to investigating potential relationships between voice behaviour and external factors.

2.2.1 Speech fundamental frequency (SF_0)

The natural speaking fundamental frequency SF_0 varies by gender and age and has the potential to be altered by voice use. It is a function of vocal fold dimensions and tension. The mean values of SF_0 by age and gender for adults are shown in Table 2.1 [112].

Table 2.1: Mean SF_0 in adults by age [77] and overall [6]

Age (years)	Mean SF_0 Hz	
	Male	Female
20-29	120	224
30-39	112	213
40-49	107	221
50-59	118	199
60-69	112	199
Overall [6]	128	225

The significantly higher mean SF_0 in women would be expected to result in a greater vocal load, or vocal dosage, for a given phonation time if all other factors are equal [7]. Research by Jian *et al.* (1994) indicated that speaking at a higher SF_0 increases the number and force of impacts between the vocal folds with an associated risk of voice fatigue and problems [8]. The SF_0 gender difference may be a factor in the apparent higher prevalence of voice problems in women in general, and in women teachers, as discussed in section 3.5.5.

The mean SF_0 typically decreases with age after peaking at age 20-29 meaning that the youngest teachers (of both genders), with the least workplace voice use experience, would typically have the highest SF_0 value, and potentially the highest voice loading if other risk factors such as phonation time (see section 2.2.2) were equal.

The relative SF_0 values for adults and children are important, as for the signal-to-noise ratio in classrooms, the noise is often the speech signal from pupils. SF_0 varies with age differently for boys and girls as they move through puberty and adolescence. For young children of both genders the SF_0 would normally be in the range 250-400 Hz [9].

Girls have the highest mean SF_0 at around 7-8 years of age reducing to an adult level between ages 11-15. Therefore many children would have the same SF_0 range as female teachers with implications for the signal to noise ratio in the frequency domain. This may be a contributing factor to the seemingly greater prevalence of voice problems in teachers of younger children as discussed in section 3.5.1.

2.2.2 Phonation time

Phonation time is the length of time (seconds) for which the vocal folds are producing speech excluding gaps or pauses. The percentage value is the phonation time as a percentage of the measurement period and allows for relative comparisons between speakers.

Teachers necessarily spend a large proportion of their working life speaking for extended periods and this cannot be readily avoided.

A number of studies have looked at typical phonation time percentages for teachers while at work, compared with non-occupational use, as well as with other professions. These are summarised in Table 2.2.

Table 2.2: Phonation time percentages for teachers

Reference	Phonation time %		
	Teachers occupational voice use	Teachers non-occupational voice use	Other professions voice use
Masuda *et al.* (1993) [10]	21%	-	Office workers 7%
Titze *et al. (*2007) [11]	23%	12%	-
Sala *et al.* (2002) [12]	40%	-	Nurses 28%
Rantala *et al.* (1994) [13]	25-40%	-	-
Hunter *et al.* (2010) [14]	30%	14%	-

Based on the data in Table 2.2 teachers have a high phonation time percentage, comparable to that of nurses and around three times that of office workers. The phonation time percentage during teaching is significantly higher than when not working.

It has also been found that among teachers as well as having high phonation times, half of this phonation was at a high voice level of 80 dB $L_{pZ,\ 0.2\ m}$, or above [10]. This indicates that high phonation times may modify the natural speaking voice level.

A study by Shield *et al.* (2015) [15] of secondary schools found that plenary sessions with the teacher speaking accounted on average for 46% of lesson time. Although different to the phonation time percentage, this indicates that teachers may speak for almost half of lesson times. For teachers of younger children, the phonation time percentage is likely to be higher than for older children due to the greater amount of oral instruction involved.

It is important to consider that the phonation time factor is not restricted solely to voice use in the workplace. Unlike some other workplace hazards such as manual handling, chemical or noise exposure, voice use is a fundamental part of general life. Therefore how an individual uses their voice outside the workplace will also have a bearing on the overall phonation time and percentage. It is possible for two individuals with similar workplace voice uses to have different leisure voice use resulting in different overall patterns of phonation and a different voice problem risk profile as a result.

2.2.3 Vocal loading

Vocal loading describes additional demands resulting from occupational voice use and is considered as a significant contributor to voice problems [16]. These demands include a number of different factors which have been identified in the literature [17] and are summarised below:

- Amount of voice use
- SF_0
- Voice level
- Phonation time
- Voice quality

Vocal loading does not appear to carry the same risk of developing voice problems for all individuals. Some individuals appear to have a greater pre-disposition to voice problems when under the same vocal loading [18]. Speaking in classrooms with high noise levels has been reported in studies to increase vocal loading [19] and to be a primary risk factor relating to voice problems for teachers [20, 21].

2.2.4 Voice dose parameters

It has been suggested in the literature that vocal loading can be considered analogous to exposure to the sun or chemicals. Such exposures are normally quantified in terms of a dosage and a similar approach has been proposed in the literature for vocal loading.

An index of vocal loading [22] is given by the Vocal Loading Index (VLI) defined by:

$$VLI = \frac{SF_0 \times t_{Phonation}}{1000}$$

The study in which the VLI was proposed showed that phonation time, $t_{Phonation}$, rather than SF_0 was the dominant risk factor, with the implication that rest periods and the planning of teaching timetables could be used to mitigate some of the risks of voice problems. One study [23] found that there was a strong correlation between phonation time (termed 'time dose' in the study) and subjective and objective voice problems. Dose parameters have been further developed by other researchers with the proposal of other metrics which are summarised in Table 2.3 [7].

Table 2.3: Voice dose parameters

Parameter	Abbreviation	Unit	Notes
Time dose	D_t	s	Phonation time only
Vocal loading index	VLI	-	Includes SF_0 and phonation time
Distance dose	D_d	m	Total movement of vocal folds includes SF_0 and phonation time
Energy dissipation dose	D_e	J m^{-3}	Energy dissipated over unit volume of vocal folds
Radiated energy dose	D_r	J	Total energy radiated from mouth during phonation

There are currently no definitive safety limits against which the various dose parameters can be assessed. Titze *et al*. (2003) [24] proposed that the vibration exposure of the vocal folds could be considered analogous to hand-arm vibration dose limits, in which a safe dose limit was approximately 520 m. The pauses in voicing in normal speech are hypothesised by Titze *et al.* (2003) [24] to aid recovery of the vocal folds and extend the effective safe dose limit. In addition there are significant differences between vocal fold and hand/arm tissues and structures, with the former perhaps being better adapted to cope with vibration compared with the latter, meaning that the dose limits may not be interchangeable and further research and refinement is needed to determine suitable safe limits.

2.3 Voice levels of adults and children

Early studies established nominal voice levels but were often undertaken in low ambient noise levels, which did not represent normal speaking conditions [25, 26, 27]. Subsequently researchers undertook measurements to examine the influence of ambient noise level on voice levels, such as the Lombard effect [28], however, these were undertaken in laboratory rather than field conditions [29]. Mean sound pressure levels for adults speaking at different voice levels, used in different standards, are summarised in Table 2.4.

Table 2.4: Average voice effort levels for adults

Source	Parameter	Voice level at 1 m						
		Relaxed	Normal	Raised	Loud	Very loud	Shout	Max
IoA/ANC Acoustics of Schools Design Guide [30]	dBA	-	60	70	-	-	80	-
BS ISO 9921-1 1996 and 2003 (male speaker) [31, 32]	dBA	54	60	66	72	78	84	90
ANSI S3.5:1997 [33] (male & female speakers)	dB	-	62	68	75	-	82	-

The average voice levels in Table 2.4 do not take account of gender and age differences which are shown in Table 2.5 [34]:

Table 2.5: Mean dBA and dBZ voice effort levels for adults and children in anechoic conditions [34]

Speaker	Age	Voice level dBA at 1 m (dBZ)				
		Casual	Normal	Raised	Loud	Shouted
Female	13-60	50 (54)	55 (58)	63 (65)	71 (72)	82 (82)
Male	13-60	52 (56)	58 (61)	65 (68)	76 (77)	89 (89)
Young children	Under 13	53 (56)	58 (61)	65 (67)	74 (75)	82 (82)

The values in Tables 2.4 and 2.5 are not for teachers specifically, and were measured under laboratory conditions. Teachers may speak in a different manner to conversational speech when teaching and therefore these levels may not be representative.

A study by Pearsons *et al.* (1977) [34] reported that mean voice levels for teachers in the classroom were 13 dB higher than for non-occupational voice use. There is likely to be variability between individuals when requested to speak at self-determined voice levels. Individuals may identify the voice level they use the majority of the time as a 'normal' level.

The values in Table 2.5 indicate that female teachers who teach children under 13 would have dBZ voice levels 2-3 dB below those of their pupils in the 'casual', 'normal', 'raised' and 'loud' voice levels. Therefore if, for discipline or instructional reasons, the teacher had to speak over pupils who were also speaking then they may need to raise their voice above the 'normal' level. A number of studies that have looked specifically at teachers' voice levels are summarised in Table 2.6.

Table 2.6: Summary of average voice levels for teachers

School type	Gender	Average voice level at 1 m dBA	Reference
Primary	All	72	[35]
Primary	Female	72	
Primary	Male	69	
Secondary	All	65	[36]
Secondary	All	71	[34]
Primary	Female	61 (dBZ)	[37]
Primary	Male	55 (dBZ)	[37]

The levels in Table 2.6 are all above 'normal' based on Table 2.5 and may represent a significant voice problem risk factor. Where data was split by gender, females had higher voice levels than males, which is the opposite of data for the general population (see Table 2.5).

The variation in frequency content is shown in Table 2.7 and Figure 2.5 for different voice levels and speaker groups [34].

Table 2.7: Average voice level $L_{pZ,\,1\,m}$ dB spectrum for different voice levels and speakers [34]

Vocal effort	Speaker	Octave band centre frequency Hz				
		250	500	1 k	2 k	4 k
Casual	Men	50	51	43	41	39
	Women	49	50	42	39	35
	Children	49	52	45	42	38
Normal	Men	55	58	51	47	43
	Women	51	54	49	44	43
	Children	53	56	51	46	44
Raised	Men	59	64	59	54	49
	Women	55	60	58	54	49
	Children	56	61	60	56	52
Loud	Men	65	72	71	66	60
	Women	58	64	67	64	57
	Children	56	64	67	65	58
Shouted	Men	70	80	84	80	73
	Women	56	70	77	76	69
	Children	55	70	76	75	70

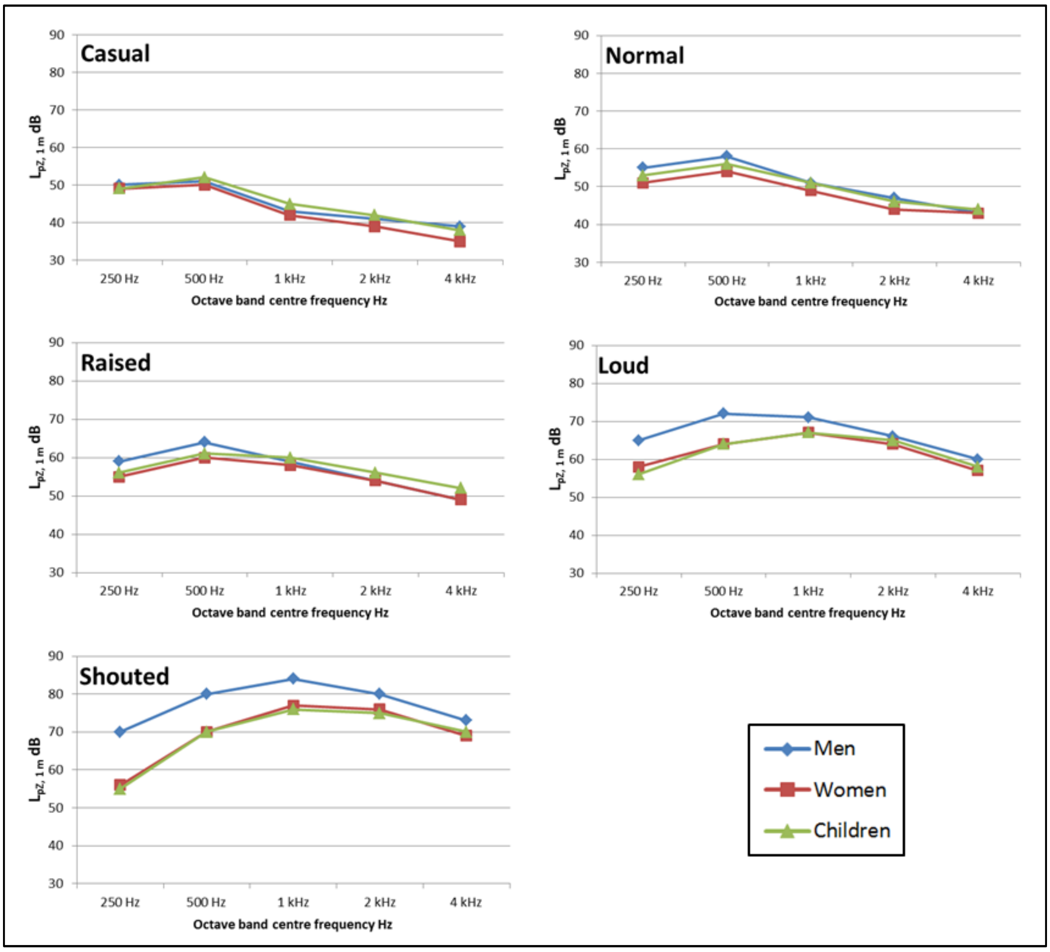


Figure 2.5: Average voice spectrum for different voice levels and speakers [34]

Table 2.7 and Figure 2.5 indicate that for 'casual', 'normal' and 'raised' speech, children have higher mean voice levels than female teachers and a similar spectrum shape, creating a potential signal to noise challenge.

In terms of the link to voice problems, studies have indicated that, for speech generated at higher sound pressure levels, the resulting force between the vocal folds is increased, with an associated risk of voice fatigue and problems [8]. This suggests that teachers who raise their voices, for example, to maintain discipline, or to be heard above noise in the classroom, may increase the risk of vocal loading. Other studies have indicated that speaking at levels above 'normal' is likely to have adverse physical effects [38].

2.4 Signal to noise ratio

Signal to noise ratio (SNR) is the difference between the wanted sound such as the teacher's voice, and unwanted sound such as traffic noise. SNR is given as the decibel difference between the two signals and is a good indication of speech intelligibility at the listener position.

The SNR contributes to the audibility and intelligibility of the teacher's voice for pupils and largely determines how loud the teacher needs to speak to be heard and understood. The interference effect of noise is a function of the SNR, how the SNR varies with time and the relative spectral content of the speech and the noise [39]. BS ISO 9921-1:1996 Ergonomics Assessment of Speech Communication [31] includes guidance on suitable signal to noise ratios shown in Table 2.8.

Table 2.8: Signal to noise ratio at the listener [31]

Signal to noise ratio at listener's position dBA	Assessment
<-6	Insufficient
-6 to -3	Unsatisfactory
-3 to 0	Sufficient
0 to 6	Satisfactory
6 to 12	Good
12 to 18	Very good
>18	Excellent

Recommended SNR values given in the literature for classrooms include:

- 12 dB [40].
- 15 dB throughout the classroom [41].
- 15-20 dB [42, 43].
- High speech intelligibility 10 dB SNR and appropriate reverberation times [34].

2.5 Conclusions

Having identified the main voice parameters in this section, and typical values for these parameters for both the general and teaching populations, the next chapter will look at the issue of voice problems in teachers in terms of prevalence, costs and risk factors.

Chapter 3 Teachers' voice problems

This chapter will give further information on voice problems and will review the literature relating to voice problems specifically in teachers, risk factors and voice training.

In this thesis the teachers considered are those teaching in primary (children aged 5-11) and secondary schools (children aged 11-18). This reflects the remit of mandatory acoustic guidance in England (see Chapter 5). The English school system is organised as shown in Table 3.1.

Table 3.1: English state school system [44]

School	Key stage	School year	Typical age range
Primary	Reception and KS1	Years R - 2	4 - 7
	KS2	Years 3 - 6	7 - 11
Secondary	KS3	Years 7 - 9	11 - 14
	KS4 (GCSEs)	Years 10 - 11	14 - 16
Further	KS5 (AS-levels, A-levels, NVQs, HNDs	Years 12 - 13	16 - 18

3.1 Voice problems

3.1.1 Defining voice problems

There is no overarching definition of voice problems that is universally accepted. A number of authors have proposed definitions:

Aronson (1985) suggested that '*A voice disorder exists where the quality, pitch, loudness or flexibility differs from the voices of others of similar age, sex and cultural group*' [45, p. 7].

Moore (1971) considered that '*When an individual speaks habitually with a voice that differs in pitch, loudness, or quality from the voices of others of the same age and sex within his cultural group, he is considered to have a voice disorder….It follows that the perceived defectiveness of any one voice will vary among listeners without change in the actual voice. It is apparent that a voice is abnormal for a particular individual when he judges it to be so*' [46, p. 535].

Voice problems do not always have associated physical manifestations. For the purposes of this thesis, voice problems are considered as including conditions (with or without associated physical pathology) which cause sufficient concern or impediment for the individual to identify themselves as having voice problems or to seek treatment.

3.1.2 Causes of voice problems

Individuals from all parts of society suffer from occasional voice problems, such as sore throats or hoarseness. This can cause the subject of occupational voice problems in teachers, or others, to be trivialised, or seen as an unavoidable occupational hazard. In contrast to occasional issues, there are more serious conditions which can cause significant problems for the individuals who suffer from them.

Aphonia (absence of voice) and dysphonia (voice changes) can be caused by a range of functional issues in different body systems and for a variety of reasons including voice misuse, trauma, infections, stress and illness.

3.2 Teacher demographics

Teaching is a large profession globally and the number of people potentially affected could be very large if an enhanced risk of voice problems applies. There are estimated to be 506,000 full time teachers in the UK (604,000 including part time teachers). In England there are around 420,000 teachers based on the most recently available data [47-51].

Teaching assistants would have similar patterns of occupational voice use as teachers. Head teachers and managerial or pastoral staff would be expected to have different patterns of voice use to classroom-based teachers.

In 2014 globally there were an estimated 62.1 million teachers in primary and secondary education [52]. Occupational voice risks for teachers are likely to be universal as the risk factors and voice use patterns would be similar in different countries even with pedagogical variations.

Gender is a factor in voice problems as men and women have physical differences in the voice system; the gender balance of the teaching profession is therefore important. In England 74% of teachers are female (86% of primary and 64% of secondary) [53]. Globally in primary education 62% of teachers are female (83% in developed countries), and 52% in secondary education (59% in developed countries) [54].

The following sections will look at the various risk factors for voice problems.

3.3 Voice problems among teachers

3.3.1 Prevalence of voice problems in teachers

Professionals requiring effective voice use (including actors, lawyers, singers as well as teachers) are potentially at risk of voice problems due to occupational voice use [55]. Anecdotally it is often considered that teachers experience voice problems disproportionately, as a result of their occupational voice use.

There have been a number of studies to determine the prevalence of voice problems among teachers using three primary methods:

1) Voice clinic attendance.
2) Questionnaire surveys.
3) Phoniatric examination of the body systems involved in speech production.

Between studies there was considerable variation in how, or if, voice problems were defined. This is a factor when comparing data from different studies. The findings of the studies using different methodologies are summarised in the following sections.

3.3.2 Voice clinic attendance

A number of studies in different countries analysed attendance at voice clinics by occupation. The underlying assumption is that the greater the attendance by a given occupational group, the greater the prevalence in the group as a whole. However, there may also be other possible explanations if a group is over represented.

Investigations of attendees in US and Swedish voice clinics (2001) [56] looked at the prevalence of voice problems by occupation along with the proportion of the general population who had that occupation. Based on clinical attendance teachers were 19.6% of attendees but only 4.2% of the population. Teaching was not the occupation with the highest risk factor; professional singers formed 11.5% of attendees but 0.02% of the population. The numbers of individuals who work in professions identified as high risk may have a bearing on how important this is considered by society.

Research by the Voice Care Network (1992) [20] in the UK identified that teachers made up 34% of attendees at the sampled speech therapists' clinics, a much higher percentage than their proportion of the population.

Sapir *et al.* (1993) [57] suggested that teachers may be reluctant to seek medical help, with fewer than 1% of respondents having sought help. This may be due to teachers being aware of small changes to their voices but not considering these serious enough to seek help.

Other researchers have suggested that even though members of a particular profession are over represented at voice clinics, voice problems may not necessarily be greater in that occupation [58]. The impact that voice problems have on that group may be problematic and disruptive to their work. Other professions with a similar prevalence of voice problems, but for which voice problems do not interfere with critical tasks, may result in less disruption to the individuals involved and a smaller proportion seeking help [58].

One additional factor that is not always considered is the relative rate of voice problems in teachers and the general population. The prevalence of voice problems in the general population is not well established [59]; estimates include 6% experiencing significant communication effects [45], and 3-4% of a population (Australia) having voice disorders [60, 71] which is lower than the apparent prevalence in teachers.

3.3.3 Questionnaires

Questionnaire studies have been undertaken by researchers to determine the extent of voice problems in teachers. The voice problems in questionnaires are often self-reported and are not normally followed up by medical examinations. Some studies used selected participant and control groups, whereas others relied on self-selection which may potentially have introduced bias.

Smith *et al.* in the United States (1997) [61] found that 15% of primary and secondary school teachers (*n* = 242) had voice problems versus 6% of a control group, and 20% of the teachers had been absent from work due to voice problems compared with 0% of the control group. This gives a 2.5 times over representation, similar to the report of 4.6 times incidence of voice problems among teachers from a voice clinic attendance study [56].

Russel *et al.* (1998) [59] found that 35% of teachers sampled in an Australian study reported voice issues every six months or more frequently during their career. These levels were considered significant, however, the study referred to the absence of statistics for the prevalence of voice problems in the general population referring to estimates by others [45].

A survey of secondary school teachers in England (*n* = 200) in 2011, found that 51% of respondents had experienced voice or throat problems in the previous two years and 17% had been absent from work as a result of these voice problems. Of these 20% had been absent for between one and four weeks [62].

3.3.4 Phoniatric examination

A robust method of identifying objective voice problems is by medical examination by a phoniatrician. Phoniatrics is the medical speciality of voice, speech, language, hearing and swallowing disorders. The expense and logistical difficulties of this approach as a research method, particularly with large sample groups, means that this approach has only been employed in a small number of studies which have generally been cross-sectional in design.

Lejska (1967) [63] undertook examinations (*n* = 722), finding symptoms of vocal pathology in 5.7% of female, and 1.4% of male teachers. Participants had ‘weak voices’ without vocal pathology at a rate of 16.5% for female, and 7% for male teachers.

Other research found higher rates of vocal pathology in female teachers, with two studies showing vocal nodules present in 9.7% [64] and 13% [65] of female participants. This indicated that the prevalence of vocal pathology was higher in female teachers than their male counterparts. This gender differential was not present in an equivalent (control) group of non-teachers.

The examination approach may underestimate the prevalence of voice problems as it may not include those who experience voice problems but do not present with physical pathology. Mathieson (1993) [5] indicated that at least 33% of patients who reported voice problems did not have identifiable voice pathology, emphasising that voice problems can still be significant for the sufferer irrespective of vocal pathology.

3.3.5 Prevalence summary

Despite indications in various studies that teachers have a higher risk of voice problems, the nature of the various studies and a lack of statistical controls mean that overall the link cannot be confirmed and that the evidence is not definitive. This is in line with the view of other reviews of the literature such as that carried out by Mattiske *et al*. in 1998 [66].

There is an argument that, irrespective of definitive evidence, the size of the teaching profession globally warrants particular attention and further investigations due to the large number of individuals potentially at risk. An elevated risk of voice problems has the potential to have substantial impacts for the teachers concerned, as well as for pupils, schools and wider society, as discussed in the following section.

3.4 Impact of teachers' voice problems

Voice problems are important not only for individual teachers who experience the effects directly but they may also affect school communities and wider society both academically and economically.

3.4.1 Effects on pupil learning

Research has shown that children perform less well during tests when instructed by a dysphonic, rather than a healthy voice, such as may happen when a teacher continues to teach with voice problems [67]. If a teacher is absent due to ill health this may also adversely affect the continuity of pupil learning. If voice problems and related absences are widespread among teachers, this has the potential to impact on the educational progress of many children.

3.4.2 Economic and societal costs

The reasons for teacher absences are not fully recorded as part of publicly available data, however based on the questionnaire surveys detailed in Chapter 14 voice problems appear to be a significant reason for absence. The most recent figures showed 2.21 million teaching days lost annually to sickness in England [68].

If voice problems are responsible, or contribute, to a proportion of teacher absences then this must be considered as an economic cost in terms of the need to employ substitute teachers. In the United States the cost of treatment and substitute teachers as a result of voice problems has been estimated at $2.5 billion annually [56]. For the UK the estimated annual figure is £15 million [68]. If teachers leave the profession or retire early due to voice problems, this has a substantial cost to society in terms of lost talent and the wasted costs of training teachers.

3.4.3 Personal costs

On a psychological level our voices are intrinsically linked to our sense of identity, with each voice being unique to the individual. Changes to voice quality can influence how individuals see themselves and influence the perceptions of others. When voice problems severely reduce the ability to speak there may be a sense of enforced isolation due to an inability to convey emotions or communicate effectively.

With the sea change in post-industrial economies away from mass manual employment, a greater proportion of the population now depend on their voice as an essential part of their occupation compared with past generations. The result is that voice problems now may be considered analogous to physical impairments in the industrial age in terms of the impact on an individual's livelihood.

As well as the general shift towards the importance of voice use in the workplace, there are specific professions for which voice quality is vital and where the demands on the voice are high such as for teachers, barristers, actors, singers and similar.

In these professions the impact of voice problems can be significant when substantial loads are placed on the voice as part of the occupation, and where speaking for long periods and/or with heavy loading cannot readily be avoided. The nature of teaching is such that during term times the voice cannot easily be rested nor the load on the voice readily reduced as a precautionary or reactionary measure without significant interventions such as with the use of voice amplification systems.

Voice quality itself is also important for teaching compared with other occupations where the need is only for effective communication but where voice quality is not a substantive requirement.

For sufferers of occupational voice problems the psychological impacts can be significant, with a study showing that nearly 76% felt that voice problems would negatively affect their future work [56]. This would be expected to cause or increase stress which as noted in section 3.5.7 is a risk factor in its own right.

There have been examples of teachers leaving the profession as a result of voice problems which indicate that the concerns of sufferers of occupational voice problems are justified. One case in 2010 [69] highlighted the apparent risks of working in classrooms with high external noise levels and the low levels of awareness of voice problems among those responsible for the occupational health and safety of teachers.

The teacher in question accepted an out-of-court settlement from her employer due to claimed chronic occupational voice problems which resulted in her no longer being able to teach. This settlement was for £145,000 and at the time of the settlement the individual had at least 15 years remaining in her career. This indicates that those who leave teaching through ill health may not be compensated fully for future lost earnings and may show why many continue teaching with voice problems.

The impact of voice problems on individuals can be assessed according to the World Health Organisation International Classification of Functioning, Disability and Health framework [70] with an example shown in Table 3.2 [71].

Table 3.2: Impact of voice disorders [71]

ICF Dimension	Impact
Impairment	Phonation difficulties Vocal fatigue Altered voice quality Altered pitch Altered resonance Altered breath control for sustaining voice and volume Hyper and hypotension in musculature Vocal cord changes, e.g. oedema, inflammation, nodules Impact on speech & language development Pain/discomfort when vocalising
Activity	Diminution of a speaker's ability to communicate effectively Reduction in speaking time from discomfort in speaking Inability to communicate by phone Dependence on synthetic voice Reduction in communicative interactions Avoidance of difficult communicative environments Reliance on communicative partners Need for assistive/augmentative communication (e.g. amplification, writing)
Participation	Effect on ability to participate fully in educational curriculum Disruption of career in professional voice users, Adverse effects on job performance, attendance, and future career choices Social isolation Limited participation Loss of autonomy Avoidance of situations
Well-being	Frustration, anxiety, mood, self-esteem, depression, repression of emotions, stress Impact on peer/adult perception Reduced self-image

Table 3.2 illustrates the wide range of impacts that voice problems can have on the sufferer and highlights how these can influence many areas of life.

3.5 Risk factors

The literature relevant to risk factors will be discussed in this section.

3.5.1 Pupil age group

Preciado *et al.* (1998) [72] found an increased prevalence of self-reported voice problems in teachers of lower age groups with rates of 36% in nursery, 25% in elementary and 21% in junior teachers. This may relate to the increased amount of oral instruction required in the teaching of younger children as it has been found that teachers speak at a higher level with younger pupils, possibly due to greater classroom noise and differences in classroom behaviour [35]. There are additional factors in terms of the voice levels and SF_0 values of younger children relative to those of the teachers (see section 2.2.1).

3.5.2 Subject taught

Teachers of certain subjects may be exposed to irritants in the classroom such as dust from metal and wood working, chemicals from painting, chlorine from swimming pools and the like. These agents can cause irritation to the voice system and may present an additional risk factor for voice problems.

Teachers of Physical Education have been shown to experience the highest rates of voice problems by subject taught [73, 74]. This may relate to working in acoustic environments poorly suited to speech, such as reverberant sports halls and swimming pools or in outdoor conditions with no natural speech reinforcement and the need to communicate over large distances.

In a study comparing teachers of different subjects, music and drama teachers did not report significant enhanced risks [73]. This may be due to higher levels of voice training and generally a greater awareness of voice use. Other reviews of the literature have noted an increased risk in teachers of singing and performing arts, along with sport and chemistry [71], therefore the evidence is not definitive.

3.5.3 Socio-economic factors

Classroom discipline may be influenced by socio-economic factors. In areas where children live in difficult circumstances it is perhaps unreasonable to expect children to arrive at school well fed, rested, relaxed and ready to learn. This may make children more disruptive and less receptive with associated voice and discipline challenges for teachers. Discipline issues may increase stress levels for teachers with associated risks of voice problems (see section 3.5.7)

In some schools there may be a significant proportion of children within the pupil cohort who do not have English as their first language. This can place additional communication demands on teachers, as these children may find it more difficult to understand the teacher's speech [75]. This may result in teachers having to repeat instructions or needing to talk louder due to more onerous speech intelligibility needs. This may also apply to children with attention disorders [76] or those with speech and language difficulties. Teacher demographics and associated risk factors will be discussed in the next section.

3.5.4 Teacher age

Teacher age has been found by Smith *et al.* (1998) [72] to be linked with voice problems. Ageing effects themselves are considered to only raise the risk of voice problems by a small amount; however the effect can be compounded by occupational voice use.

The physical effects of ageing relate to atrophy of the muscles and changes to the structure and lubrication of the vocal folds. These changes along with a reduction in respiratory capacity have the effect of reducing the frequency and dynamic ranges of the voice and altering the SF_0.

Ageing affects the voices of men and women differently with changes at different times of life. The main ageing effects in men typically occur between 40 and 50 years of age. For women these effects are at the time of the menopause [55] when hormonal changes typically lead to a permanent increase in the mass of the vocal folds and a resultant lowering of SF_0 [77]. The average age for the menopause in the UK is 51 [78].

3.5.5 Teacher gender

There is research to show that women, irrespective of occupation, have a higher frequency of voice disorders compared to men. As the majority of school teachers are women this may contribute to the apparent high prevalence of voice problems in teachers overall.

Smith *et al.* (1998) [38] found that, almost without exception, the full range of adverse vocal symptoms were reported at a significantly higher rate in female respondents compared with male respondents, and that the gender factor was more significant for the teaching rather than the non-teaching group.

Over 38% of female respondents reported that teaching had had an adverse impact on their voices (33% for men), and female respondents were more likely to seek medical attention for voice problems (19% versus 8%) [38]. However this difference in seeking medical attention has also been found to apply to the general population [79] and may not indicate a greater prevalence in itself.

Another study by Smith *et al.* in 1998 [72] investigated whether there was a greater prevalence of voice problems taking account of occupation and work activities along with gender. Female teachers consistently reported a greater prevalence of voice problems, with 38% of female teachers reporting both acute and chronic voice problems compared to 26% of their male colleagues. This was irrespective of the subject taught or number of years of teaching. Other studies have found similar patterns [59, 60].

Phoniatric examinations were undertaken in a study by Lejska (1967) [63] as mentioned previously. The study found higher levels of voice pathology in female teachers. Other studies have found similar results [64, 65].

There are a number of physiological factors which may contribute. Women typically have lower hyaluronic acid levels, a material important in the repair and resilience of the vocal folds [80].

Pregnancy and the menstrual cycle can both have short term effects on the voice, where variations in oestrogen levels can cause increased mass of the vocal folds leading to a reduced SF_0 and decreased upper range [77]. As previously noted in section 3.5.4 significant changes occur to the vocal fold tissues in women of menopausal age and this may lead to particular vulnerabilities for female teachers

[55]. It has also been suggested that women may be at greater risk of developing voice disorders due to different coping strategies for stress, depression and anxiety [81].

3.5.6 Stress

Stress is a significant contributory factor to ill health in general and also to occupational health and voice problems. Stress can be defined as an interaction between environmental demands and an individual's ability to respond to those demands.

Stress is, in statistical terms, one of the biggest workplace health problems across all occupations. In the UK stress accounted for 35% of all work related ill health cases and 43% of all working days lost due to ill health in 2014-2015 [82].

Teachers have relatively high rates of work related stress, anxiety and depression according to official estimates, the rate being second only to health professionals, with teachers having an estimated rate of 2190 cases per 100,000 people employed (almost twice that of the general population). Around half of all ill health retirements in teachers are due to stress and/or psychiatric illnesses, with the other half for physical illnesses or disabilities [83]. The high prevalence of stress in teachers implies a systemic mismatch between the requirements of the profession and the abilities of teachers to meet these demands.

Education as a sector is subject to a high degree of political intervention with a heavy burden of administration and bureaucracy. There are frequent changes to curricula, assessment techniques and performance criteria as well as the pressures associated with league tables and Ofsted inspections which are likely to create intrinsic stress for teachers. This is coupled with the demands of teaching itself, particularly against a backdrop of low teacher morale, discipline problems, large class sizes and limited resources.

There has also been the integration of children with special educational needs into mainstream schooling which may place an additional responsibility on teachers. These occupational factors are in addition to the general stresses applicable to all in the modern world and the interaction between personal and workplace stress must also be considered in terms of the stress capacity of individuals.

Stress can have a number of effects on the voice which are discussed further in the next section.

3.5.7 Voice related effects of stress

Research by Green (1989) [84] indicated a relationship between stress and voice problems. A number of stress responses can influence voice production directly:

- Neck, shoulder and back tension affect the movement of the larynx and rib cage.
- Dry mouth.
- Fast and shallow breathing which can affect phonation efficiency.

Other changes can influence the voice system indirectly:

- Stress hormones released as part of the physiological response.
- Frequent urination and diarrhoea can cause dehydration increasing the potential for vocal damage.
- Suppressed immune system increasing vulnerability to respiratory tract infections.
- Indigestion and acid reflux irritating the voice system.
- Interference with swallowing which may encourage throat clearing or coughing.

3.6 Voice training and management

This section will detail different types of voice training and their influence on voice problems.

3.6.1 Types of voice training and management

Voice training includes a number of different approaches summarised in Table 3.3 [85].

Table 3.3 Indirect and direct methods

Direct methods	Indirect methods
Breath support	Case history
Co-ordination	Normal voice
Glottal attack	Presenting features
Pitch	Voice rest
Laryngeal manipulation	Vocal hygiene
Voice projection	Lifestyle
Airflow techniques	Counselling
Intonation	Posture
Rate	Relaxation
Resonance	Management of laryngopharyngeal reflux
Complexity	
Visual biofeedback	
Generalise	

The management of voice problems may involve training, including vocal hygiene and methods for conserving the voice [86], as well as specific strategies such as The Accent [87] and Estill [88] Methods. Voice training can also include guidance on maintaining discipline, the use of non-vocal cues for pupils and other pedagogical approaches.

3.6.2 Vocal hygiene

Vocal hygiene [55] encapsulates a holistic approach to maintaining healthy and efficient vocal function. This includes developing and maintaining good habits in a number of areas which include maintaining hydration, avoiding irritation to the respiratory tract by avoiding smoking and certain foods, and techniques such as warming up and changing the style of speech. Individuals are also encouraged to make a conscious effort to consider their voice performance, take cognisance of persistent changes and to seek medical advice swiftly if necessary.

3.6.3 Prevalence of voice training

Voice instruction is not a mandatory part of teacher training in the UK. It is difficult to establish the extent to which teachers received instruction on voice care as it differs between training establishments.

A survey of teachers (*n* = 490) undertaken by the Association of Teacher and Lecturers in 2008 found 87% had received no voice training as part of their teacher training and less than 1% had received separate instruction [89]. This indicates that the provision of voice training is poor.

It is noteworthy that voice training can range from a single session to regular workshops. Therefore the small proportion of teachers who reported having training may have received only a very brief session.

3.6.4 Influence of voice training on voice problem prevalence

The survey by the Association of Teachers and Lecturers (2008) [89] found that 57% of those who had received training felt it had helped them use their voice more effectively and 87% felt that voice training should be made compulsory as part of teacher training.

In terms of the influence of training on voice problems a study in 1981 [90] examined teachers who had received one hour per week of voice instruction during their teacher training. This retrospective study showed that the participants who had not received voice training reported a greater prevalence of voice problems and that these problems were more significant. Another study (1994) [91] found that teachers who had voice training, particularly in terms of vocal hygiene, experienced significantly less vocal fatigue than those who had not received instruction.

3.7 Conclusions

As discussed in this chapter there are indications of a high incidence of voice problems in teachers. The large size of the teaching population means that many individuals may be at risk, and the associated costs of voice problems, in many different ways, can be significant. Poor acoustics can make for difficult speaking conditions and the role of classroom acoustics in how teachers use their voices and associated risks, will be considered further in the following chapters. The next chapter will explain the main room acoustic parameters in relation to classrooms.

Chapter 4 Classroom acoustics

This chapter will provide a brief introduction to the acoustic parameters relevant to this thesis and a review of the literature relating to acoustics in classrooms.

4.1 Room acoustic parameters

4.1.1 Reverberation time

One of the primary acoustic parameters of a room influencing speech intelligibility is the reverberation time.

Reverberation time (RT_{60}) is the time in seconds for sound in an enclosed space to reduce by 60 decibels once interrupted, from -5 dB to -65 dB. The derivation of RT_{60} is illustrated in Figure 4.1.

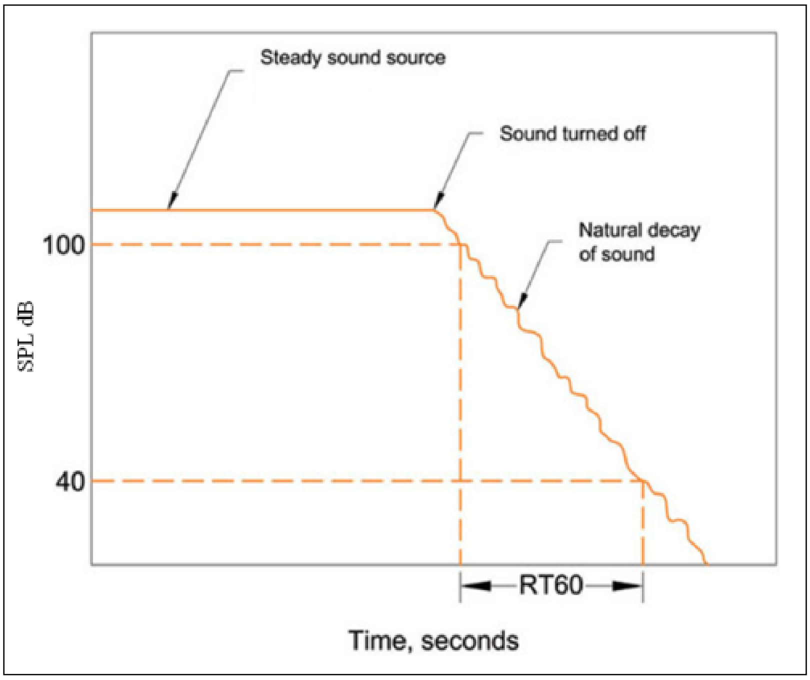


Figure 4.1: RT_{60} derivation [92]

Due to practical issues with measuring 60 dB above the noise floor the decay time over 20 dB or 30 dB is normally used and the RT_{60} calculated. This derivation is shown in Figure 4.2.

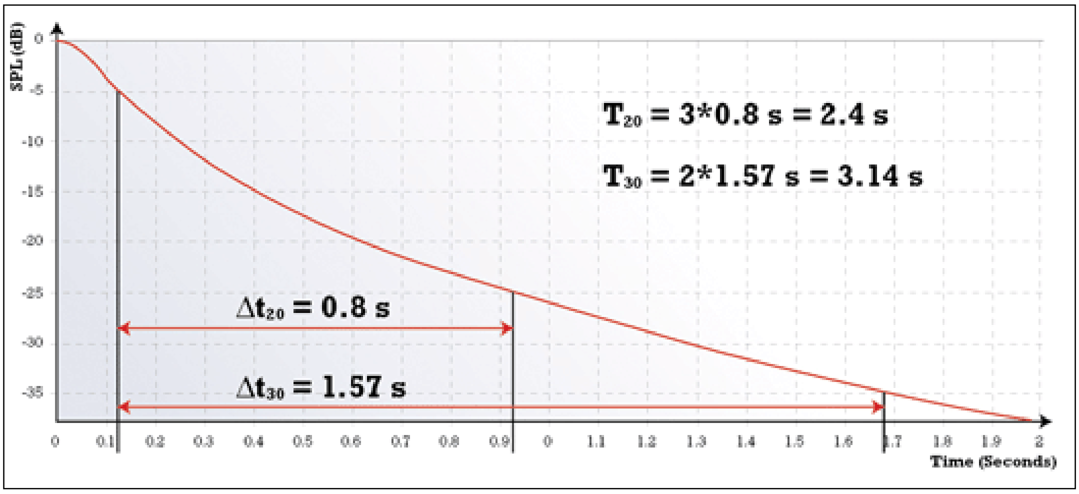


Figure 4.2: T_{20} and T_{30} derivations [93]

The notation T_{20} refers to a measurement of reverberation time over the -5 to -25 dB decay, this is multiplied by a factor of three to give the RT_{60} value. T_{30} refers to the -5 to -35 dB decay and is multiplied by a factor of two to calculate RT_{60}.

Reverberation time is proportional to the room volume and inversely proportional to the amount of sound absorption. Materials such as carpets, sound absorbent ceiling tiles and soft furnishings provide sound absorption, whereas materials such as concrete, glass, plaster and wood tend to reflect sound. The amount of absorption in a room is measured in units of Sabine m^2 and is termed ‘A’.

The reverberation time in a room, and the absorbent properties of materials, and therefore the total absorption (A m^2) will vary with frequency therefore reverberation times are considered over a range of frequencies.

An appropriate reverberation time for a classroom would provide support to speech from early reflected sound reaching the listener and being perceived as part of the original sound. Signals delayed longer are termed late reflections and reduce speech intelligibility.

An overly long reverberation time in a room can be tiring to the listener and make communication difficult by extending utterances and masking the start of the next sound. Too short a reverberation time can be perceived as not providing voice support to the speaker and may not provide sufficient sound level for distant listeners.

Within a normal room there are three different zones of sound from sound sources.

- The **near field** in the immediate vicinity of a sound source. Here the sound pressure level (SPL) may not decrease with distance.
- The **direct field** is the region where the direct sound from the source is dominant. The SPL will decrease according to the inverse square law with distance; that is by 6 dB with each doubling of distance from the source.
- The **reverberant field** is the region where sound reaching the receiver from multiple reflections dominates. In this region the sound level is constant and sound is diffused so the level does not change with distance from the source.

At a certain distance from a noise source, known as the room radius, the direct component and the reverberant component of the sound are equal. Below the room radius distance the direct element is dominant; above the room radius distance the reverberant element dominates.

4.1.2 Early decay time

Early Decay Time (EDT) is a reverberation time parameter which is calculated from the initial 10 dB decay from 0 dB to -10 dB and represents initial reflections from nearby surfaces. If the EDT and T_{20}/T_{30} reverberation times are equal this indicates that the decay curve is a constant gradient. A short EDT is a good indicator of speech clarity as early reflections will be perceived as enhancing the direct sound.

4.1.3 Speech transmission index (STI)

Speech intelligibility can be described as the percentage of speech which is correctly understood by a listener. STI values are a method of quantifying how a given space will affect intelligibility and is dependent upon the relationship between noise and reverberation time. STI has a value between 0 and 1, the higher the value the better the speech intelligibility. The guidance values are shown in Table 4.1 for adult native English speakers [94].

Table 4.1: Intelligibility ratings of STI values [94]

Intelligibility rating	STI
Excellent	> 0.75
Good	0.60 to 0.75
Fair	0.45 to 0.60
Poor	0.30 to 0.45
Bad	< 0.30

4.2 Noise levels

4.2.1 Hearing

Sound is the phenomenon of the ear detecting and perceiving compressions and rarefactions in atmospheric pressure.

The international system (SI) unit of pressure is the Pascal (Pa), a measure of force per unit area in Newtons per square metre with 1 Pa = 1 N/m^2. The ear in a young, healthy person is able to perceive sound pressure over a wide dynamic range between the threshold of hearing (0.00002 Pa) and the threshold of pain (200 Pa), at 1 kHz.

The ear has a logarithmic response to changes in sound pressure and therefore a logarithmic scale is used to measure sound. The range is represented using a decibel scale relative to the reference pressure at the threshold of hearing as shown in the equation below where p is measured pressure and p_{ref} is 2×10^{-5} Pa.

$$SPL = 20\, lg\left(\frac{p}{p_{ref}}\right)$$

The response of the ear is not the same at all frequencies. The thresholds of hearing and pain vary across the frequency range of the ear, which is typically 20 Hz to 20 kHz in a healthy young person. This frequency range is normally sub-divided into third octave or octave wide bands.

4.2.2 The measurement of sound in decibels

Owing to the non-linearity of the ear a set of equal loudness curves were developed by Fletcher and Munson (1933) which weighted sound across the frequency range to mirror the ear's response [95]. This evolved into a series of weighting networks for use in sound level meters [96].

The convention is that the A-weighting (although originally only intended for use with lower noise levels) is used for the majority of broadband noise levels. This is denoted by the use of 'A' as in dBA. Unweighted values are denoted by dBZ.

The measurement of sound is intended to give an objective measurement of how sound would be perceived at a given location. Sound level meters have been developed to mirror the response of the ear and its non-linearity. Modern sound level meters consist of a precision calibrated microphone, an analogue to digital converter with analysis and data storage carried out by a microprocessor-based system. Sound level meters are classified by accuracy in BS EN 61672-1:2003 [96] with Class 1 being the most accurate.

Sound level meters have different settings for how frequently sound is sampled during measurements. The measurements in this thesis are undertaken using a 'fast' time weighting which means a sampling period of 0.125 s. The measurement duration is over a user-defined period e.g. 1 minute. The measurement period is sub-divided into samples according to the time weighting.

4.2.3 Noise measurement parameters

A range of measurement parameters have been developed for different applications on sound level meters. Those relevant to this thesis are defined in this section.

L_{eq} is the equivalent constant sound pressure level of a time-varying signal and has the same total energy over the same time period. L_{Aeq} is the A-weighted value. An example L_{eq} is shown in Figure 4.3.

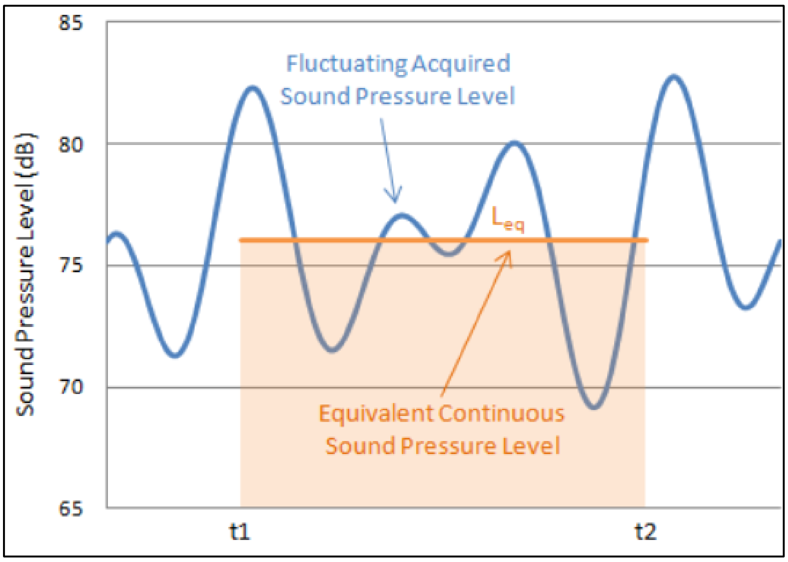


Figure 4.3: L_{eq} from a time varying signal [97]

Statistical parameters are levels exceeded for a defined percentage of a measurement period. L_1 is the value exceeded 1% of the time and is similar to the L_{fmax} parameter. L_{10} is the value exceeded 10% of the time and is representative of intermittent sources, for example traffic. L_{90} is the value exceeded 90% of the time and is representative of the background noise climate. L_{fmax} is the maximum sound pressure level during the measurement period. L_{Afmax} is the corresponding A-weighted value. The L_{Amax}, L_{A10} and L_{A90} parameters are illustrated in Figure 4.4.

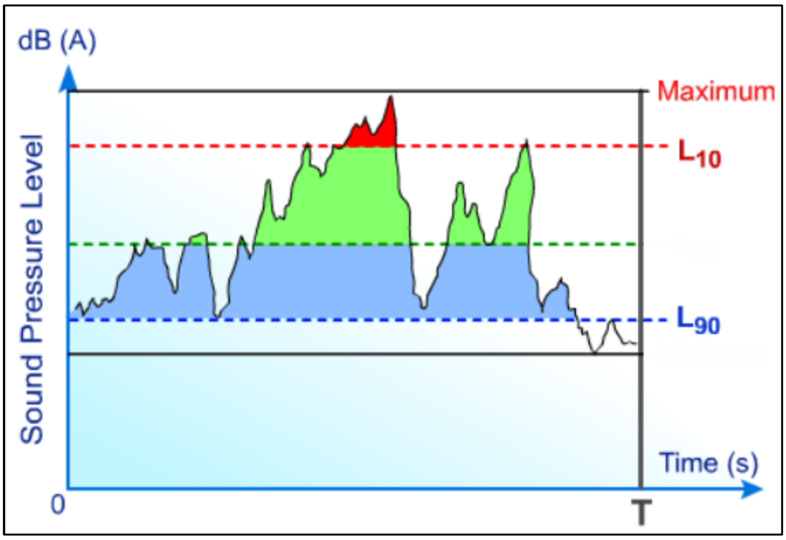


Figure 4.4: Example statistical parameters [98]

4.3 Noise levels in classrooms

4.3.1 Unoccupied classroom noise levels

The notation UANL is used to describe the level of unoccupied indoor ambient noise levels. This includes noise from external environmental sources such as traffic, aircraft and mechanical ventilation, but excludes noise from school activities.

A number of studies have measured unoccupied noise levels in classrooms and have typically found average noise levels around 45 dB L_{Aeq} [99, 100, 101]. Studies have found that primary school classrooms tend to have higher UANLs than secondary schools (see Table 4.2).

Table 4.2: Unoccupied noise levels in previous studies

Reference	School type	UANL L_{Aeq} dB	UANL L_{A90} dB
Shield *et al.* (2007) [35]	Primary	47	37
Shield *et al.* (2015) [15]	Secondary	34	31

These levels indicate that the primary school classrooms were substantially above current guidance limit of 35 dB L_{Aeq} (see 5.4.2), but the secondary school classrooms met the current guidance levels.

The overall unoccupied noise levels if more than 10 dB below the occupied noise levels would not contribute numerically to the occupied noise level. However the UANL may contribute, particularly at lower frequencies, to the occupied noise level if the difference is less than 10 dB in each frequency band.

4.3.2 Occupied classroom noise levels

The presence of pupils in a classroom raises the internal noise level substantially over the unoccupied condition.

A review of the literature (2003) [102] suggested the following typical levels for different activities:

- Silent activity 56 dB L_{Aeq}

- Individual working 65 dB L_{Aeq}
- Group work and movement around the classroom 77 dB L_{Aeq}

It has previously been found that occupied noise levels in secondary schools correlated positively with UANL [15]. It may be the case that higher unoccupied levels will lead to teachers needing to increase their vocal effort to be heard.

Shield *et al*. (2015) [15] found correlations between the mid-frequency reverberation time, termed T_{mf} (see 5.4.1), and UANL L_{Aeq} (r = 0.35, p < 0.01) and L_{A90} (r = 0.24, p < 0.01) as well as UANL and occupied L_{Aeq} (r = 0.38, p < 0.01) indicating that higher occupied conditions occurred in rooms with higher UANL and T_{mf} values. The two studies are summarised in Table 4.3 below.

Table 4.3: Mean occupied noise levels in previous studies

Reference	School type	Occupied L_{Aeq} dB	Occupied L_{A90} dB
Shield *et al.* (2007) [35]	Primary	72	54
Shield *et al.* (2015) [15]	Secondary	64	51
	Difference	8	3

4.3.3 Signal to noise ratios (SNR) in classrooms

Signal to noise ratio (SNR) is the difference between the wanted sound such as the teacher's voice, and unwanted sound such as traffic noise (see 2.4).

Typical SNR values in classrooms have been identified by a number of studies and have been found to range from -7 to +5 dB [40, 99, 103, 104] indicating that many teachers may work in acoustic conditions that are less than ideal.

There are indications from the literature that the SNR requirements of younger children are more onerous than those of older children [105]. This implies that internal noise levels should be lower and/or teachers would need to speak louder in classrooms for younger children.

SNR is often considered simply in terms of the overall weighted values, however the nature of the signal and the noise is such that the SNR in the spectral domain is also important. This is because comparable dBA values can have very different spectral contents leading to different signal to noise ratios in the key speech bands, though there is no established guidance on what these should be in classrooms.

4.4 Speech intelligibility in classrooms

4.4.1 Reverberation times in classrooms

Reverberation time criteria for classrooms are defined in many standards and guidance documents as discussed in Chapter 5. The primary consideration is for suitable speech intelligibility for children whereas the requirement for healthy voice use for teachers is often not considered.

Studies in the literature have been undertaken to measure reverberation times in unoccupied classrooms. These can have large variations due to the range of room volumes and finishes, as well as what (if any) standard they were designed to. Table 4.4 gives a summary of measured reverberation time values in other studies.

Table 4.4: Mean unoccupied T_{mf} reverberation times in previous studies

Reference	School type	Unoccupied T_{mf} (seconds)
Shield *et al.* (2007) [35]	Primary	0.6
Shield *et al.* (2015) [15]	Secondary	0.6

One study [35] found that the mean reverberation time (T_{mf}) was 0.6 s with a range of 0.3 - 1.2 s reflecting a range of classrooms constructed in different eras.

The presence of pupils provides additional sound absorption and diffusion which, if adding significantly to the overall absorption in the room, reduce the reverberation time. This lowering of reverberation time would normally be considered an improvement in acoustic terms; however the additional absorption, whilst reducing the reverberation time and improving intelligibility also has the effect of lowering the teacher's voice level within the room and potentially requiring a higher vocal effort as well as reducing the level of the speaker's own voice at their ears.

One study [106] found that the average reverberation time in occupied conditions was 10% lower than when unoccupied.

4.4.2 Interaction of reverberation time and noise

The effects of external noise intrusion and activity noise within the classroom have been discussed in section 4.3.1 and 4.3.2. However there is also an interaction between reverberation time and internal noise levels.

Reverberation times in a typical classroom will be longer at lower frequencies [106] due to the nature of absorptive materials. This means that noise levels will be higher and persist for longer at lower frequencies due to the prolonging effect of reverberation.

External noise intrusion into classrooms will also tend to be at lower frequencies due to the buildings having higher levels of sound insulation at higher frequencies. The human hearing mechanism is affected by a phenomenon termed the upward spread of masking. This means given sounds affect the ability of the listener to hear other simultaneous sounds in the same frequency bands as well as sounds in frequency bands above it. Thus low frequency noise below speech frequencies can still influence speech intelligibility.

For identical classrooms with the same intrusive noise level, if the reverberation time is twice as long in one classroom then the noise will be 3 dB higher due to decreased sound absorption. This reverberant effect applies to activity noise in classrooms as well as noise intrusion.

Higher noise levels due to reverberation would influence voice levels of teachers by way of the Lombard effect [28] (see section 6.1).

4.4.3 Influence of reverberation time on speech intelligibility

Reverberation time and ambient noise levels mainly determine the ability of a listener to perceive and extract information from speech. Other factors such as the distance between the speaker and listener, voice level, and the listener’s hearing acuity have an influence on speech intelligibility. Classrooms are complex spaces in which to determine speech intelligibility as the speaker to listener distance will vary, as will the dynamic noise climate.

Inside classrooms the distance between the talker and the listener is usually not critical as the listener is likely to be in the reverberant field (and as a result there will be limited variations in speech levels with distance).

Young children perform less well than adults in unfavourable acoustic conditions as they lack the cognitive ability to interpolate missing speech information and therefore have more onerous acoustic requirements [75].

A study by Bradley *et al.* (1999) [107] looked at the relative effects of reverberation time and noise on speech intelligibility and found that, in adults, the SNR was the most important parameter. Generally shorter reverberation times improve speech intelligibility; however the contribution of noise within the classroom is normally the limiting factor [108].

If children are unable to understand instruction then the teacher may have to repeat themselves or change speech characteristics in an attempt to overcome the issues. Children may become inattentive and unruly due to difficulties in hearing their teacher.

There are some indications of the influence of reverberation time on behaviour. In two studies there were indications of improvements in pupil behaviour in classrooms where reverberation times had been reduced [15, 109].

4.5 Conclusions

This chapter has identified the main parameters which define classroom acoustics along with how these are measured and typical values defined in the literature. The reverberation time and internal noise level in a classroom are important in achieving good levels of speech intelligibility, and may also influence voice behaviour. The following chapter will examine guidance and legislation relevant to both voice use and classroom acoustics in general.

Chapter 5 Current guidance and legislation

This chapter outlines health and safety guidance and legislation in relation to the health of teachers and then details regulatory and guidance frameworks relevant to the acoustic design of schools and voice use. The guidance and legislation reviewed is that applying to England only.

5.1 Health and safety legislation

Voice problems in teachers, if acquired at, or exacerbated by, work may be an issue of health and safety in the workplace.

For member states of the EU, such as the UK, the main organisation governing health and safety in the workplace is the European Agency for Health and Safety at Work (EU-OSHA) [110]. The remit of EU-OSHA includes making EU workplaces safer and healthier for employees by promoting risk prevention measures to improve working conditions. The primary EU framework in terms of legislation on health and safety at work is Directive 89/391/EEC [111].

5.1.1 Directive 89/391/EEC

Directive 89/391/EEC details minimum health and safety standards to be applied by member states.

The Directive requires employers to adopt a pre-emptive approach to health and safety management by undertaking risk assessments and adopting preventative measures. It also requires that health and safety management forms an intrinsic part of general management procedures to ensure an integrated approach.

EU member states are obliged to implement the directive through national legislation. In the UK this is done via the Health and Safety at Work etc. Act.

5.1.2 Health and Safety at Work etc. Act

The Health and Safety at Work etc. Act 1974 [112] implements the requirements of Directive 89/391/EE. The act ensures the health, safety and welfare of persons at work and places duties on both employees and employers. Employers must, as far as practicable, maintain the workplace in a safe condition without risks to health.

The act places a requirement on employers to ensure the health of employees by arranging medical examinations, health surveys, together with the monitoring of conditions in the working environment. There is a requirement for the provision of protective clothing or equipment which could potentially include voice amplification systems for voice support in classrooms. For employees there is a responsibility to take reasonable care for their own health and safety: 'reasonable care' is not defined.

The act also sets out principles for health and safety management in the workplace. These include the Management of Health and Safety at Work Regulations 1999 [113] which are discussed in the next section.

5.1.3 The Management of Health and Safety at Work Regulations 1999

These regulations reflect the general principles of prevention in Directive 89/391/EEC. The regulations require employers to undertake assessments of the risks to the health and safety of employees which they are exposed to whilst at work. The risks to health and safety identified in the assessment are to be notified to employees, along with details of the preventative and protective measures taken as a result. There is, in addition, a requirement for health surveillance to be provided by the employer where the risk assessment identifies a need for this.

The need for employers to show compliance with Directive 89/391 EEC has led to the development of management guidance documents which will be discussed in the next section.

5.1.4 BSI and HSE guidance

British Standard OHSAS 18001:2007 Occupational Health and Safety Management Systems - Requirements [114] details a suitable management system which uses the model known as Plan Do Check Act (PDCA). The standard further details the need for organisations to have, and implement, a procedure for dealing with actual and potential non-compliance. An example of non-compliance could be where the voice ergonomics of a teacher had not been considered and voice problems had arisen as a result.

The UK's Health and Safety Executive gives the following definitions for hazards and risks [115]:

'A hazard is something (e.g. an object, a property of a substance, a phenomenon or an activity) that can cause adverse effects'.

'A risk is the likelihood that a hazard will actually cause its adverse effects, together with a measure of the effect'.

In terms of the voice health of teachers it may be appropriate to consider that some voice problems (the effect) may result from occupational voice use (the hazard) and that the risk of this may be more significant for teachers than for the general population (the likelihood).

If there is a risk and a hazard present then it would be appropriate to undertake a risk assessment to determine if the hazard can be reduced or eliminated. Although the voice is used in almost all work roles, in the case of professions which place a particularly high workload on the voice, there may be a need for specific consideration.

There appears to be limited attention paid to the risks of occupational voice problems for teachers in school workplace assessments. The HSE has produced a health and safety checklist for classrooms [116]. This primarily focuses on classroom safety for pupils and does not refer to voice health for teachers. The checklist is shown in Appendix A.

A risk assessment form [117] specific to voice care for teachers has been developed by Voice: *The union for educational professionals* and is included in Appendix A.

Although well intentioned, these template workplace risk assessments do not appear to consider the myriad of factors covered by 'acoustics', nor individual susceptibility factors such as gender or voice problems.

The management of noise at work perhaps gives a guide to how the risks of occupational voice problems could be considered. The Control of Noise at Work Regulations 2005 [118] specify a framework for determining noise exposure at work, provide action and limiting levels and guidance on hearing surveillance and hearing protection. Although not directly comparable there are many potential parallels to the use of the voice in the workplace; however there is currently no specific legislation relating to occupational voice health in the UK.

5.1.5 Summary

In health and safety terms teachers with voice problems are typically treated on a case by case basis by their employers (that is the school body). This means that voice problems are considered as individual cases of illness or voice misuse, rather than as a potentially broader issue of occupationally acquired or work-exacerbated conditions. Therefore the working environment, working practices and other factors are not assessed on a wider basis.

As a result the hazards associated with voice problems may escape the attention and consideration of an occupational health and safety management system and the potential for there to be a causal relationship between teachers' voice issues and the tasks at work, or the working environment, are not investigated. This means that potential risks applicable to the wider profession are not identified or addressed.

A comprehensive voice screening and monitoring procedure designed for teachers might, for instance, include an ENT examination, voice health questionnaires and voice performance tests. This would help to identify those individuals who may have greater susceptibility to voice problems and thus inform an individual program of care and monitoring. This type of approach is currently used for workplace hearing surveillance programs.

The next section reviews Building Regulations in relation to school acoustics.

5.2 Building Regulations

The English Building Regulations are statutory instruments which mandate various aspects of prescribed building types. The current English Building Regulations comprise a number of different parts including Part E - Resistance to the Passage of Sound. The requirements are not retrospective, and buildings are required to comply with the regulations only at the time of completion but not in perpetuity.

Building Regulations approval is given by a Building Control Body (BCB), normally either Building Control Officers within council departments or Approved Inspectors, which are private companies. A BCB has discretion to interpret the regulations and their decision is binding and can be challenged only by appealing to the Secretary of State [119].

5.2.1 Approved Document E 2003

The Building Regulations 2000 Resistance to the Passage of Sound Approved Document E 2003 edition (incorporating 2004 amendments) [120] (ADE) was the first Building Regulations document to include acoustics in purpose built and converted schools. Prior to that school acoustics were not included in the Building Regulations.

ADE: 2003 excluded the following:

- Existing school refurbishment.
- Temporary school buildings in place for up to 28 days.
- Administration and ancillary areas.
- Standalone nursery schools.
- Colleges/sixth form colleges.
- Further or higher education.
- Universities.
- Community and adult education facilities outside school sites.

In reference to schools ADE: 2003 stated in Requirement E4, that:

'Each room or other space in a school building shall be designed and constructed in such a way that it has the acoustic conditions and the insulation against disturbance by noise appropriate to its intended use' [120, p. 8].

The normal way of satisfying the requirements of Requirement E4 was to meet the values for sound insulation, reverberation time and indoor ambient noise given in section 1 of Building Bulletin 93 2003 (BB93:2003) [121]. This means that compliance with other acoustic specifications in BB93 was not mandatory.

The wording 'normal way of satisfying' meant that it was possible to propose different acoustic criteria to those detailed in BB93:2003. These were termed 'alternative performance standards' (APS) and are detailed in 5.4.3.

ADE:2003 was further amended in 2015 [122] following the publication of Building Bulletin 93 2015 [123].

Residential apartments and housing developments must either be constructed using approved constructions or submit to independent airborne and impact sound insulation testing of 10% of the different construction types within the units on completion. These requirements do not apply to schools.

ADE:2015 simply refers to requiring BB93 compliance. Neither BB93:2003 nor BB93:2015 mandated testing but both documents strongly recommend that pre-completion acoustic testing is required in the building contract as the best practical means of ensuring that the design intents are met.

The absence of compulsory testing means that many school buildings are not tested and although the design criteria may be known, the acoustic performance achieved is not. A number of acoustic properties are dependent not only on appropriate design, but on high standards of workmanship. There is significant scope for greatly reduced performance from poor workmanship and for issues not to be identified before the school is in use.

In terms of voice ergonomics for teachers, ADE:2015 does not refer to this specifically but includes the requirement for the school building to '*have acoustic conditions appropriate for its intended use*' [122, p. 8]. This may be interpreted as classrooms being suitable for teachers to safely use their voices in.

In addition to the Building Regulations there are School Premises Regulations which are detailed in the following section.

5.3 School Premises Regulations

The Education Act 1996 [124] placed a duty on the Secretary of State to define standards for all maintained school premises in England and Wales. These standards were set out in the School Premises Regulations (SPR) and apply to all school buildings in perpetuity. The requirements for independent schools are contained in the Education (Independent School Standards) Regulations 2014 [176] which has the same acoustic requirements as the SPR.

The current SPR 2012 [125, p. 2] Regulation 7 states:

'The acoustic conditions and sound insulation of each room or other space must be suitable, having regard to the nature of the activities which normally take place therein'.

Advice on compliance with the requirements of the SPR is given in the Department for Education document *Advice on standards for school premises* published in March 2015 [126, p. 9] and states:

'In classrooms, class bases and other areas used for teaching, this will allow teachers to communicate without straining their voices'.

No further guidance on voice strain is given in the document.

The SPR does not require pre-completion testing. Both the current SPR and ADE refer to BB93 which is detailed in the following section.

5.4 Building Bulletin 93

5.4.1 BB93:2003

BB93:2003 [121] was the first building bulletin document to have mandatory status via Building Regulations Approved Document E (2003) [120].

BB93:2003 contained two distinct sections, Part 1 contained criteria and Parts 2-7 gave guidance for detailed design purposes. The criteria relevant to this thesis are summarised in Table 5.1. IANL in this thesis refers to the BB93 parameter only, UANL is used in this thesis for other unoccupied ambient noise level parameters. T_{mf} is the mid frequency reverberation time calculated as an arithmetic mean of the reverberation times in the 500, 1000 and 2000 Hz octave bands.

Table 5.1: Acoustic requirements under BB93:2003

Classroom type	Reverberation time T_{mf} (seconds)	Internal ambient noise level $L_{Aeq,\ 30\ minutes}$ dB
Primary school (children aged 5-11)	≤ 0.6	≤ 35
Secondary school (children aged 11-18)	≤ 0.8	≤ 35

The values were to be achieved in finished but unoccupied and unfurnished rooms and the internal ambient noise level (IANL) excluded noise generated by teaching activities in the school itself. The internal noise level criteria in BB93:2003 were to be achieved with ventilation systems in normal operation. For many sites the internal noise level criteria would not be achievable with open windows.

The BB93:2003 advisory panel included Roz Comins of the Voice Care Network UK [127] which is recognized as a leading organization in best professional practice for the use and care of the voice. Therefore the factor of teachers' voice use was considered.

The introduction to BB93:2003 includes the following section relevant to teachers' voice use:

'Poor acoustic conditions in the classroom increase the strain on teachers' voices as most teachers find it difficult to cope with high noise levels. This often leads to voice problems due to prolonged use of the voice and the need to shout to keep control. Recent surveys in the UK and elsewhere show that teachers form a disproportionate percentage of voice clinic patients' [121, p.1].

Further discussions on teachers' voices are given in BB93:2003 with a chapter dedicated to the design of rooms for speech. It states that the following factors should be considered (in order of importance):

- Indoor ambient noise levels.
- Room size – floor area, shape and volume.
- Amount of absorption required to achieve reverberation time.
- Type, location and distribution of absorption.
- Special considerations for non-standard rooms (reflectors and diffusers).
- Electronic sound reinforcement systems.

The internal ambient noise levels in BB93:2003 were chosen in order to provide an adequate SNR without undue strain on the teacher's voice, while also minimizing distraction from noise intrusion. BB93:2003 also states that some teachers do not have sufficiently strong voices to achieve the optimum SNR values. BB93:2003 refers to evidence of a greater risk of voice damage for teachers and that few teachers have voice training.

Sound amplification systems are primarily covered in the document in relation to the teaching of hearing impaired pupils, but the potential benefits for teachers' voices are also detailed.

5.4.2 BB93 2015 revision

BB93:2003 part 1 was superseded in 2014 by BB93:2014 (amended 2015) [123]. Approved Document E was updated in 2015 to refer to BB93:2015. The document superseded only Part 1 of BB93:2003 and contained criteria only, with Parts 2-7 of BB93:2003 remaining applicable until the *Acoustics of schools: a design guide* was published in 2015 [30].

BB93:2015 is, for the majority of school construction projects, the touchstone document in terms of acoustics forming the design basis in terms of ADE compliance and contractual obligations.

Whereas BB93:2003 applied to new buildings only, BB93:2015 also contained minimum requirements for refurbished classrooms. Since 2010 a policy of creating

Free Schools has been implemented by the UK government. These are independent state-funded schools which can be started by interested bodies and can occupy existing buildings often not originally intended for educational purposes. The emphasis was therefore on forming schools by conversion and refurbishment of buildings, as well as by new constructions.

The requirements for internal ambient noise levels (IANL) from external noise intrusion and services noise in primary and secondary school classrooms are shown in Table 5.2:

Table 5.2: BB93:2015 internal ambient noise level criteria for classrooms

Classroom type	Internal ambient noise level $L_{Aeq,\ 30\ minutes}$ dB	
	New classroom	Refurbished classroom
Primary school (children aged 5-11)	≤ 35	≤ 40
Secondary school (children aged 11-18)	≤ 35	≤ 40

BB93:2015 requires that for regular noise events such as aircraft or train movements, internal noise levels in the school rooms should not exceed 60 dB $L_{A1,\ 30\ minutes}$. The noise limits apply during normal teaching hours; these are typically Monday to Friday 09:00-15:30 hours in England.

For schools with building services equipment including ventilation plant, this should be designed at a suitable level such that the overall noise levels in the different spaces do not exceed the IANL criteria for intrusive noise and building services noise.

BB93:2015 provides criteria for different modes and types of ventilation detailed in Table 5.3.

Table 5.3: BB93:2015 ventilation conditions, system type and associated IANL tolerance

Condition	Ventilation system	Noise level limit
Normal - ventilation for normal teaching and learning activities	Mechanical	Table 5.2 value
	Natural	Table 5.2 value +5 dB
	Hybrid	Mechanical system noise Table 5.2 value
		Total noise level: Table 5.2 value +5 dB
Summertime - ventilation under local control of teacher to prevent overheating - allowable during the hottest 200 hours of the year	Mechanical	Table 5.2 value +5 dB
	Natural or hybrid	≤ 55 dB
Intermittent boost	Mechanical	Table 5.2 value +5 dB
	Natural	≤ 55 dB
Process - extract can be automatic for safety reasons and/or under local control of the teacher	Mechanical and/or natural	IoA/ANC guide for operational noise levels [30]

Noise from the school itself affecting internal areas via internal walls and floors is not covered by way of a noise criterion in BB93:2015 but with a matrix for airborne and impact sound insulation. Sound insulation criteria are also given for corridor walls separating classrooms from circulation areas and the control of reverberation in circulation areas is dealt with by way of defining minimum areas of sound absorbent treatment.

The criteria for classroom reverberation times are shown in Table 5.4.

Table 5.4: BB93:2015 reverberation time criteria for classrooms

Classroom type	Reverberation time T_{mf} (seconds)	
	New classroom	Refurbished classroom
Primary school (children aged 5-11)	≤ 0.6	≤ 0.8
Secondary school (children aged 11-18)	≤ 0.8	≤ 1.0

The standards in BB93:2015 are minimum standards; however the majority of school construction projects target meeting, rather than bettering, the criteria in BB93:2015.

This is a result of the type of construction contracts that are often implemented in the UK. Currently projects tend to be constructed on what are termed a 'Design and Build' basis which involves the contractor tendering against a set of performance requirements with freedom, within certain constraints, to determine how they wish to achieve these acoustic specifications. The commercial considerations mean that in a majority of cases the construction will be determined to meet the contractual requirements without a margin and that the most cost efficient method of delivering this will be used. The contractor is able to retain any cost savings they can identify in the construction.

If a particular acoustic requirement is not contained in BB93:2015 then it can be difficult or impossible for acoustic consultants to modify the design or to justify additional costs associated with enhancements.

5.4.3 Alternative performance standards (APS)

Both BB93:2003 and BB93:2015 give scope for alternative criteria to be proposed and accepted on a project, the rationale being that a universal requirement cannot be applied to all projects and in all situations and that other factors may take priority over acoustics.

BB93:2003 did not specify limits to APS criteria, which allowed BCBs to make judgements as to what was accepted.

The provision for APS may arguably have been used by contractors as a method of routinely derogating from guidance on the grounds of cost judgements rather than on the grounds of particular educational, environmental, or health and safety reasons. Building Control and the school bodies were perhaps not always able to make informed judgements on the implications of alternative criteria.

This flexibility was reduced significantly under BB93:2015 which gave fixed limits to criteria for refurbishments though the scope to apply alternative criteria outside the BB93:2015 refurbishment limits remains in the wording of Requirement E4.

5.5 Other recommendations

5.5.1 BREEAM

The Building Research Establishment Environmental Assessment Methodology (BREEAM) [128] is a method of assessing, rating and certifying the sustainability of buildings. Registration is optional unless required by the Local Planning Authority (LPA) or by a client.

The Health and Wellbeing acoustic credits (termed Hea 05) normally require compliance with the criteria in BB93:2015. The main impact of BREEAM Hea 05 compliance is that in order to be awarded the credit, a program of pre-completion testing is mandatory. On many school projects this credit is the main driver for undertaking testing and reinforces BB93:2015 compliance. However the BREEAM rating is based on a total score and the acoustic credits are not necessarily sought on all projects.

5.5.2 BS 8233

BS 8233:1999 Guidance on Sound Insulation and Noise Reduction for Buildings [129] contained UANL guidance limits for classrooms of 35 dB L_{Aeq} for a ‘good’ level and 40 dB for a ‘reasonable’ level.

The maximum noise levels which permitted reliable speech communication at different speaker to listener distances and for different voice levels were also detailed. This was intended for industrial workplace applications but was also relevant to the classroom.

The standard gave guidance on reverberation times in unoccupied rooms for speech. These mid frequency (500 Hz values) for speech use were given by room volume as 0.4

seconds at 50 m^3, 0.5 seconds at 100 m^3, 0.6 seconds at 200 m^3 and 0.7 seconds at 500 m^3.

BS 8233:1999 was superseded by BS 8233:2014 [130] which referred to BB93:2003 for detailed guidance on school design.

5.5.3 BS EN 614-1:2006

British Standard BS EN 614-1:2006+A1:2009 Ergonomic Design Principles, Terminology and General Principles [131] contained a number of requirements which could be interpreted as applying to voice use in teachers.

The standard described work fatigue as being mental or physical, local or general non-pathological manifestations of excessive strain which is completely reversible with rest, which could apply to some voice problems.

Although the document was written in terms of considering the ergonomics of machinery design the principles could also readily apply to the use of the voice by teachers.

BS EN 614-1 gave guidance on how to consider ergonomics for the range of a particular parameter in the population of employees. The guidance was that, at least, the 5th to 95th percentiles should be considered, and when health and safety aspects were relevant this was to be extended to at least the 1st and /or 99th percentiles, taking due account of gender balance in the employee population. In terms of voice ergonomics this would mean that in the case of voice level, for instance, design would be based on giving due consideration to those individuals with the quietest voice levels rather than the mean voice level.

5.5.4 The World Health Organisation

The World Health Organisation (WHO) Guidelines for Community Noise [132] stated that classrooms should have suitable noise levels to ensure speech intelligibility and good communication.

The document stated that the signal to noise ratio should be at least 15 dB in rooms for teaching, recommending that ambient noise levels should not exceed 35 dBA in classrooms, with the aim to be as low as possible, with a reverberation time below 0.6 seconds being described as desirable for adequate speech intelligibility. The guidelines did not refer specifically to voice care or related issues.

5.5.5 The Essex Study

The Essex Study (2012) [109] detailed research undertaken at one English secondary school. This involved four similar classrooms being used to study the effect of changing reverberation times.

One classroom was used as a control, with the remaining three being refurbished to the standard BB93:2003 reverberation time criterion (T_{mf}), to the BB93:2003 standard for hearing impaired children (more onerous T_{mf} value) termed BB93 HI, and to BATOD (The British Association of Teachers of the Deaf) [43] standard reverberation time of less than 0.4 seconds from 125 Hz – 4 kHz (all in unoccupied conditions).

The study found that both staff and pupils rated the BB93 HI and BATOD classrooms highest in terms of the subjective effect on pupil behaviour and participation from hearing impaired children. Occupied noise levels were also found to have reduced, both in terms of L_{Aeq} (the researchers stated that this is expected to be dominated by the teacher's voice) and the L_{A90} (expected to be the underlying noise level generated by pupils). The researchers stated that this reduction allowed the teachers to use a lower voice level thus reducing vocal stress while still achieving a marked improvement in the SNR ratio.

Essex County Council (ECC) subsequently adopted the BB93 HI criterion as applying to new and refurbished classrooms on the basis that the enhanced standard had benefits for staff and pupils (both those with and without hearing impairments), although ECC have now reverted to BB93 compliance only [133].

5.6 Conclusions

Reviewing the guidance and legislation indicates a number of documents which could be interpreted as requiring a safe environment for teachers to use their voice in. The voice is not specifically referred to in health and safety guidance and it appears that convention, generally, has not applied these considerations to voice care.

The current approach to voice health seemingly has parallels to how other bloodless injuries such as noise-induced hearing loss were approached in the past. There are perhaps those in the teaching profession itself and the wider society who consider voice problems to be a trivial matter and therefore a significant attitudinal shift may be needed.

Guidance documents on schools make reference to consideration of the voice and the need to provide a suitable environment fit for purpose in its intended use. This would logically seem to encompass being fit for speaking in without detriment to health, but this is an interpretation rather than being referred to explicitly in the guidance.

There would seem to be a weakness in the school guidance and requirements in England, in that without compulsory pre-completion testing, the true acoustic performance of new schools is not known. There has never been compulsory school testing in England so even with good guidance school buildings may not meet the current recommendations, which themselves may not be appropriate for voice ergonomics.

Unlike the Building Regulations, the SPRs *do* require suitable acoustic conditions to be maintained in perpetuity and refer specifically to the voice of the teacher. However, it is noteworthy that the SPRs do not appear to be enforced by any responsible body and as such must be considered to have little power.

In summary, whereas the existing guidance provides general comments and aspirations in terms of providing suitable speaking conditions, there appears to be a lack of specific detail on how this is best achieved, or of any robust mechanism for ensuring the recommendations and requirements are actually enforced.

The following chapter will examine the literature relating to the effects of classroom acoustics on the teacher's voice.

Chapter 6 The effect of classroom acoustics on the teacher's voice

This chapter reviews the known effects of room acoustics on the voice. There are currently a number of researchers actively investigating the interactions between the teacher's voice and classroom acoustics. These include the Nordic Voice Ergonomic Group which comprises voice experts from the five Nordic Countries, and shows that there is an ongoing interest and concerns relating to the topic.

6.1 Lombard effect

Voice parameters are subconsciously modified by speakers in response to various factors including ambient noise. The Lombard effect (1911) [28] is an involuntary response whereby the speaker modifies their voice level, SF_0, speech speed and syllable duration to enhance audibility.

This has implications for teachers speaking in classrooms with high noise levels, and for whom long term changes in speaking patterns could have associated risk factors for developing voice problems.

The Lombard effect has been quantified in various studies summarised in Table 6.1 which indicated that teachers raised their voice in relation to ambient noise at a greater rate than general speakers.

Table 6.1: Lombard effect

Reference	Lombard effect speech level change with noise level	
	General speakers	Teachers
Bottalico *et al.* (2012) [37]	-	1 dB/dB (L_{A90})
Korn (1954) [29]	0.4 dB/dB	-
Pearsons *et al.* (1977) [34]	0.6 dBA/dB (L_{Aeq})	1 dBA/dB (L_{Aeq})

The influence on the teaching voice of different noise types is discussed in the next section.

6.2 Influence of different noise types on voice parameters

The Lombard effect can cause various modifications to voice parameters; however different noise types can influence voice parameters in different ways.

Rantala *et al.* (2015) [134] found UANL and activity noise affected voice parameters differently. The study showed UANL influenced voice level and SF_0, while activity noise affected the voice spectrum. Other studies have also found that higher UANL in laboratory conditions affected SF_0 [135] and voice level [106].

There has been found to be an increase in $SF_{0,\ mean}$ of 1 Hz per dB increase in background noise level (L_{A90}) in occupied classrooms [37] and 2.4-2.7 Hz [139] per dB increase in background noise level (L_{A90}) in unoccupied classrooms.

These findings may be due to UANLs being more consistent over time than activity noise, the result being that teachers have no choice but to compete vocally with the UANL. Activity noise levels may overlap with the speech frequency range and produce different SNR demands on the teacher's voice. Activity noise levels may be linked to pedagogy and discipline, with the teacher having scope to control and influence the noise from the children in the classroom which would not generally apply to the UANL.

The Lombard effect only influenced the SF_0 in men in the study by Rantala *et al.* (2015) [134]. This may be due to the Lombard effect being related to ambient noise levels rather than activity noise levels (constant duration rather than short duration sources). The UANL would tend to be low frequency dominated in classrooms and therefore may influence male voices more due to their lower average SF_0, see Table 2.1.

The study by Rantala *et al.* (2015) [134] also indicated that teachers in higher UANL classrooms spoke in a louder voice generally (both before and after the teaching day) indicating a shift in the habitual voice level.

A study by Jónsdóttir (2009) [74] found a higher prevalence of vocal symptoms in sports teachers compared with other teachers. This implied that speaking over high activity noise levels, exacerbated by long reverberation times and long speaker to listener distances, increased the risk factors for this group of teachers. In addition to vocal symptoms the sports teachers had higher voice levels and SF_0 values. This indicated potentially long term changes with greater risks of vocal loading from high

UANL and/or activity noise levels and possible compensation strategies in the speaker, both conscious and subconscious.

6.3 Influence of reverberation time on voice parameters

Reverberation and noise levels are inter-related and both have scope to influence voice behaviour. Reverberance will increase the levels of externally and internally generated noise, as well as affecting how the speaker perceives their own voice. The reverberant effect increases all noise sources and therefore raises both the wanted (speaker's voice) and unwanted (other sources) noise levels.

Studies have been carried out examining relationships between teachers' voice parameters and reverberation times. A significant relationship between teachers' voice levels and EDT (the initial reverberant decay, see 4.1.2 for further definition) was found [35] which indicated that the longer the EDT the lower the voice level. EDT represents the initial voice reflections from the closest surfaces and the speaker may be aware of the voice reinforcement effect of the room and adjust their voice level subconsciously in response. Cipriano *et al.* (2017) [136] indicated similar findings - that speakers increased their voice levels linearly as the level of their voice at their own ears reduced. In rooms with the lowest reverberation times the teachers' voice levels were highest irrespective of background noise levels.

Pelegrín-García *et al.* (2011) [137] and Bottalico *et al.* (2017) [138] found higher phonation times in more reverberant conditions which may result from teachers adjusting their pedagogy and speaking style. The study by Pelegrín-García *et al.* (2011) [137] also found that SF_0 increased in rooms with higher reverberation times.

There are indications that increased classroom reverberation times may also increase the occupied noise levels due to effects on the noise produced by the students, with one study [139] reporting a 5 dB increase in occupied L_{A90} per 1 second increase in reverberation time.

Although conventional wisdom is that from a speech intelligibility perspective, the lower the reverberation times the better, this may not always apply for intelligibility or for voice ergonomics. Hodgson *et al.* (2002) [108] found that when the noise source is closer to the listener than the speech source, the optimum reverberation time was greater than zero for speech intelligibility. When considering voice parameters and associated risks for teachers' voices the reverberation time and EDT in particular should not be minimised.

Bottalico *et al.* (2012) [37] found that classroom reverberation times of 0.75-0.85 seconds correlated with minimum voice levels in teachers, with lower or higher reverberation times corresponding with higher voice levels.

6.4 Conclusions

The studies reviewed in this chapter indicate that classroom acoustics can influence teachers' voice behaviour and parameters including in ways which may raise the risk of vocal loading and voice problems. To the best of the author's knowledge, studies of this type have not been carried out in England, where pedagogy, acoustic design criteria and classroom constructions may be different from those countries studied in the literature. Therefore there is scope to expand knowledge in this area.

The studies undertaken as part of this thesis were designed to provide additional information on the relationships between voice parameters and room acoustics both by means of field measurements and an online survey which are detailed in the following chapters.

Chapter 7 Measurement of the teacher's voice: choice of instrumentation and pilot study

7.1 Introduction

The aim of the voice measurements element of this study was to measure the voice parameters of teachers during a typical working day, in their normal classroom. The measurements were to be made with minimal disruption to normal classroom activities and to minimize the effects on teacher and pupil behavior.

To provide an acoustic context to the gathered voice data, classroom acoustic parameters were also measured. The following measurements were made for each teacher in the study:

1) Acoustic measurements of the internal ambient noise levels in the unoccupied classroom and other room acoustic parameters including reverberation time.
2) General noise during lessons including the teacher's voice and other sources.
3) Measurements of the teacher's voice only.

Items 1 and 2 were relatively straightforward as there was established guidance for these, however measuring the teacher's voice parameters in isolation required a novel approach.

7.2 Requirements of the measurement approach

The ideal method for measuring voice data was considered to be a method which excluded other noise sources. The system needed to be able to measure the participant during their normal workplace activities discreetly without being overly cumbersome or restrictive to the extent that it would affect the classroom teaching dynamic.

Different options for achieving this were considered and are discussed in the next section.

7.3 Voice measurement methods – microphone and statistical

The most obvious method was by measuring sound pressure levels from a fixed position in the classroom. However this would not allow the voice level of the teacher to be accurately determined as it would include noise from other sources and there would be variations in the distance from the teacher to the fixed microphone.

Alternative methods, such as shadowing the teacher with a sound level meter, were considered but discounted as these would not provide reliable data due to the directionality of the voice. Such an approach would also include noise from other sources and had the potential to change the normal classroom dynamic.

A method of determining the teacher's voice level and other noise sources from a single position measurement within a classroom was identified in the form of a statistical analysis approach by Hodgson *et al*. (1994) [140]. This used sound pressure level frequency (that is frequency in terms of the occurrence rather than the spectral meaning) to isolate ventilation noise, student noise and the voice of the speaker. The study was undertaken in university lectures which were considered to be different to school teaching both in terms of the pedagogy, the levels of noise expected from the listeners and also that the lecturer would be in a relatively fixed position compared with school teachers.

There was also the additional factor that contrary to the normal ventilation strategy for the rooms in the study (undertaken in Canada), the majority of school classrooms in the UK are naturally ventilated and therefore the underlying ambient noise climate may not be sufficiently constant to be identifiable as a discrete component in the distribution.

The measurement requirements were not unique to this study and a number of technical solutions and devices have been developed by others. The main driver for these devices has been, aside from research use in the field, the use by health professionals who wish to gather data on patterns of voice use in patients with voice disorders. These specialist devices were further investigated during the initial phases of this study and are discussed in the following section.

7.4 Voice measurement methods - ambulatory phonation monitors (APMs)

In order to measure the voice parameters of the participant only, it was identified that an Ambulatory Phonation Monitor (APM) or Portable Voice/Vocal Accumulator (PVA) could be used.

These devices measure voice parameters including level, phonation time, phonation percentage and SF_0 (see Chapter 2). APMs can measure during usual work patterns in the normal workplace with minimal disruption and for long periods.

A number of APM devices have been developed for both research and commercial applications [110, 141-144]. These commonly consist of one or more transducers which measure voice related parameters and a portable microprocessor within a belt pack unit.

APMs using microphones to measure the voice signal have been developed. These microphones are typically contact microphones positioned on the neck [10, 141, 142, 144] or conventional acoustic microphones positioned on the head [143]. The less discreet transducer mountings may alter the behavior of pupils as it would be obvious that measurements were taking place, as well as being cumbersome for the participant to wear.

Early devices typically measured only phonation duration and either voice sound level or SF_0. The use of microphones meant that the signal gathered contained both the participant's voice and environmental noise.

APMs with accelerometer transducers have been developed. The use of a miniature accelerometer positioned below the larynx is discreet once fitted and easily concealed. As the accelerometer does not measure airborne sound, non-target audio sources are not measured.

Baken *et al*. (1987) found that the fundamental frequency of the voice was not affected by the transmission through neck tissues [6].

Speech comprises voiced, voiceless and silent components. Voiceless phonation relates to phonemes which are generated without using the vocal folds, for instance /p/, /s/ and /f/ in the English language. APMs would not capture voiceless phonation.

However, as the majority of voice problems are associated with the vocal folds, the unvoiced sections of speech are assumed to not significantly contribute to pathologies or symptoms associated with the vocal folds themselves.

An additional advantage of the APM is that it does not measure speech content and thus avoids issues of confidentiality and privacy.

On the basis of these considerations it was decided that an APM device would be the best measurement method for gathering voice data in this project. The commercially available APM devices were therefore reviewed as detailed in the following section.

7.5 Choice of APM

There were two main APM models available commercially that were considered appropriate for use in this study.

7.5.1 Sonvox VoxLog

The Sonvox VoxLog comprises a neck collar with an accelerometer measuring fundamental frequency and phonation time, and a microphone measuring voice and environmental noise levels with a belt pack containing the data logging system. The device is shown in Figure 7.1.

Figure 7.1: Sonvox VoxLog system [145]

The ambient noise estimation is undertaken only when voice activity is not detected by the accelerometer, meaning that in order to determine continuous classroom noise levels an additional sound level meter system would be required.

The raw data is not retained or accessible using the software and only summary data can be accessed.

The system does not require calibration and does not require fixing to the subject. From a research perspective this may introduce uncertainty into the data as the transducer may move during measurements. For these reasons the system was discounted for this study.

7.5.2 KayPENTAX APM 3200

The KayPENTAX APM 3200 was similar to the Voxlog but did not include an integrated microphone. The system is shown in Figure 7.2.

Figure 7.2: KayPENTAX 3200 APM control box and 3203 accelerometer with an AA battery for scale

The waist-worn control box measures approximately 45 mm (h) x 95 mm (w) x 158 mm (d) and weighs 386 g, including batteries, and is claimed to measure for up to 12 hours without battery changes.

The accelerometer is shown in Figure 7.3. It consists of a rectangular metal accelerometer assembly embedded in a circular silicone pad with a flat rear side and integrated cable which connected to the control box.

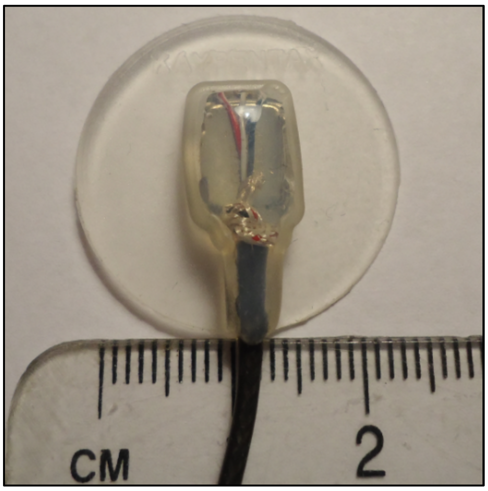


Figure 7.3: KayPENTAX 3203 miniature accelerometer

It was felt that the APM 3200 system was relatively discreet which would assist in recruiting participants and not overly affecting the normal classroom dynamic.

The APM calculates a number of speech parameters including the average sound pressure level (L_p) and SF_0 at a sampling rate of 20 Hz. Proprietary software (version 1.5) could be used for analysis or the raw data could be exported for analysis in other software packages. It was therefore decided to use the KayPENTAX system for this study.

7.6 Accuracy of the APM

KayPENTAX does not publish uncertainty specifications for the APM. Hillman *et al.* (2006) undertook research on the prototype version of the APM and the version used for this study. They found that for sound pressure levels estimated from acceleration the average mean error was less than 3.2 dB with standard deviations of less than 6 dB compared with simultaneous microphone based measurements of the acoustic signal [146].

Švec *et al.* (2005) used similar measurement principles but different equipment, and found that in terms of estimating $L_{p,\ mean}$ from skin acceleration, the differences varied by different amounts depending on the voice level. This was based on L_p values measured simultaneously with a microphone. The largest differences had an uncertainty of less than 3 dB (95% confidence level) and therefore showed good agreement with the APM-specific studies [147].

Švec *et al.* (2005) also found that the estimation of L_{eq} from acceleration data was less accurate than that of L_p. This was considered to be potentially a result of the sensitivity of the L_{eq} value to short duration high L_p values. These short term high values may manifest differently in terms of the acoustic signal relative to the acceleration in the skin [147].

Schutte *et al.* (1983) [148] found that if voice measurements were made with an alternative method such as a sound level meter rather than an accelerometer, a variation of ±2 dB would be expected to occur if the mouth to microphone distance varied by 50 mm.

Hillman *et al.* (2006) [146] looked at the difference between accelerometer estimated phonation time and simultaneous microphone measured phonation. This study found that the accelerometer method gave a higher phonation time but that the difference was less than 3%.

In terms of SF_0 estimation the difference between the microphone and accelerometer derived values was found to be less than 13 Hz by Hillman *et al.* (2006) [146] when considering the signal filtered to the human SF_0 range 70-400 Hz.

Therefore the accuracy of the APM approach was considered comparable with alternative methods, and suitable for considering relative values of voice parameters between different subjects.

The APM equipment did not measure acoustic spectrum data, therefore the L_p values extrapolated were considered dBZ rather than A-weighted. Although this did not impact on relative voice levels between participants it meant that the APM data could not be directly compared with dBA voice levels in guidance documents without further analysis.

7.7 Dynamic range of APM

The APM accelerometer has a dynamic range of 42.1 dB over a frequency response range of 25 Hz to 7 kHz (±3 dB) according to the manufacturer [149]. Buekers *et al.* (1995) [143] reported that the mean voice range is approximately 55 dB for men and 51 dB for women when sustaining a single vowel. This range extends from the softest phonation without whispering to the loudest without screaming.

The range of voice levels used by teachers is likely to be smaller. BS ISO 9921-1 1996 [31] gives a range of 36 dBA from 'relaxed' voice level to 'maximum'. Therefore it is considered that the APM 3200 has a dynamic range appropriate to the study.

7.8 Accelerometer attachment and placement

The APM accelerometer was developed to be located over the hollow area above the suprasternal (or jugular) notch and below the larynx on the centre line of the body. The anatomy is shown in Figure 7.4.

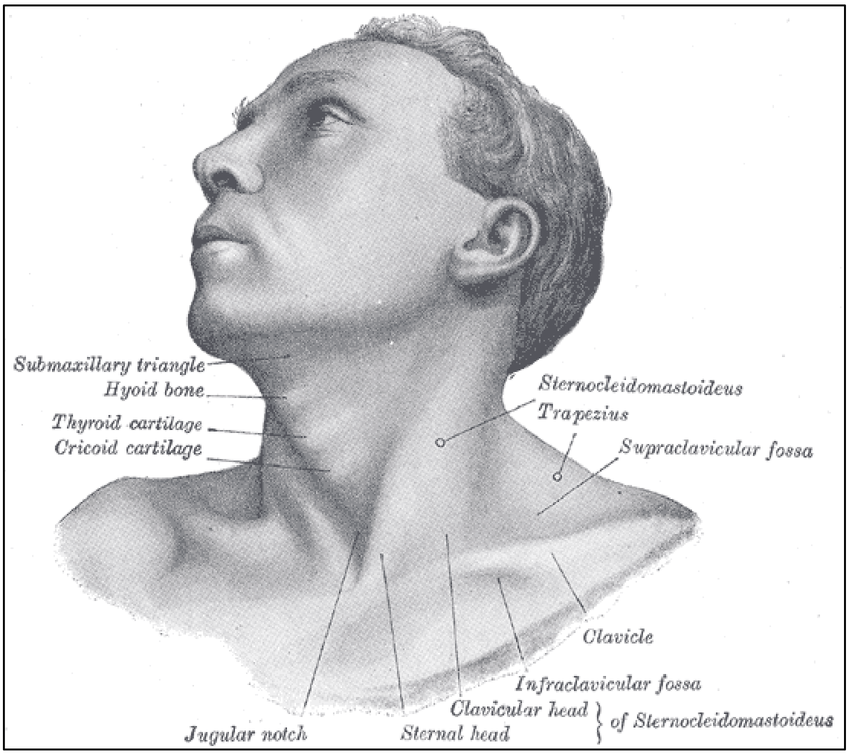


Figure 7.4: Anatomy of the neck showing suprasternal (jugular) notch [150]

Figure 7.5 shows the accelerometer in place on a participant.

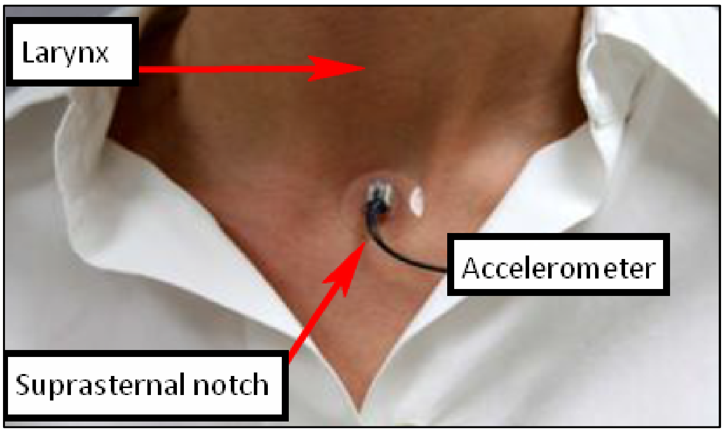


Figure 7.5: The miniature accelerometer glued to the skin over the suprasternal (jugular) notch [149]

The optimum APM position depends on individual physiologies and the accelerometer must be effectively bonded to the skin to ensure that acceleration in the skin is correctly detected. Stevens *et al.* (1975) found that the sternal notch was where maximum amplitude signals could be expected and that the exact positioning was not critical [151]. Cheyne *et al.* (2003) considered that the location was inconspicuous and relatively comfortable for long periods of measurement [152].

In this study the accelerometer was secured in place with Factor II B-401 Secure Medical Adhesive [153] on the flat side of the accelerometer. This adhesive was supplied with the APM equipment and retains adhesion in the presence of moisture or perspiration.

It was found during the initial pilot measurements that there was a risk of cables being snagged by lanyards, neck ties and the like and this resulted in a number of abortive measurements due to the accelerometer being loosened. To give extra protection a surgical tape was applied over the accelerometer to give additional strain relief. This method has been used in another APM study by Švec *et al.* (2005) and was not considered to affect the results [147].

After attaching the accelerometer the system was calibrated as detailed in the following section.

7.9 APM calibration procedure

The APM was calibrated prior to the measurements in a room with suitably low ambient noise levels. A metal bar acted as the distance guide that rested between the participant's upper lip and nose to maintain a fixed 0.15 m distance to the microphone.

The calibration microphone was a dynamic type with unmarked casing, but is believed to be a Shure SM48 model. The microphone had an integrated windscreen to reduce high pressure plosives which would register as a significantly higher SPL due to the associated air pressure peaks rather than the true acoustic pressure levels.

The microphone was supplied with an individual microphone calibration factor. This factor was entered into the APM software during the initial setup.

The microphone assembly is shown in Figure 7.6 with the windscreen removed.

Figure 7.6: Microphone capsule and distance guide

The calibration position and equipment setup are shown in Figure 7.7.

Figure 7.7: Calibration procedure using a microphone with distance guide [149]

The calibration procedure itself involved the participant being fitted with the accelerometer, allowing the adhesive to cure, fitting the surgical tape, running the cable in a practical position for the participant and fitting the control box with charged batteries.

The accelerometer was then connected to the control box, as was the calibration microphone and a mains power supply. The control box was connected to a PC running the proprietary APM software.

The influence of sound reflections from nearby surfaces during the calibration process has been considered. As the calibration procedures were all undertaken with the same distance guide and on similar table surfaces, the reflected sound measured by the microphone would be similar between different participants. The study is primarily concerned with the relative values of voice parameters between the participants which would not be affected.

Calculations indicate that for the relative distances that the reflected sound would travel to and from the nearest surface the contribution to the direct sound level would be around 1 dB.

There is also the effect of the directionality of the microphone which has a -5 dB sensitivity at 90° off axis at the primary speech frequencies [154]. This would mean that the reflections would not contribute to the overall level measured by the microphone.

The system software allowed individual records to be created for each participant with details of the individual and associated notes. The calibration procedure was controlled from within the main software and required the participant to phonate at different voice levels.

There are a number of different phonation patterns recommended for the calibration procedure in the operating manual for the APM [149]. In this study participants were requested to take a deep breath and produce the ‘a’ vowel for 1-2 seconds at soft, medium and loud voice levels with short gaps of around 1-2 seconds in between. These voice levels were self-determined based on the full range that participants would expect to use during their normal teaching.

Hillman *et al.* (2006) [146] investigated the relative accuracy of APM calibration using the sustained ‘a’ vowel technique compared with continuous speech. Hillman *et al.* found that for non-dysphonic subjects, the difference between the two calibration methods in terms of the average error of voice sound pressure level estimates (L_p) was not statistically significant.

As the participant phonated, data points were displayed representing acceleration measured by the throat accelerometer against microphone L_p. Once seven data points have been measured a best-fit line is shown on the plot.

The calibration measurements in this study typically required more than 30 data points to achieve a suitable best-fit line. On occasions it was not possible on the first attempt to successfully calibrate the system; minor adjustments to the placement of the accelerometer by removing and refitting resolved these issues.

The software contained an automatic warning if the calibration was not considered valid. An example calibration plot is shown in Figure 7.8.

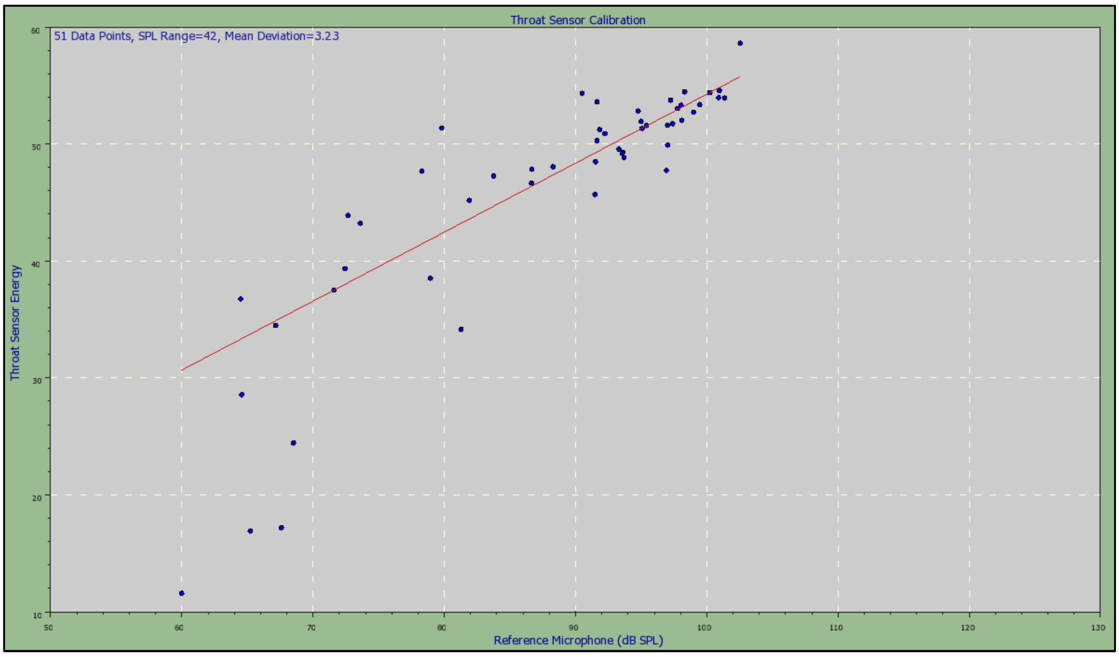


Figure 7.8: Calibration plot example

7.10 APM measurement and data retrieval

The APM device setup contains no user-defined settings in terms of measurement parameters, it effectively consists of a black-box, closed system measuring all the parameters throughout the time of measurement. A prescribed set-up methodology is detailed in the APM equipment manual [149]. This is advantageous as there is no risk of the participant altering, or affecting, the measurements as would be the case of equipment with setting buttons on the device.

Once calibrated, the APM was set into measurement mode via the software and the microphone, external power and computer were disconnected. The participant then continued their working day as normal having been given emergency contact details in case of equipment issues or similar concerns.

At the end of the day the author met with the participant. The accelerometer was checked for any signs of detachment or rotation from the original calibrated position. The measurements were then stopped by disconnecting the accelerometer cable from the control box. The accelerometer was removed with a medical alcohol wipe. An alcohol wipe was also used to remove all adhesive from the accelerometer for hygiene reasons and to prevent the buildup of old adhesive material.

The data was retrieved by connecting the control box to a computer running the proprietary APM software where it could be processed and analysed as described in the following section.

7.11 APM software data analysis

The proprietary APM software has a number of processing functions available and it is possible to analyse defined periods of the overall measurement. The software can give summary details of the total measurement time, mode and mean values of SF_0, average and maximum voice levels, phonation time and percentages. An example screen image from the software is shown in Figure 7.9.

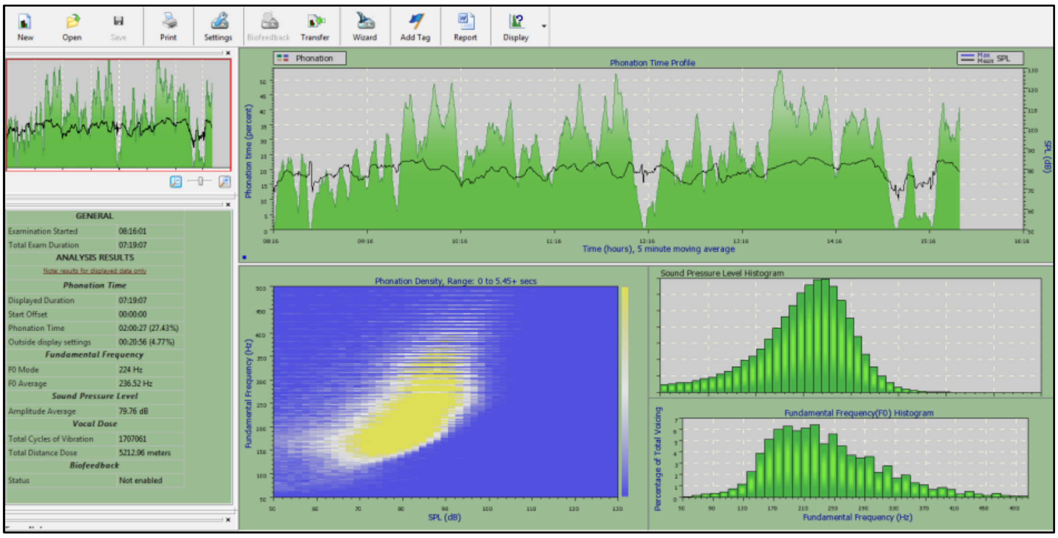


Figure 7.9: Example APM software data view

The screenshot in Figure 7.9 (a larger version is included in Appendix J) shows in the top right section the full measurement period. This was from the time prior to lessons commencing, when the participant was fitted with the equipment, until after lessons had finished.

The proprietary APM software gave the ability to crop sections at either end of the measurement duration which were outside the period of interest, these would then be excluded from the summary data provided by the software on the various voice parameters. The summary data for the various voice parameters for the selected period is shown in the text box to the left hand side of Figure 7.9.

The normal measurement data included periods where the participants were not speaking prior to the start of teaching and after the school day had finished. These redundant periods were excluded and the data analysis related only to the relevant sections of the working day when the participant was teaching.

A typical plot is shown in Figure 7.10 (see Appendix J for a larger copy) with the phonation percentage on the left y axis (green trace) and extrapolated voice level at 0.15 m from the mouth on the right y axis (black trace) against time on the x axis.

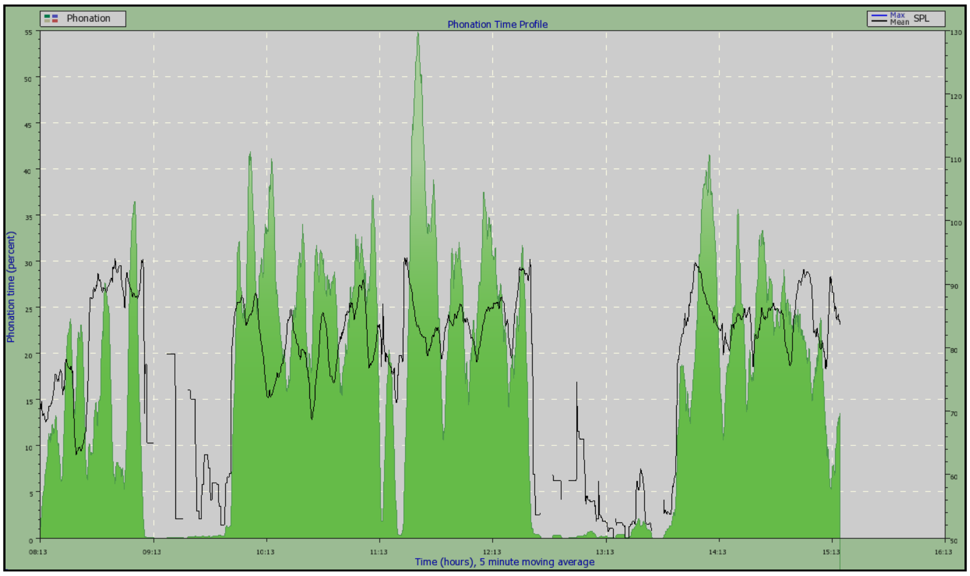


Figure 7.10: Example APM software data trace

The APM estimates L_p at 0.15 metres from the participant's mouth. Voice level data in the literature is normally at 1 metre from the mouth and therefore a correction factor was applied to standardize the data using the equation below:

$$L_2 = L_1 - 20\ Log\left(\frac{r_2}{r_1}\right)$$

Where: L_1 = L_p at the reference distance.

L_2 = L_p at the distance to be calculated.

r_1 = reference distance from the source.

r_2 = distance from the source for calculation.

Based on this approach a distance correction of -16.5 dB was applied to the APM data.

7.12 Initial pilot measurements

A number of pilot measurements were carried out to develop the measurement methodology.

Initially these involved two members of academic staff at London South Bank University with measurements being made during lectures. These measurements allowed the author to become proficient in fitting the APM equipment and to determine the most suitable methods of running cables between the throat accelerometer and the control box. Images of the participants wearing APM belt packs are shown in Figures 7.11 and 7.12.

Figure 7.11 and 7.12: APM fitted to participants during initial pilot measurements showing belt pack and accelerometer cable

Following these initial pilot measurements it was possible to refine the measurement protocol. The initial pilot exercise allowed the key ethical issues to be identified and discussed with the supervisory team and the most suitable approaches to be considered and developed. This was key to applying for, and being granted, ethical approval for the research project. Ethical approval was granted under UREC number 1283 (see section 9.2).

There then followed pilot measurements on school teachers. These were based at a secondary school and involved four teachers measured each for a normal teaching day. The room acoustics, unoccupied and occupied noise levels, were also measured in the relevant classrooms.

These pilot measurements allowed the practicalities of calibration and measurements in real schools to be honed. The data gathered during these pilot measurements with teachers have been considered in conjunction with the data gathered in the subsequent wider study.

7.13 Conclusions

The APM device identified in this chapter allowed for direct measurements of the teacher's voice independent of other acoustic sources and provided a practical means of gathering voice data in real school environments with an appropriate level of accuracy and detail.

The initial pilot measurements with university teaching staff allowed the practicalities of APM use to be understood prior to use with teachers. Once the methodology for the APM use was established then the approach for benchmarking the classroom room acoustics parameters in terms of reverberation times and noise levels was developed. The next chapter will detail the equipment used for the acoustic measurements of the classrooms along with the development of the methodology.

Chapter 8 Acoustic measurements of classrooms: equipment and methodology

8.1 Introduction

Following the pilot measurements, the methodology for measurements of the classroom acoustics was refined. This chapter gives details of the approaches and equipment used to acoustically benchmark the unoccupied classrooms and for measurements of occupied noise levels.

8.2 Unoccupied classrooms

Acoustic measurements were made in the classrooms, while unoccupied, in which the participating teachers taught. These were typically made during school holidays to avoid noise generated by school activities as per the IANL criteria in BB93:2015 [123]. The classrooms were measured with the regular furniture and equipment in place. Only the author was present during these measurements.

All sound level meters used in this study held a valid calibration certificate at the time of measurements and a field check of calibration was undertaken before and after each measurement set. This field check procedure is intended to identify any drift in the calibration level between periodic laboratory calibrations.

8.2.1 Unoccupied ambient noise levels (UANLs)

UANLs were measured using a Norsonic 140 Class 1 sound level meter, which is the highest classification in terms of accuracy as defined in BS EN 61672-1:2003 [96].

Measurements were made in accordance with the methodology referred to in BB93:2015 [123]. Measurements were carried out between 09:00 and 15:00 hours, which are the typical core teaching hours in England.

Maintenance works and other activities often occur during school holidays making it difficult to capture extended periods of ambient noise without unrepresentative noise sources. Therefore internal noise level measurements were typically made over several 1 minute periods during times considered representative of typical ambient noise conditions, excluding internally generated noise. A logarithmic average was calculated for each classroom.

8.2.2 Room acoustics

Room acoustic parameters were measured using both a sound level meter and a software based system for completeness. The sound level meter was a Brüel & Kjær Type 2260 Investigator (Class 1) equipped with building acoustics software. This meter was used with an amplifier and dodecahedron loudspeaker system, with the test signal generated by the sound level meter as shown in Figure 8.1.

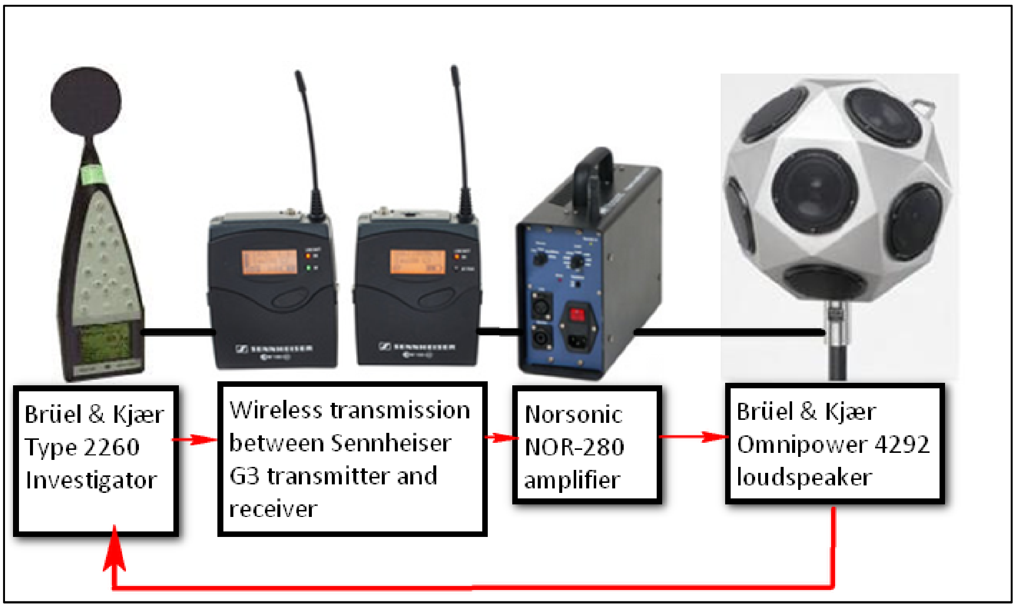


Figure 8.1: Sound level meter reverberation time measurement chain

Reverberation times were measured using the interrupted source method in octave bands at six measurement positions spatially averaged for each of two source loudspeaker positions in line with BS EN ISO 3382-2:2008 [155]. The reported results are the mean values across all measurement positions.

Measurements of room impulse responses were made using WinMLS 2004 [156]. WinMLS enables a variety of acoustic measurements to be made, in this instance measurements were made using a swept sine method. The measurement signal chain is indicated in Figure 8.2 and a typical measurement arrangement is shown in Figure 8.3.

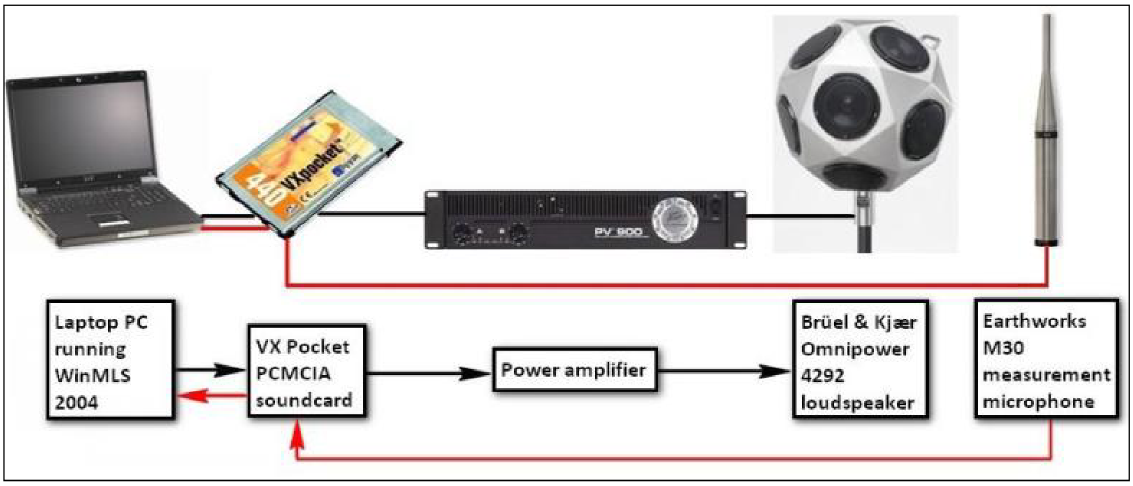


Figure 8.2: WinMLS measurement signal chain

Figure 8.3: Typical arrangement for room acoustic measurements

The typical measurement window from WinMLS is shown in Figure 8.4:

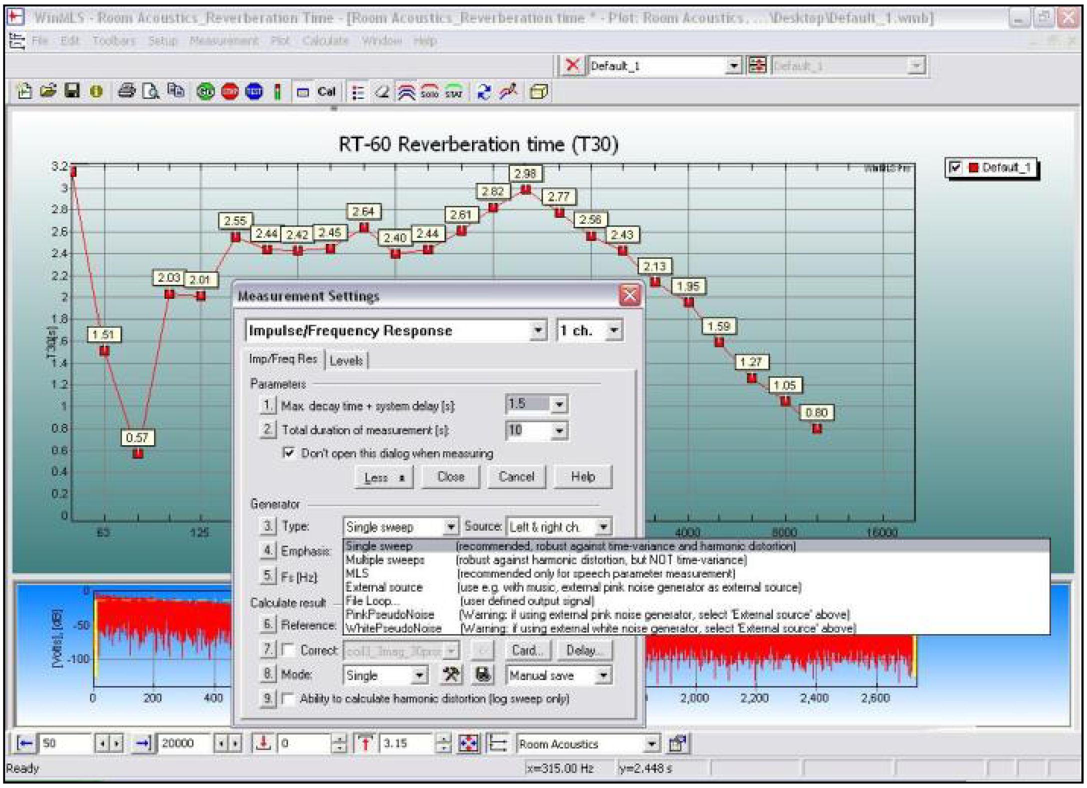


Figure 8.4: Typical WinMLS operating window

In addition to the main reverberation time parameter of RT_{60}, WinMLS is also able to calculate EDT and a range of other parameters in both overall and spectrum values.

8.3 Occupied classrooms

During the working day when the teacher's voice was measured (see Chapter 9), the general activity noise levels were measured simultaneously in their classroom with a sound level meter.

The equipment was installed at the most distant pupil position from the teacher in the classroom, normally at the rear of the classroom. This is where the signal to noise ratio (SNR) between the teacher's voice and ambient noise would be lowest. At this position the listener would be at the greatest distance from the speaker but ambient noise would be at the same general level due to external noise intrusion and activity noise.

The sound level meter used, a Norsonic 140, has the capability to measure simultaneously over two different time periods. Measurements were made in both 1 second and 1 hour intervals simultaneously of A-weighted and spectral values.

As the sound level meter was not attended by the author during the day it was mounted securely and protected to avoid equipment damage and prevent the equipment falling onto children. The sound level meter body was locked in a flight case with the microphone fixed externally to the case handle. The microphone was fitted with a 50 mm diameter windshield. A typical location of the sound level meter is shown in Figure 8.5.

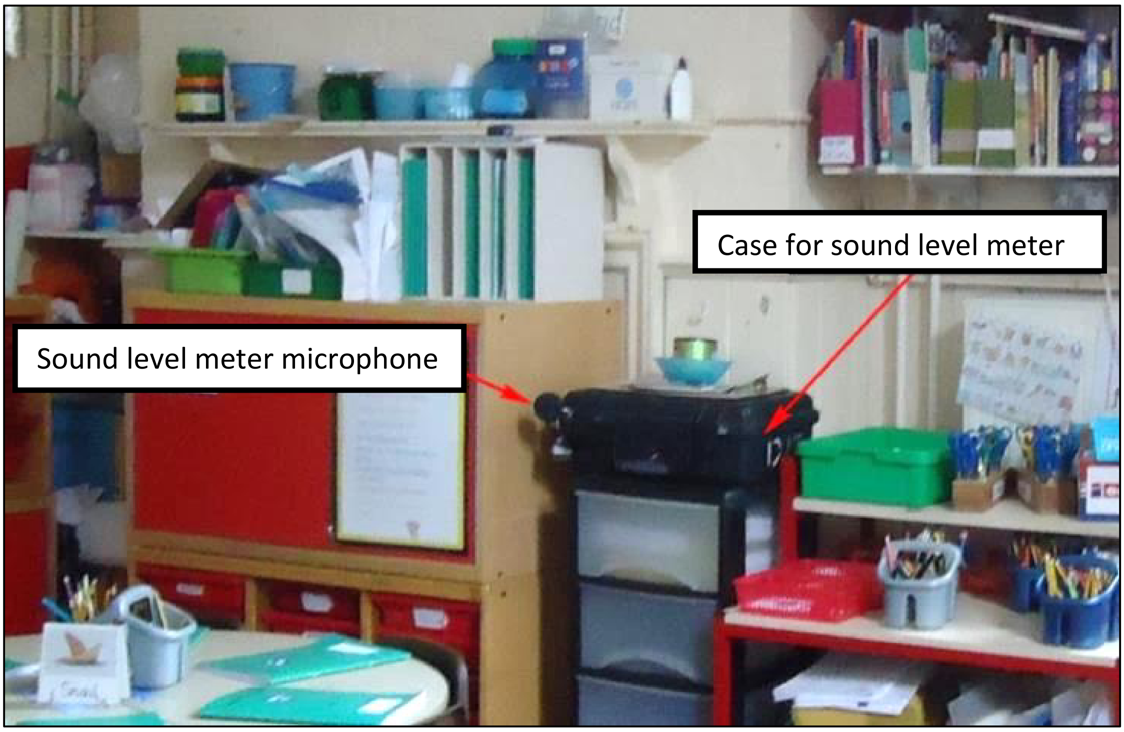


Figure 8.5: Typical sound level meter location for occupied noise measurements

The sound level meter was installed prior to lessons commencing and retrieved after the end of the school day. During post processing only the lesson period data was analysed.

To comply with the ethical approval, audio recording was not used. To avoid influencing the normal classroom dynamic the author was not present in the classroom during the measurements. The teacher gave feedback to the author on the nature and timing of different activities during that teaching day.

8.4 Conclusions

This chapter has described the equipment and procedures used in measuring noise levels and room acoustics in both empty and occupied classrooms, in order to obtain the most representative and reliable data. Chapter 9 gives details on the recruitment and demographics of the schools and teachers that participated in the measurements. Chapter 10 summarises the results of the classroom acoustics measurements and Chapter 11 the teachers' voice measurements.

Chapter 9 Voice and acoustic surveys

9.1 Introduction

This chapter details the process of gaining ethical approval for the voice measurements element of the project, along with the recruitment of schools and teachers to participate in the study. The chapter then gives details of the schools and the participating teachers.

9.2 Ethical approval

Due to the involvement of human participants both for the voice measurements and the online survey of teachers, ethical approval was required from the University Ethics Committee.

The research was designed to be compliant with the *Code of Practice for Research Involving Human Participants, by London South Bank University Research Ethics Committee, July 2011* which ensured compliance with the university's legal and insurance requirements and provided an ethical framework. The primary requirements were as follows:

For the voice measurements:

1) Data protection - data was to be securely stored and any use of the data in public documents had to be anonymised.

2) Psychological intrusion - participants had the ability to withdraw at any time. Information on sources of further help and advice for those concerned about voice strain was provided.

3) Bodily contact - equipment fitting could involve bodily contact between the researcher and participant. The fitting process was explained to the participant prior to gaining consent and they were offered the option of fitting the equipment themselves with the author's assistance if required.

4) Misunderstanding of social/cultural boundaries - a full explanation of the procedure was given to the participants along with the opportunity to discuss and query any aspect of the testing as well as to withdraw from the study.

For the online survey points 1 and 2 also applied.

An application for ethical approval was submitted in December 2012 and following correspondence with the LSBU Ethics Committee approval was granted in April 2013 (reference UREC 1283). A copy of the ethical approval letter is contained in Appendix B. In addition, in order to gain access to schools it was necessary for the author to obtain a Criminal Records Bureau check.

9.3 Recruitment of schools and teachers

Recruiting schools to participate in the study proved challenging and relied heavily on the author's contact network. Ideally the schools would have been selected based on producing a representative range; however it was necessary to utilize all the schools that were willing to participate to maximize the number of participants.

The initial contact normally involved the author meeting with the head teacher to explain the research project. This was followed by visiting prospective classrooms and meeting teachers interested in participating.

An invitation letter was provided to the head teacher giving written details of the study and requirements (see Appendix C).

Once a school had agreed to participate, the author attended the school to undertake benchmarking measurements of the unoccupied classrooms and visits were arranged for the main voice measurements.

9.4 Preliminary information

Prior to the measurements, participants were given a detailed information sheet explaining the procedure involved, the potential risks where applicable and how the gathered data would be used. This also stated that participants could withdraw from the study at any time without consequence.

A unique participant number was assigned to each individual, details of which were kept in secure electronic format accessible only to the author and supervisory team. A copy of the information sheet and consent form is included in Appendix C.

Following the signing of the consent section, the participants were requested to fill in a questionnaire, shown in Appendix E, which covered various aspects of their teaching experience, general and voice health and experiences with acoustics as well as voice problems in general. This information was invaluable in gathering information on other factors which could be considered alongside the voice and room acoustic data.

9.5 Details of participating schools

For logistical reasons the participating schools were in South East England. Each school was assigned a number for ease of reference and anonymity. Six schools were involved in the study - five primaries and one secondary school.

The schools were representative of the range of building types currently in use in England, including older schools which have been extended and refurbished since original construction, and more modern buildings. The school locations are shown in Figure 9.1 and detailed in Table 9.1.

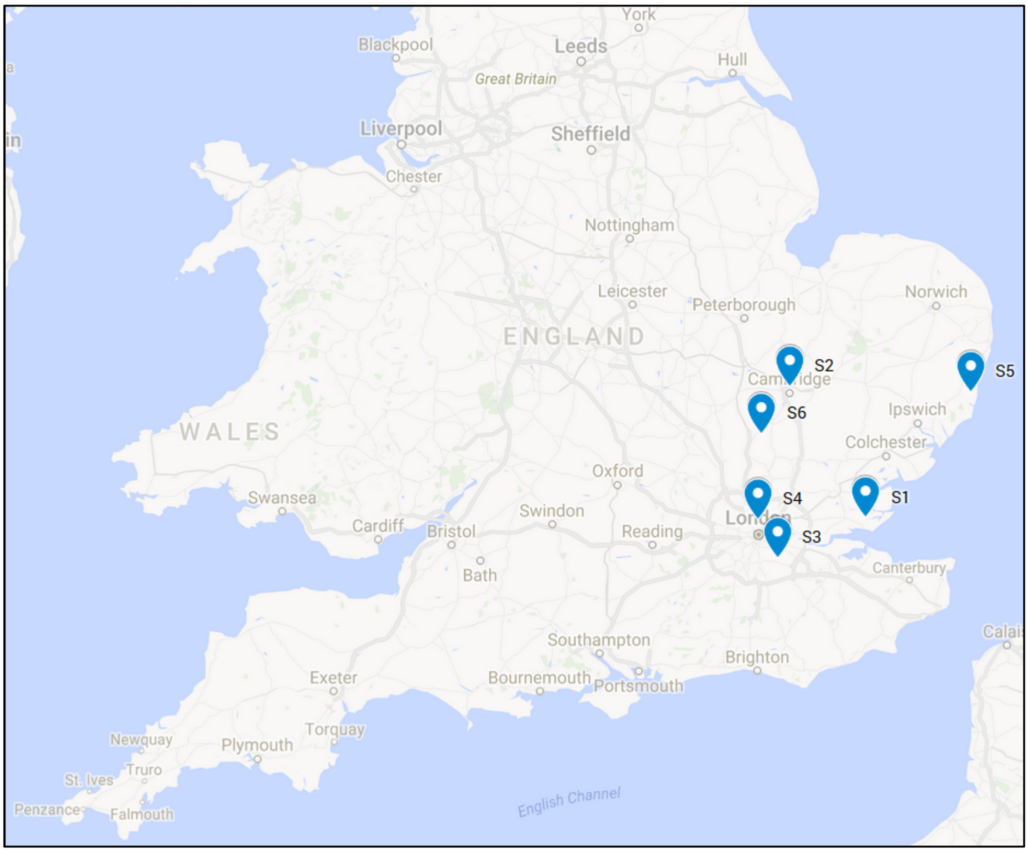


Figure 9.1: School locations

Table 9.1 – School information [157]

School	Location	Type	Age range	Constructed	Pupil no.	Free school meals % (UK mean)	Ofsted rating
S1	Urban	Academy converter	11-18	1957	1200	15.8 (28.2)	Outstanding
S2	Urban	Community school	4-11	1989	200	7.6 (26.6)	Outstanding
S3	Metropolitan	Academy converter	5-11	1891	500	23.8 (26.6)	Good
S4	Metropolitan	Community school	3-11	1884	470	17.1 (26.6)	Outstanding
S5	Rural	Community school	4-11	1875	100	16.5 (26.6)	Good
S6	Urban	Community school	3-9	1974	150	3.1 (26.6)	Good

The range of free school meal provision for the schools indicated a range of social demographics in the school intakes. All schools had mixed gender classes. No free schools were involved in the study. All schools had 'good' or 'outstanding' Ofsted ratings.

9.6 Classroom information

A range of classroom types were selected ranging from classrooms constructed in the late 1800s to those refurbished to modern acoustic standards in recent years. The classrooms measured in this study all predated the current guidance in BB93:2015 [123] and therefore would not necessarily comply with the latest acoustic requirements. Figures 9.2 and 9.3 show examples of older and more recently built classrooms representative of those involved in the study.

Figure 9.2: Classroom constructed in the 1890s

Figure 9.3: Classroom constructed in the 1970s

All classrooms were naturally ventilated without mechanical ventilation or air conditioning.

Each classroom was given a reference number which includes the school number. Two participants taught in the same classroom. Floor plans of the schools and classrooms along with photographs are contained in Appendix D. The general physical properties of the classrooms are summarised in Table 9.2 and detailed in the next section.

Table 9.2: Classroom physical properties

School	Classroom	Year	Volume m^3	Ceiling height m	Finishes			
					Walls	Floor	Ceiling	Glazing
S1	S1C1	1957	120	2.5	Plaster + absorbent panels	Carpet	Tiled grid	DG*
	S1C2	1957	171	3.1	Plaster	Carpet	Plaster	DG
	S1C3	1957	125	2.7	Plaster + absorbent panels	Carpet	Tiled grid	DG
	S1C4	1957	136	2.5	Plaster	Carpet	Tiled grid	DG
S2	S2C1	1989	144	2.4	Plaster	Carpet	Plaster	SG**
	S2C2	1989	242	2.4	Plaster	Vinyl	Plaster	SG
	S2C3	1989	131	2.4	Plaster	Carpet + some vinyl	Plaster	SG
	S2C4	1989	114	2.4	Plaster	Carpet + some vinyl	Plaster	SG
S3	S3C1	1890	282	4.7	Plaster + painted brick	Parquet + some carpet	Plaster	SG
	S3C2	1890	256	4.7	Plaster + painted brick	Parquet + some carpet	Plaster	SG
	S3C3	1998	142	2.6	Plaster	Carpet some vinyl	Plaster	DG
	S3C4	1998	149	2.5	Plaster	Carpet some vinyl	Tiled grid	DG
S4	S4C1	1884	279	4.6	Plaster + painted brick	Vinyl	Plaster	SG
	S4C2	1884	234	4.8	Plaster + painted brick	Vinyl some carpet	Plaster	SG
	S4C3	1884	326	5.3	Plaster + painted brick	Wood some carpet	Plaster	SG
S5	S5C1	1875	426	4.9	Plaster + painted brick	Vinyl	Plaster	SG
S6	S6C1	1974	174	2.4	Plaster	Ceramic tiles	Tiled grid	DG
	S6C2	1974	173	2.4	Plaster	Ceramic tiles	Tiled grid	DG
	S6C3	1974	166	2.4	Plaster	Carpet + vinyl	Tiled grid	DG

*DG = double glazed **SG = single glazed

9.6.1 Physical properties of classrooms

The majority of the classrooms were located either on school sites where there was low external environmental noise or where the arrangement of the school site meant classrooms were screened from environmental noise. The main exceptions were classrooms S3C1 and S3C2 which were both located adjacent to a busy road.

The secondary school classrooms were all at a single school in a quiet location away from main roads and therefore may not represent typical secondary school conditions. The primary school classrooms were located in several schools and contained a wider range of internal noise levels. Secondary schools have traditionally been on larger sites than primary schools due to the number of pupils requiring larger buildings and also more comprehensive sporting facilities leading to bigger grounds. This means that secondary schools buildings may typically be at a greater distance from roads and therefore may have lower external noise levels compared with primary schools.

Many of the oldest classrooms remained as originally constructed with what would now be considered poor acoustics. This included single pane windows which offered relatively poor sound insulation from external noise, and ventilation openings without acoustic attenuation as well as a lack of sound absorption.

For all the classrooms the overall mean volume was 199 m^3 (*SD* 81.7 m^3) with a mean ceiling height of 3.2 m (*SD* 1.10 m). The older classrooms, built between 1875 and 1957 (n = 10), had relatively high ceiling heights (mean 4.0 m, *SD* 1.07 m) and large volumes (mean 236 m^3, *SD* 94.1 m^3) which, with limited sound absorption, resulted in relatively long reverberation times. The newer classrooms, built between 1974 and 1998, had lower ceiling heights (mean 2.4 m, *SD* 0.07 m) and smaller volumes (mean 159 m^3, *SD* 34.6 m^3).

9.7 Participating teacher information

Twenty teachers were measured in total in the study. All taught full time and were fully qualified. Prior to measurements each participant filled out the participant questionnaire; this is detailed, along with responses, in Appendix E. The details of the participants are summarised in Table 9.3.

Table 9.3: Teachers information summary

Participant reference	School reference	Primary/ secondary	Classroom reference	Gender	Age	Years teaching	Voice training
1	S1	S	S1C2	F	24	<1	Yes
2	S1	S	S1C1	M	27	1	No
3	S1	S	S1C3	M	38	16	No
4	S1	S	S1C4	F	34	1	Yes
5	S2	P	S2C3	F	38	15	No
6	S2	P	S2C4	F	39	16	No
7	S3	P	S3C2	F	60*	11	Yes
8	S5	P	S5C1	F	49	26	No
9	S4	P	S4C2	F	59	11	Yes
10	S4	P	S4C3	M	38	12	No
11	S6	P	S6C1	F	30	9	Yes
12	S6	P	S6C3**	F	22	<1	No
13	S2	P	S2C1	F	33	7	No
14	S3	P	S3C1	M	28	1	Yes
15	S2	P	S2C2	F	46	4	Yes
16	S4	P	S4C1	F	45	16	Yes
17	S6	P	S6C3**	M	28	<1	Yes
18	S6	P	S6C2	F	27	3	No
19	S3	P	S3C4	F	23	3	No
20	S3	P	S3C3	M	27	1	Yes

* Estimated – not provided.

** Participants number 12 and 17 both taught in classroom S6C3.

Further information on the participants is detailed in the following sections.

9.7.1 General

Four participants taught in the secondary school and sixteen in primary schools. The secondary school teachers were measured during the pilot measurements. All teachers taught in classes with no more than 33 pupils.

Each teacher was measured during what they identified as a typical working day, carrying out normal activities in their usual classroom. Measurements were made typically from 09:00 to 15:00 hours during core teaching hours and did not include preparation time, meetings and other activities outside these times, or non-occupational voice use. These other periods of phonation may have contributed to the overall voice loading for participants which would not have been captured in the measurements.

Participants who were suffering from voice problems or respiratory infections at the time were excluded from the study.

9.7.2 Gender of participants

For the participants overall 70% (*n* = 14) were female and 30% (*n* = 6) were male. For the secondary school participants (*n* = 4) the split was equal. For the primary school participants 75% (*n* = 12) were female and 25% (*n* = 4) were male. For the profession as a whole 74% overall in England are female (86% of primary school and 64% of secondary school teachers) [87]. Therefore the gender makeup of the participants was representative of the profession overall, but the ratio of females to males was lower in primary and higher in secondary schools than in the wider profession.

9.7.3 Age of participants

The mean age of all the participants was 36 years (*SD* 11.0) with the age for one participant being an estimate. The average teacher age for England in 2013 was 39.2 [158], and therefore the age profile of participants in this study is considered similar to that of the profession as a whole.

9.7.4 Teaching experience of participants

The participants in the study were at different points in their careers, from newly qualified to those nearing retirement. The mean period of teaching was 8 years (*SD* 7.1) with those reporting having less than one year of experience being counted as one year.

The mean length of teaching experience for England is 12.4 years [158] meaning the participants in this study had a marginally lower experience profile than the wider profession.

9.7.5 Voice training of participants

Fifty percent of participants had received voice training. This voice training ranged from a single session to more comprehensive instruction.

9.7.6 Participant questionnaires

The main findings are summarised below with the full response data in Appendix E.

- 60% of participants had previously lost their voice completely.
- 50% said their voices felt tired at times.
- 90% had used their voice with a sore throat indicating significant loading on the voice.
- 35% reported that their voice deteriorated with use.
- 90% stated that their voice recovered with rest; however in practice it may be hard to take voice rest when teaching.
- 20% stated that their voice had altered in the past year and 30% that their voice was less flexible – this may indicate short-term reversible effects as well as longer-term permanent changes to the voice.
- 10% had sought advice on their voice with 5% having had speech and language therapy due to voice problems. This indicated that, although many participants appeared to be aware of voice changes through occupational use, only a small number sought advice or treatment to assist.

- 25% of participants reported shouting often, with 90% saying that they talked over background noise and 35% reporting working in difficult acoustic conditions.
- It was reported by 65% of the participants that they put too many demands on their voice; 60% felt that they used their voice too much and 25% worried about their voice.

These responses indicated that there were concerns about the voice amongst the participants and that their patterns of occupational voice use may be impacting on their voice characteristics. A number of responses to the questionnaire have been analysed along with the voice measurements and classroom acoustic data and are referred to in subsequent sections.

9.8 Conclusions

The schools, classrooms and teachers that participated in the study have been selected to be as representative as possible of the current teaching profession and conditions in England. The classrooms represented the full range from classrooms unchanged since their original construction in the 19th Century to those featuring modern constructions.

The results of the participant questionnaires showed that 65% reported too many demands on their voice with 60% having lost their voice completely at times and 50% saying that their voice felt tired at times. These findings are in agreement with other studies (see section 3.3.3) that reported a relatively high percentage of teachers experiencing and being concerned about voice problems. The next chapter gives the results of the classroom acoustic surveys.

Chapter 10 Acoustic survey results

10.1 Introduction

This chapter gives the results of the acoustic measurements made in the classrooms in terms of unoccupied room parameters and occupied noise levels. These provide an acoustic context to the voice measurements.

10.2 Classroom acoustics data

School S1 was the sole secondary school with the remaining schools S2-S6 being primary schools; therefore the two types of school are considered separately.

Mean values given are arithmetic averages. All decibel values are rounded to the nearest whole decibel. EDT_{mf} and A_{mf} are EDT and total absorption ('A') values calculated at the T_{mf} frequencies as defined in sections 4.1.1, 4.1.2 and 5.4.1. All reverberation time values are RT_{60} calculated from measured T_{20} values. Spectral data for unoccupied parameters are contained in Appendix F.

The acoustic parameters measured and calculated for the unoccupied classrooms are summarised in Tables 10.1 and 10.2 for the secondary and primary school classrooms respectively.

Table 10.1: Acoustic data for unoccupied secondary school classrooms

School	Classroom	L_{Aeq} dB	L_{A1} dB	L_{A90} dB	T_{mf} (s)	EDT_{mf} (s)	A_{mf}	Room radius m
S1	S1C1	23	32	20	0.4	0.4	46	0.9
	S1C2	28	33	25	1.0	1.2	26	0.7
	S1C3	24	27	23	0.3	0.3	60	1.1
	S1C4	27	33	23	0.9	0.9	24	0.7
Mean value		26	31	23	0.7	0.7	39	0.9
SD		2.1	2.4	1.8	0.30	0.37	14.9	0.17

Table 10.2: Acoustic data for unoccupied primary school classrooms

School	Classroom	L_{Aeq} dB	L_{A1} dB	L_{A90} dB	T_{mf} (s)	EDT_{mf} (s)	A_{mf}	Room radius m
S2	S2C1	35	38	34	0.7	0.6	35	0.8
	S2C2	35	41	34	0.5	0.5	76	1.2
	S2C3	29	34	27	0.5	0.5	40	0.9
	S2C4	37	40	37	0.6	0.5	32	0.8
S3	S3C1	37	44	33	0.8	0.8	54	1.0
	S3C2	38	49	28	0.9	0.9	48	1.0
	S3C3	28	33	26	0.7	0.7	34	0.8
	S3C4	28	36	26	0.3	0.3	73	1.2
S4	S4C1	29	32	29	1.1	1.0	41	0.9
	S4C2	32	33	32	0.8	0.8	47	1.0
	S4C3	30	33	29	1.0	1.0	51	1.0
S5	S5C1	32	34	31	0.9	0.8	78	1.2
S6	S6C1	29	34	27	0.4	0.4	68	1.2
	S6C2	26	30	25	0.4	0.3	75	1.2
	S6C3	30	39	26	0.4	0.3	73	1.2
Mean value		32	37	30	0.7	0.6	55	1.0
SD		3.7	5.0	3.6	0.24	0.24	16.5	0.16

The unoccupied acoustic characteristics of the classrooms are discussed in the next section.

10.3 Unoccupied classroom noise levels

The unoccupied noise levels are shown in Figure 10.1 with the BB93:2015 [123] new construction IANL criterion. Although compliance is not mandatory or retrospective for classrooms built prior to the guidance, it provides a benchmark for the measured classrooms.

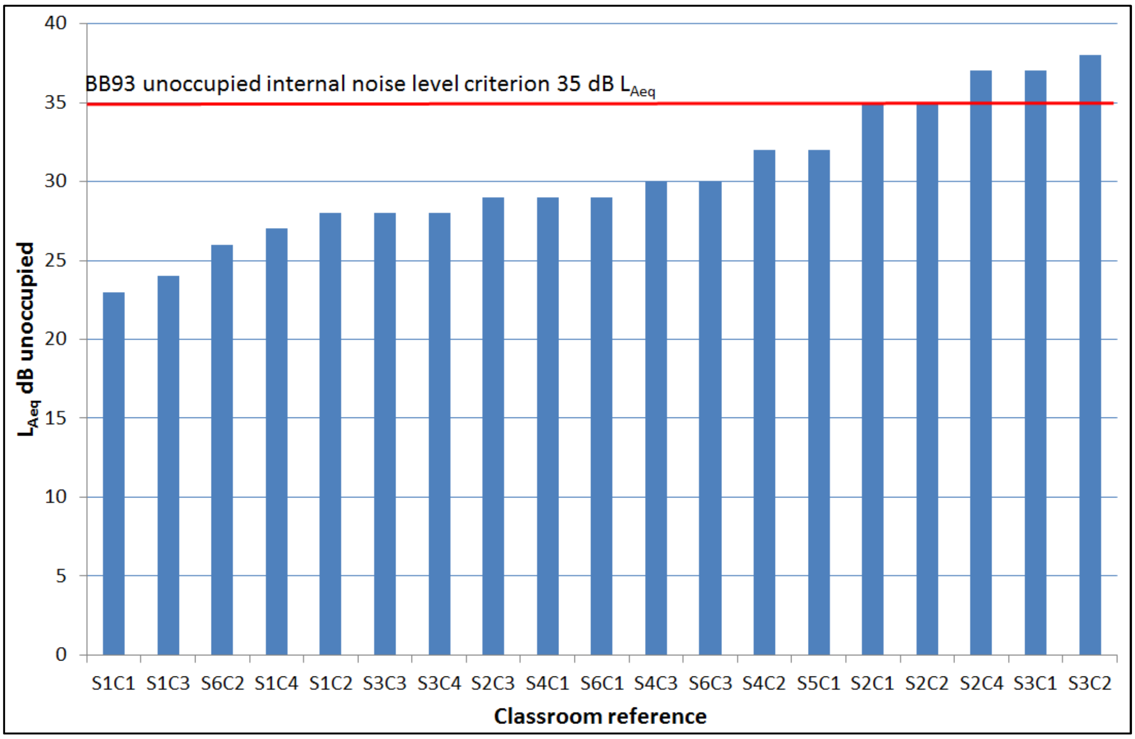


Figure 10.1: Unoccupied L_{Aeq} noise levels by classroom

The unoccupied noise levels ranged from 23 to 38 dB L_{Aeq}. The results show that three classrooms did not meet the current BB93:2015 [123] IANL criterion.

The L_{A90} UANL values may provide a better indication of the underlying noise levels when the school is not operating. It is often impossible to exclude all extraneous noise and even short duration events can significantly increase the L_{Aeq} value. The unoccupied L_{A90} values are shown in Figure 10.2. If the L_{A90} values represent the underlying UANL, there is one classroom above the BB93 IANL level.

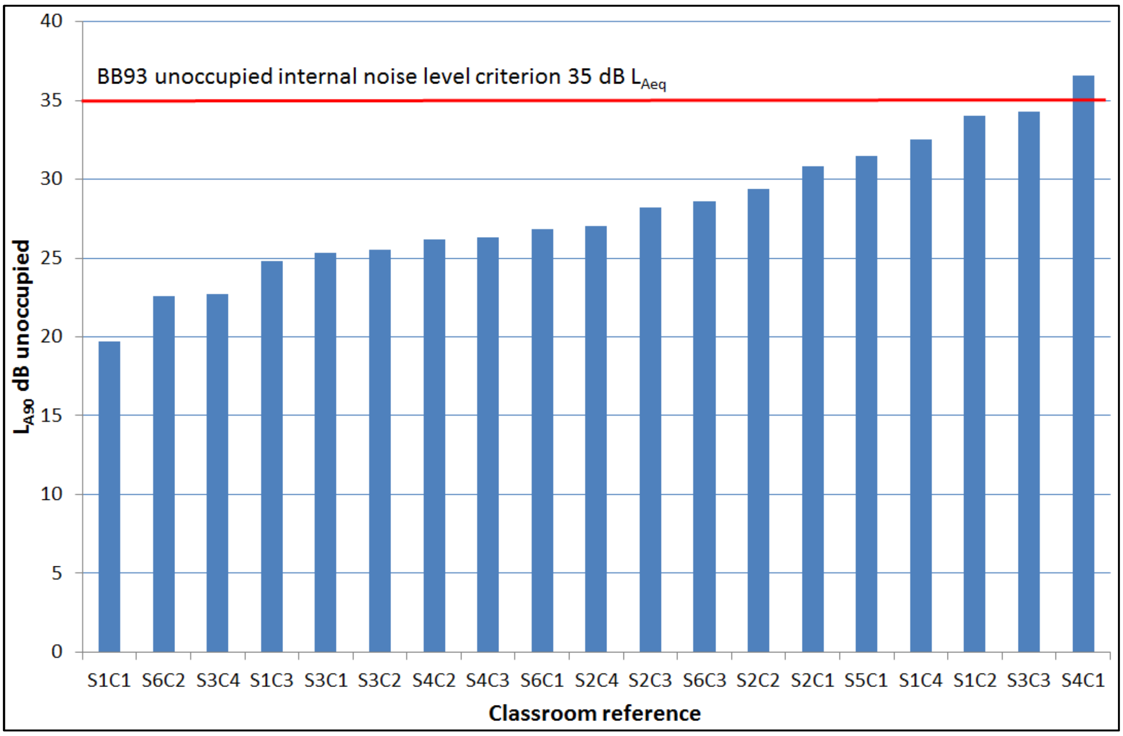


Figure 10.2: Unoccupied L_{A90} noise levels by classroom

A histogram of the UANL L_{Aeq} noise levels is shown in Figure 10.3. This shows that in 16 of 19 classrooms the levels were less than or equal to 35 dB L_{Aeq} with the greatest number (n = 12) in the 26 to 30 dB L_{Aeq} range. No classrooms were lower than 21 dB L_{Aeq}.

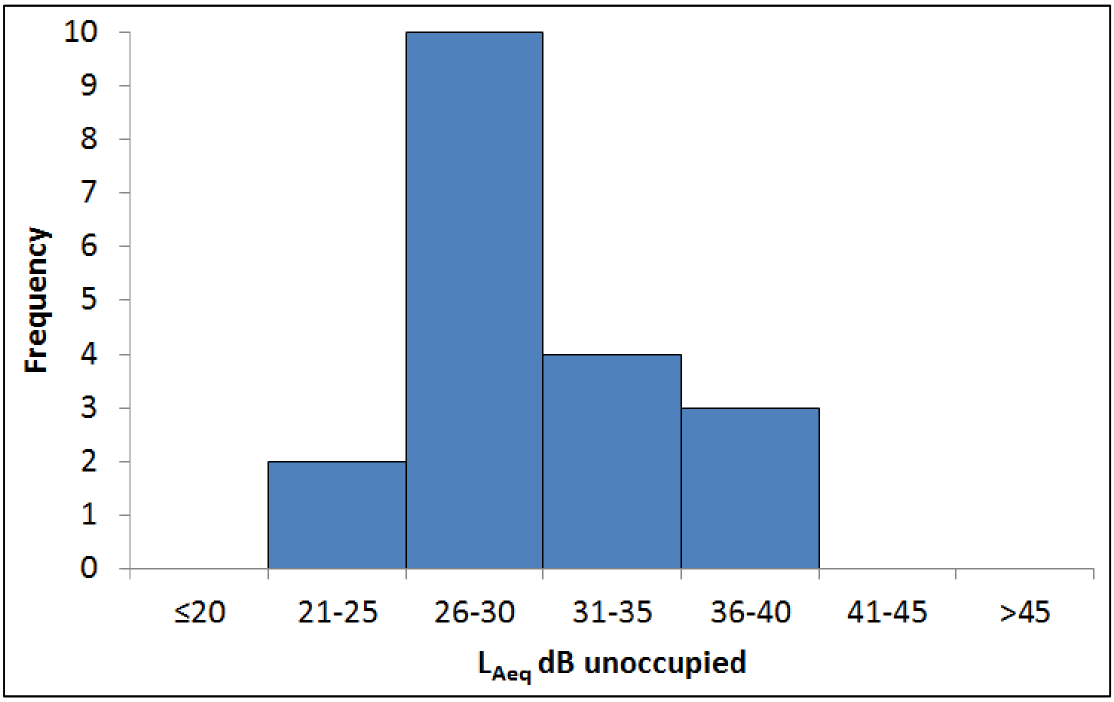


Figure 10.3: Frequency distribution of unoccupied L_{Aeq} noise levels (all)

The majority of primary school classrooms (*n* = 10) were in the UANL 26 to 30 dB L_{Aeq} range but three were in the 36 to 40 dB L_{Aeq} range which exceed the BB93:2015 IANL criterion. The four secondary school classrooms ranged from 23 to 28 dB L_{Aeq}.

In terms of L_{A1} all classrooms were within the BB93:2015 [123] limit of 60 dB. Three of the primary schools had values above 40 dB L_{A1} which may result from being adjacent to a busy road and having single glazed windows. L_{A10} values are often used as an indication of traffic noise levels; these were significantly above the L_{A90} values in locations where, subjectively, traffic noise was high indicating a significant contribution from traffic sources.

10.4 Reverberation times

There was a significant range of reverberation time values between the classrooms, with T_{mf} ranging from 0.3 to 1.1 seconds, with a mean value of 0.7 seconds (*SD* 0.24).

The T_{mf} values by classroom are shown in Figure 10.4. The primary school classrooms are shown with blue bars and secondary classrooms with green. The current BB93:2015 criteria for new build classrooms are also shown. For refurbishments the criteria are 1.0 seconds for secondary and 0.8 seconds for primary school classrooms.

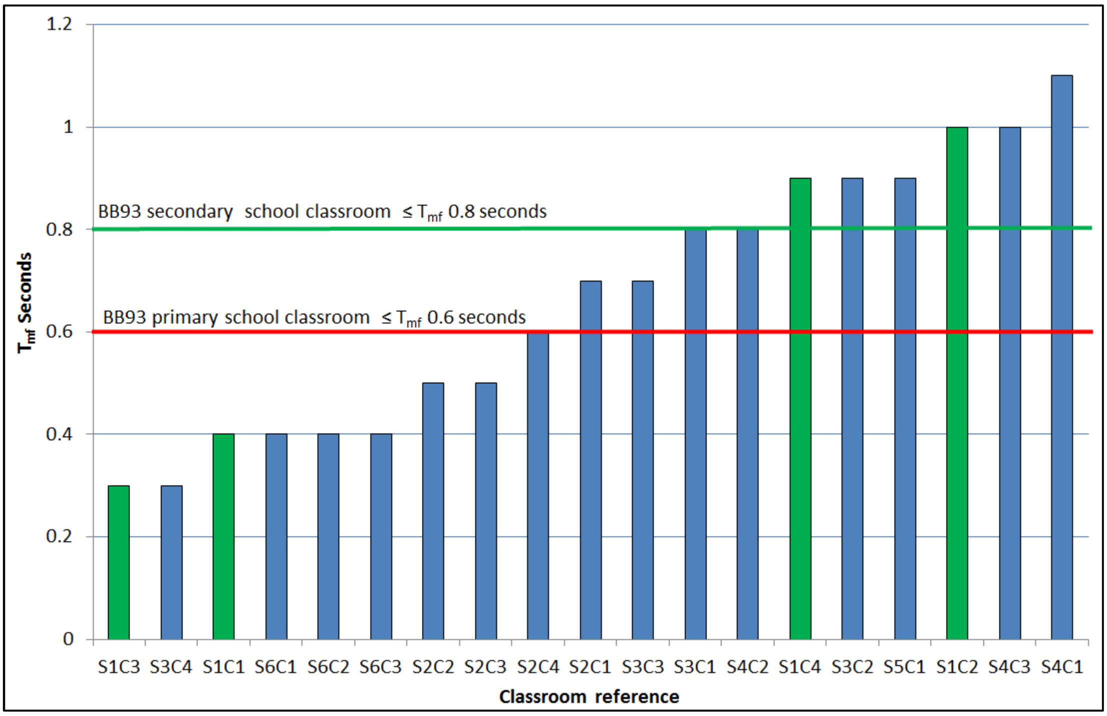


Figure 10.4: Unoccupied reverberation time T_{mf} by classroom

Of the secondary school classrooms, two exceeded the criterion for new constructions but complied with the refurbishment criterion. Of the primary school classrooms, eight exceeded the new build criterion and four exceeded the refurbished criterion.

The secondary school included in the measurements (School S1) had classrooms specifically treated to a range of reverberation times and is therefore not necessarily representative of general school conditions.

The EDT_{mf} values were similar to the T_{mf} values indicating a consistent rate of decay in the reverberation time. The comparative values of EDT_{mf} and T_{mf} are shown in Figure 10.5.

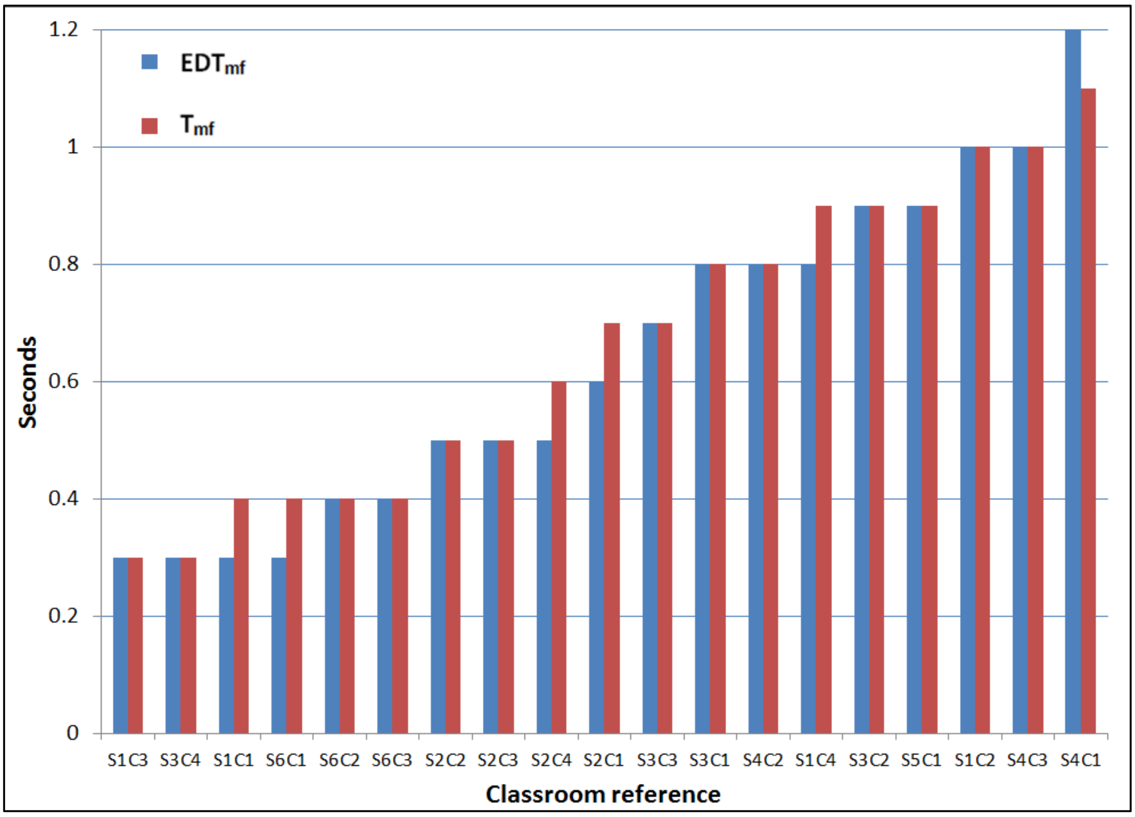


Figure 10.5: Unoccupied reverberation time EDT_{mf} and T_{mf} (all classrooms)

The total absorption area (A_{mf}) for each primary school classroom has been calculated based on the T_{mf} values. A histogram of the A_{mf} values is shown in Figure 10.6.

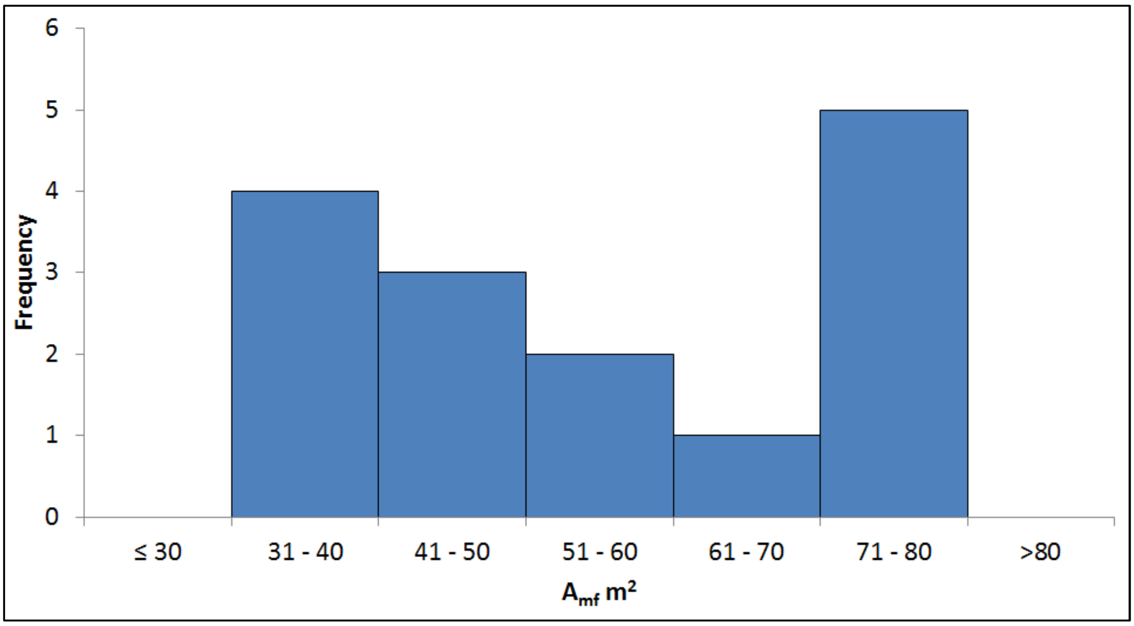


Figure 10.6: Unoccupied A_{mf} (primary classrooms)

The data in Figure 10.6 shows that classrooms tended to have either low or high values of A_{mf}. This is a result of the surface finishes and volumes in the classrooms which tend to be consistent among classrooms built in the same period; either having large volumes and predominantly hard finishes or smaller volumes and some absorptive finishes.

The secondary school classrooms were not included in the analysis due to the specialist nature of the treatment in these spaces.

The room radius (see section 4.1.1) was calculated for the classrooms and is shown in Figure 10.7 for all classrooms with primary school classrooms shown as blue bars and secondary school classrooms as green bars.

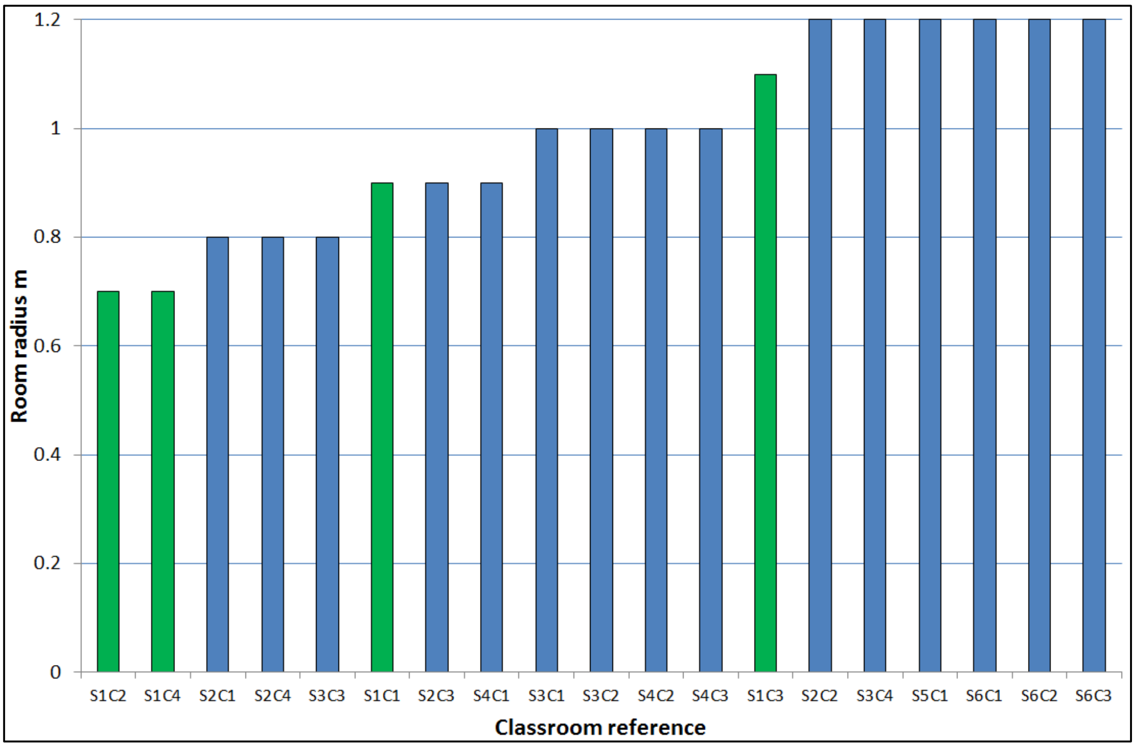


Figure 10.7: Unoccupied room radius m (all classrooms)

The room radius values show that as the room radius was 1.2 metres or less, the majority of pupils who will sit at distances greater than 1.2 metres from the teacher, will be in the reverberant field.

10.5 Compliance with current standards

Of the classrooms measured, two did not comply with the current new build standards for both unoccupied IANLs and reverberation time. Three of the classrooms had IANLs that exceeded the current criterion for new classrooms; all rooms complied with the IANL criterion for refurbished classrooms.

Previous studies (see section 4.3.1) [15, 100] found that primary school classrooms tend to have higher unoccupied noise levels than those in secondary schools, but similar reverberation time values. This corresponds with the measurements in this study.

10.6 Occupied classroom noise levels

The arithmetic mean 1 hour occupied noise levels are shown in Table 10.3, corrected to the nearest decibel. These values include the teachers' voices. The spectral values are shown in Appendix G.

The arithmetic mean is considered to better represent typical occupied classroom noise levels compared to the logarithmic average which is an average energy value over the working day and would be skewed towards higher values.

Table 10.3: Occupied classroom noise levels

Participant reference	Classroom reference	L_{Aeq} dB		L_{A90} dB		L_{Afmax} dB	
		Mean	*SD*	Mean	*SD*	Mean	*SD*
1	S1C2	63	5.3	37	6.5	89	3.7
2	S1C1	60	2.3	40	5.2	87	1.7
3	S1C3	60	2.0	41	1.3	86	2.8
4	S1C4	64	2.8	45	3.6	91	2.9
5	S2C3	69	3.1	45	6.3	93	4.3
6	S2C4	69	4.0	41	3.5	91	4.5
7	S3C2	67	1.9	50	4.1	88	1.9
8	S5C1	63	3.8	42	4.4	87	4.3
9	S4C2	67	5.6	50	6.4	89	4.0
10	S4C3	66	4.6	45	2.9	89	4.5
11	S6C1	65	2.2	45	3.7	91	3.5
12	S6C3	64	3.5	41	4.3	92	4.4
13	S2C1	67	3.2	42	9.1	92	2.5
14	S3C1	63	2.5	46	3.1	86	3.3
15	S2C2	68	4.5	50	4.9	92	4.7
16	S4C1	71	5.0	48	6.2	92	3.4
17	S6C3	66	3.6	40	6.4	90	3.5
18	S6C2	68	3.3	41	6.8	94	2.0
19	S3C4	65	2.6	42	4.0	93	3.2
20	S3C3	67	3.8	49	3.4	91	4.0
Overall mean		66	-	44	-	90	-
Range		60-71	-	37-50	-	86-94	-
Overall *SD*		2.8	-	3.8	-	2.4	-

As well as the 1 hour period measurements of occupied noise levels 1 second measurements were also made simultaneously. These values when plotted show the variations in L_{Aeq} and L_{Afmax} parameters over the teaching day, with different teaching periods having different noise characteristics. Typical plots of the 1 second data are shown in Figures 10.8 and 10.9.

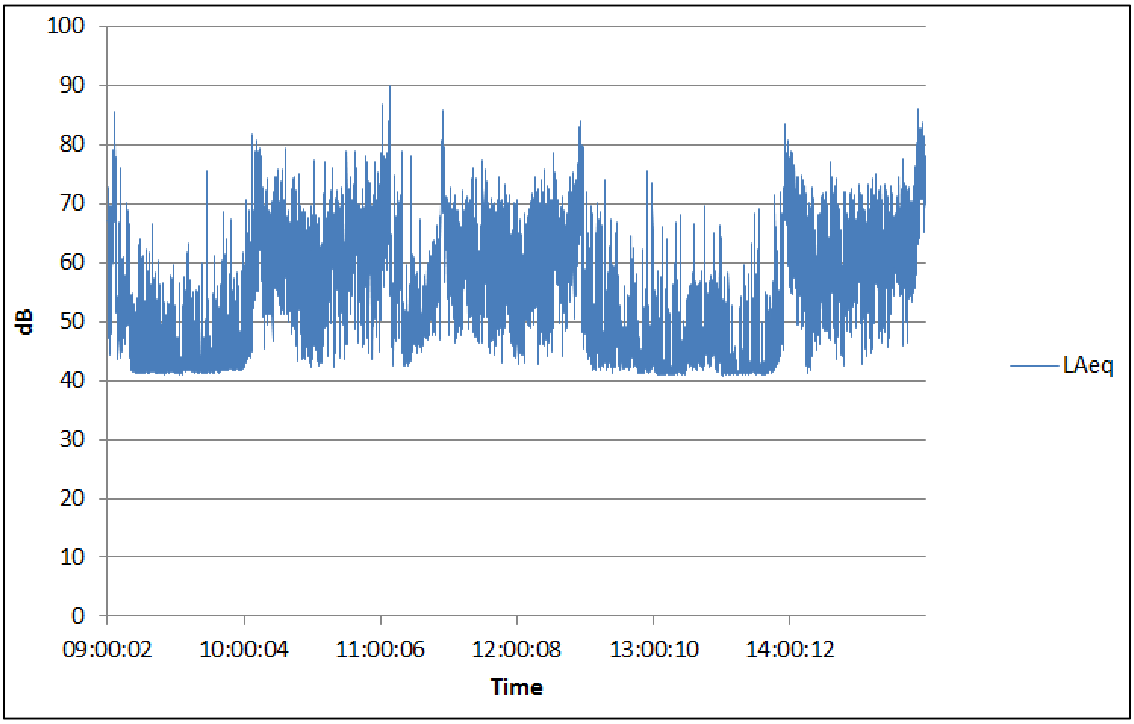


Figure 10.8: Example occupied noise levels $L_{Aeq,\,1\,second}$

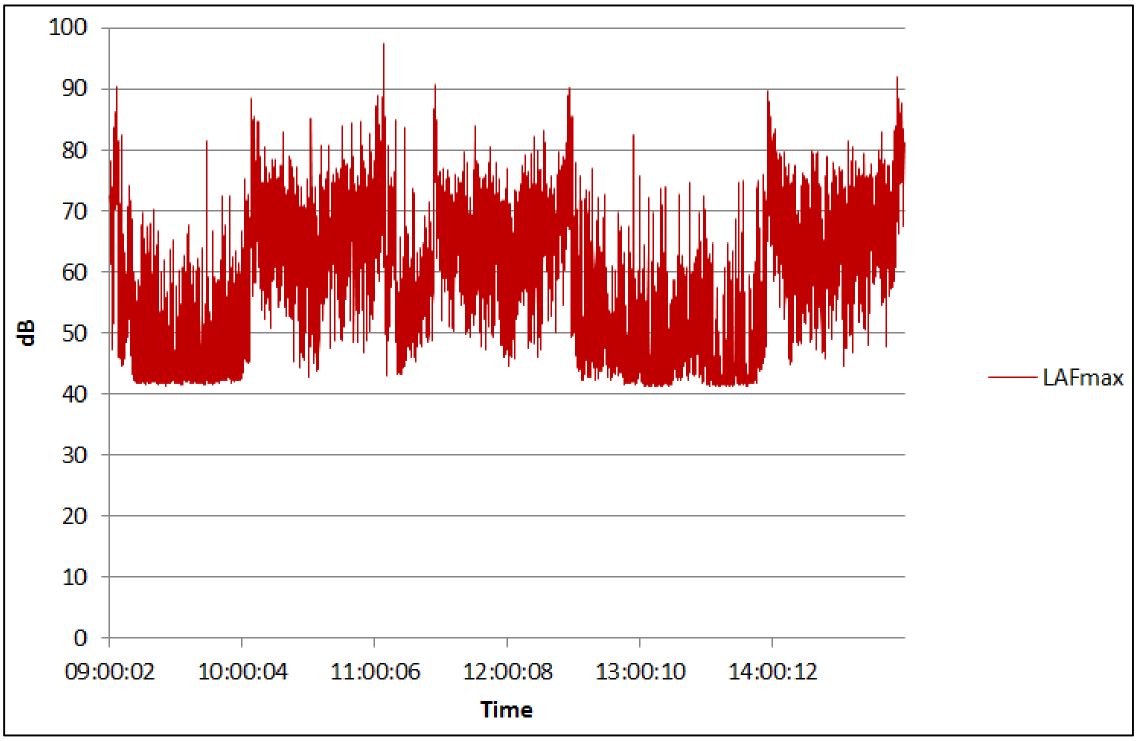


Figure 10.9: Example occupied noise levels $L_{Afmax,\,1\,second}$

During school operations the occupied noise levels ranged from 60 to 71 dB L_{Aeq} with a mean value of 66 dB L_{Aeq}. The L_{Aeq} noise levels in occupied classrooms were more than 10 decibels above the unoccupied ambient levels. For the L_{A90} values this was also the case with the exception of participants 13 and 6 where the difference was less than 10 dB.

This difference means that the UANL did not contribute numerically to the occupied dBA noise level, which was controlled by activity noise. However there remains the potential for ambient noise to have an influence on activity noise levels via the Lombard effect [28] (see section 6.1).

Analyses have been carried out to consider the occupied noise levels in terms of school type as summarised in Table 10.4, corrected to the nearest decibel.

Table 10.4: Occupied classroom noise levels by school type

School type	$L_{Aeq, 1\ hour}$ dB			$L_{A90, 1\ hour}$ dB			$L_{Afmax, 1\ hour}$ dB		
	Mean	Range	*SD*	Mean	Range	*SD*	Mean	Range	*SD*
Primary	67	63-71	2.1	45	40-50	3.5	91	86-94	2.2
Secondary	62	60-64	1.8	41	37-45	2.9	88	86-91	1.9

Table 10.4 shows lower levels in all parameters in the secondary classrooms compared with primary classrooms, with a difference of 5 dBA in the mean L_{Aeq} values.

Occupied classroom noise levels in previous studies are included in section 4.3. These showed higher mean L_{Aeq} values in the primary schools (5 dB) and secondary schools (2 dB higher) compared with the data in this study. However the differences between the primary and secondary schools' occupied noise levels in Table 10.4 are comparable with these previous studies.

10.7 Low frequency noise

The spectrum values for both L_{eq} and L_{90} for unoccupied and occupied conditions have been analysed (see Appendix G). This analysis showed that the occupied L_{eq} values were not more than 10 dB higher than the unoccupied values in each octave band for only one participant.

When UANL L_{90} values were considered (which give a better representation of underlying ambient noise levels) the difference between UANL and occupied noise in the 63 Hz octave band was less than 10 dB for eight participants, and in the 125 Hz band less than 10 dB for two participants. For these two participants this also applied at a number of other frequencies. An example of this is shown in Figure 10.10.

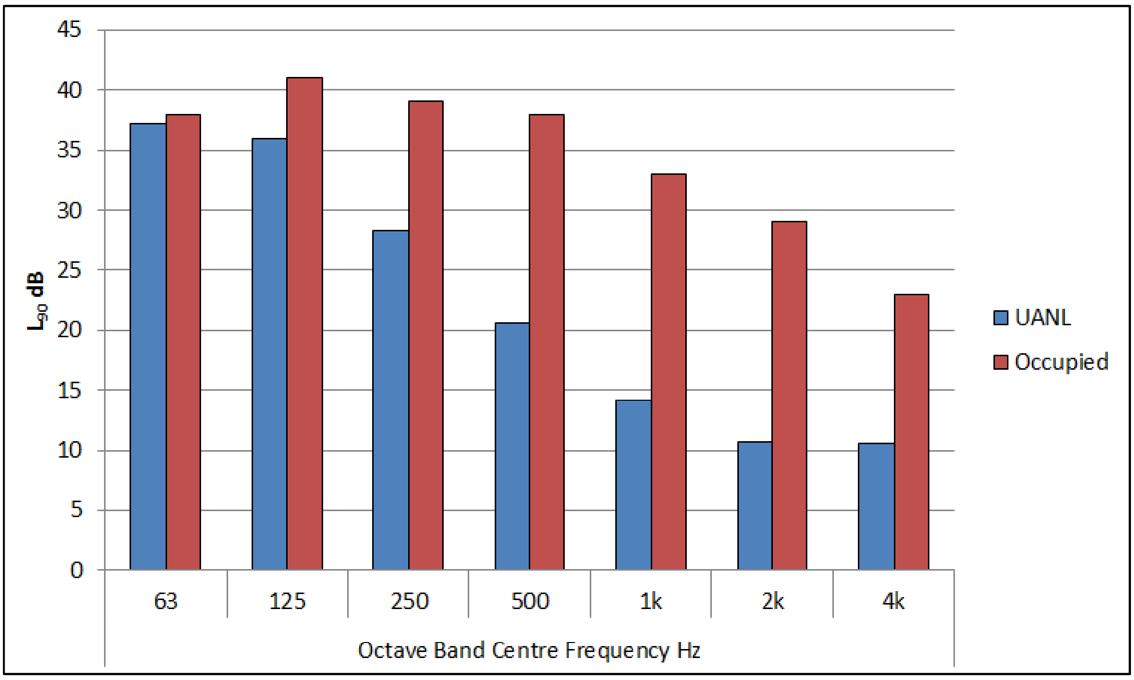


Figure 10.10: Example spectrum differences between UANL and occupied conditions

This means that for a number of participants, the low frequency UANL had the potential to be significant even during occupied conditions.

Low frequency noise may arise due to road traffic and other external, environmental sources, or from building services equipment within the building. This is potentially significant as the 125 Hz band coincides with the mean male SF_0 value. In addition, the phenomenon of the upward spread of masking (see section 4.4.2) means that low frequency noise has the potential to also affect female SF_0.

The extra sound absorption provided by pupils in the classrooms has the potential to reduce environmental noise intrusion, but it would also have the same effect on the teacher's voice, therefore the true underlying UANL contribution when a room is in use is not straightforward to establish.

10.8 Conclusions

The acoustic measurements showed that the classrooms ranged from those that complied with the contemporary acoustic requirements (see Chapter 5), in some cases bettering the requirements with a margin, to those which did not meet the criteria. This is considered to give a good representation of the classroom types in use in England at this time and reflects the different environments in which teachers work.

The measured occupied noise levels were significantly above the unoccupied levels in terms of overall dBA values. However, the difference between occupied and unoccupied levels was less than 10 decibels in some frequency bands meaning there was potential for contributions from unoccupied noise sources to the overall, occupied noise levels, particularly at lower frequencies, which could influence teachers' voice parameters.

The next chapter will detail the results of the voice measurement survey, which used the methodology described in Chapter 7.

Chapter 11 Voice measurements: results and analysis

11.1 Introduction

This chapter presents the results for the different voice parameters measured and compares these with values detailed in studies by others and with guidance documents. The relative values of participants are considered by factors such as gender and school type to identify indications of differences and examine possible explanations for these.

11.2 APM results

The voice data for all participants is shown in Table 11.1, together with the gender of each participant.

Table 11.1: Voice measurement results

Participant reference	Gender	Fundamental frequency SF_0 mean Hz		Phonation time (s)	Phonation %	Voice level mean $L_{pZ,\ 1\ m}$ dB
1	F	258		1981	22	57
2	M	152		3678	16	62
3	M	135		2942	18	60
4	F	225		3241	13	66
5	F	237		6475	26	63
6	F	197		6917	28	72
7	F	252		7113	26	75
8	F	266		5656	23	65
9	F	282		4805	18	68
10	M	123		3111	13	64
11	F	250		4570	18	58
12	F	223		4666	18	71
13	F	256		4501	18	79
14	M	187		5867	22	61
15	F	250		8346	25	76
16	F	238		9490	26	75
17	M	151		5056	19	70
18	F	253		13146	31	78
19	F	277		5751	27	62
20	M	150		3580	15	63
		Male	Female			
Mean		150	247	5545	21	67
SD		19.7	21.6	2531.9	5.1	6.7

The vocal loading index (VLI) is a measure of relative 'work' done by the voice system. It includes the SF_0 value in calculation and is therefore influenced by gender due to differences in the mean SF_0 values. Therefore analyses have taken this factor into account. The vocal fold distance (VFD) values were calculated using the APM software for the lesson periods, the VLI values were calculated using the formula shown in section 2.2.4 and are included in Table 11.2.

Table 11.2: Vocal loading index all participants

Gender	Participant reference	Vocal fold distance m	Vocal loading index
F	1	1294	510
M	2	2685	561
M	3	875	397
F	4	2960	728
F	5	4685	1531
F	6	7577	1360
F	7	9808	1791
F	8	4974	1506
F	9	5264	1356
M	10	2533	383
F	11	3276	1145
F	12	6149	1039
F	13	8558	1151
M	14	4022	1098
F	15	8346	1375
F	16	9490	1552
M	17	5056	724
F	18	13146	2018
F	19	5751	1995
M	20	3580	614
Mean		5501	1142
SD		3077.8	501.1

11.3 Voice levels

The voice levels measured for the participants had a mean value of $L_{pZ,\ 1\ m}$ 67 dB (*SD* 6.7 dB) and ranged from 57 to 79 dB. The data is shown for all participants in Figure 11.1.

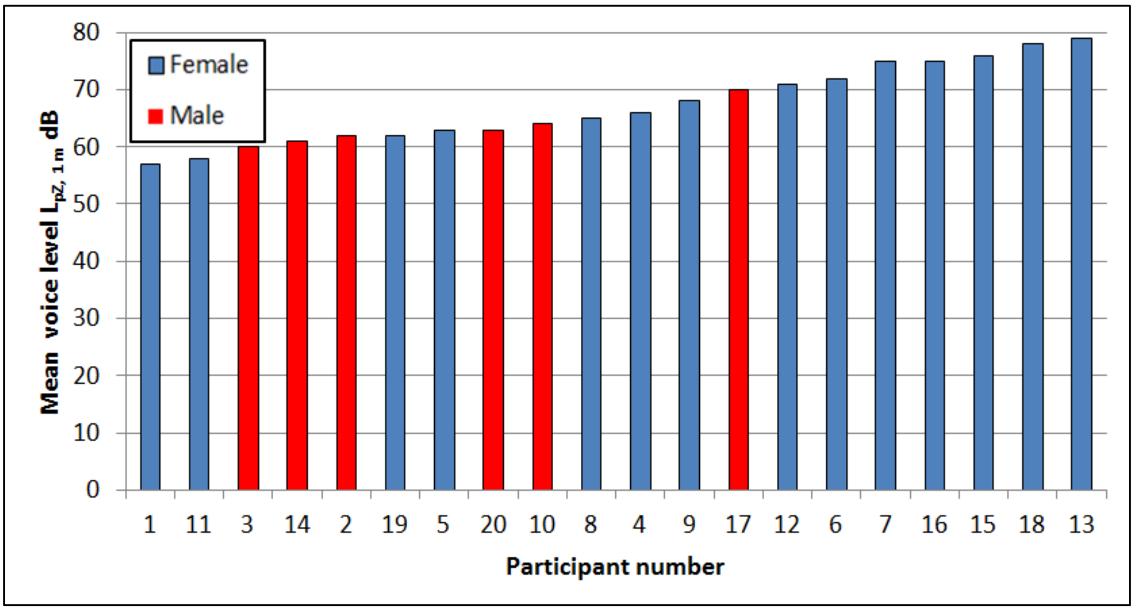


Figure 11.1: Voice level $L_{pZ,\ 1\ m}$ dB (all participants)

The voice level values for all participants are shown in histogram form, in 5 dB bands, in Figure 11.2. The most frequently occurring voice levels were in the band 61 to 65 dB.

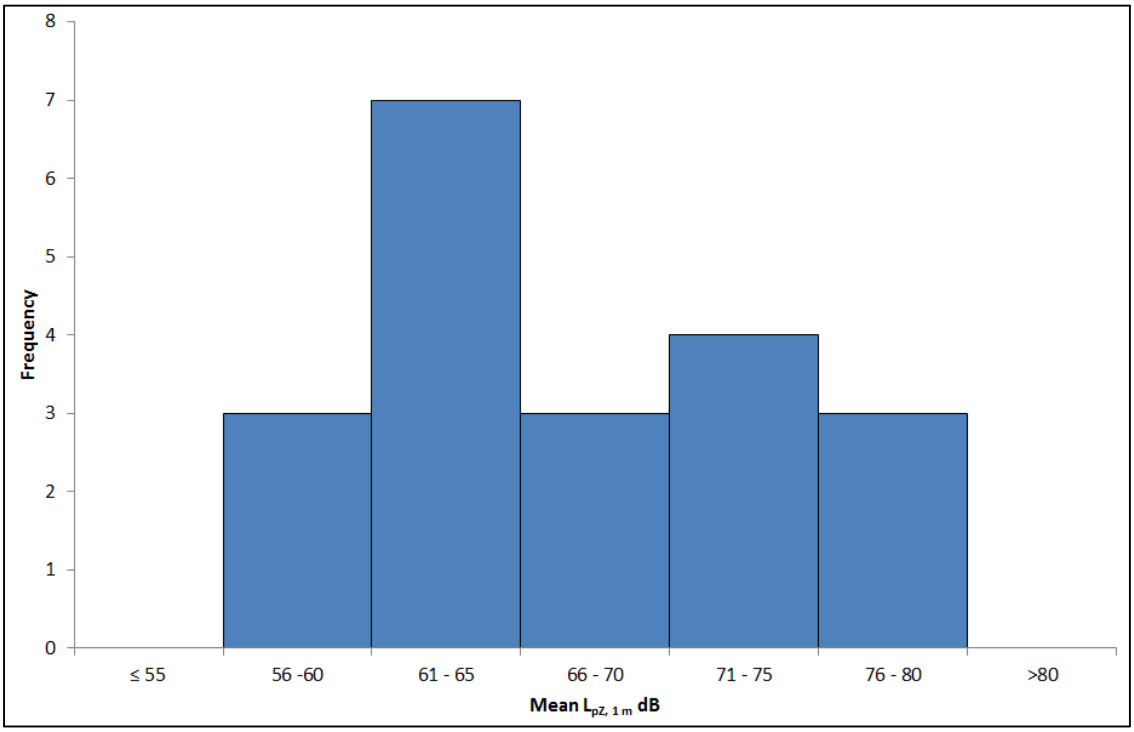


Figure 11.2: Voice level mean $L_{pZ,\ 1\ m}$ dB (all participants)

When considering voice level by gender, the male participants had a lower mean value of $L_{pZ,1\,m}$ 63 dB (*SD* 3.2 dB) than the female participants' mean value of $L_{pZ,\,1\,m}$ 69 dB (*SD* 7.0 dB). This is the opposite of the average voice levels in guidance documents for the general population (see section 2.3) where males have higher voice levels at all vocal effort levels (casual to shouted). In the data set only one male participant had a mean voice level above the overall mean.

The range for the female participants was 22 dB compared with 10 dB for the male participants. Table 2.5 shows that the average female dynamic range is 5 dBA less than that of males, with a 7 dBA lower maximum level, this means that not only are the female participants in this study speaking at high absolute levels, they are speaking at a level which is a higher proportion of their maximum level compared with the male participants. This may be related to the typical female teacher's SF_0 being in a similar part of the spectrum as that of younger children, with resultant challenges in terms of achieving adequate signal to noise ratios (see section 2.3).

When considering voice levels by school type the secondary school participants had a lower mean voice level of $L_{pZ,\,1\,m}$ 61 dB (*SD* 3.3 dB) compared with the primary school participants' voice level of $L_{pZ,\,1\,m}$ 69 dB (*SD* 6.4 dB), which may be a result of higher occupied noise levels in primary schools (see section 4.3) and different pedagogy. This difference in voice levels is in agreement with studies by others (see section 2.3).

The data for primary school teachers only is shown in Figure 11.3, the most frequently occurring voice levels being in the range 61 to 65 dB. The number of secondary school participants was small therefore a histogram has not been produced for this group.

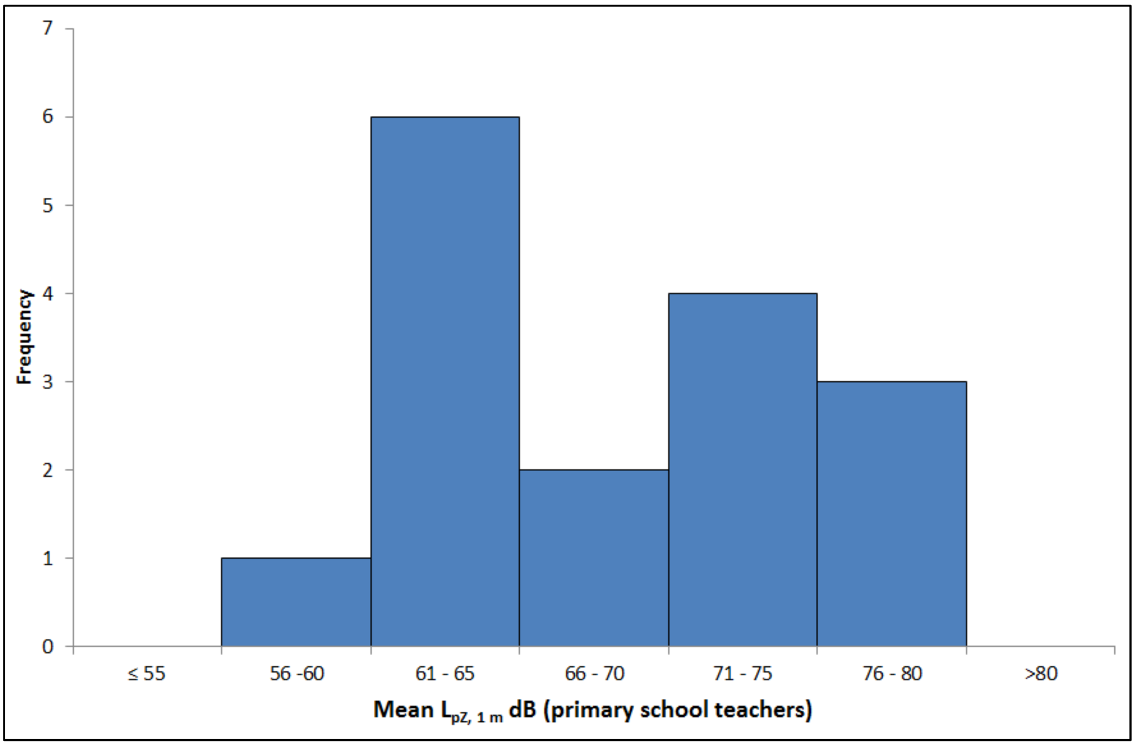


Figure 11.3: Voice level mean $L_{pZ, 1 m}$ dB (primary school teachers only)

In order to categorise the participants' voice levels in terms of vocal effort category [30, 31, 32] the dBZ values needed to be converted to dBA values. Without spectral data this cannot be calculated and therefore the dBA values have been estimated based on the typical differences between dBA and dBZ values levels at different vocal effort levels (see Table 2.5). The dBA values for the vocal effort categories are shown in Table 11.3.

Table 11.3: Vocal effort categories [31, 32]

Vocal effort categories	dBA at 1 m
Relaxed	≤54
Normal	55-60
Raised	61-66
Loud	67-72
Very loud	73-78
Shout	79-84
Maximum	85-90

The values in BS ISO 9921-1:2003 [32] are based on male speakers, however these categories for vocal effort are considered relevant for comparison between the participants in this study. The mean value for all participants of $L_{pZ,\,1\,m}$ 67 dB would be placed in the 'loud' category. The results of this analysis are shown in Figure 11.4.

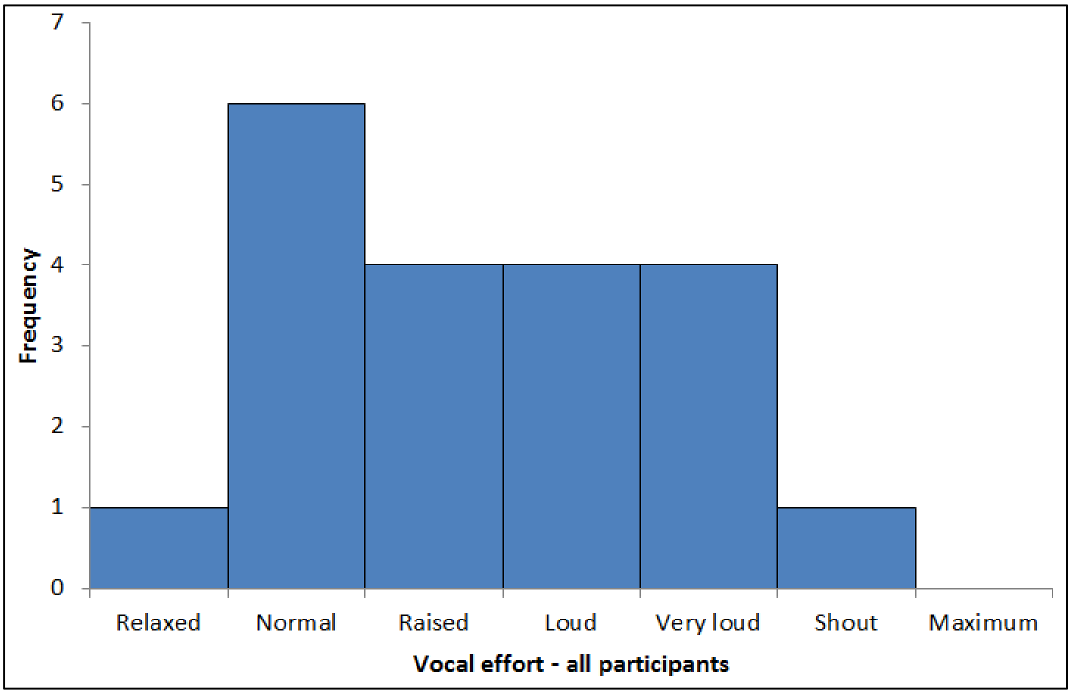


Figure 11.4: Vocal effort categories – all participants

Figure 11.4 shows that seven of the twenty participants (35%) had mean voice levels in the 'normal' category or lower. The remaining 65% had mean voice levels classified as above 'normal' including one participant in the 'shout' category. No participants were in the 'maximum' category. The data has been further analysed by gender. Figure 11.5 shows the voice categories by gender for all participants.

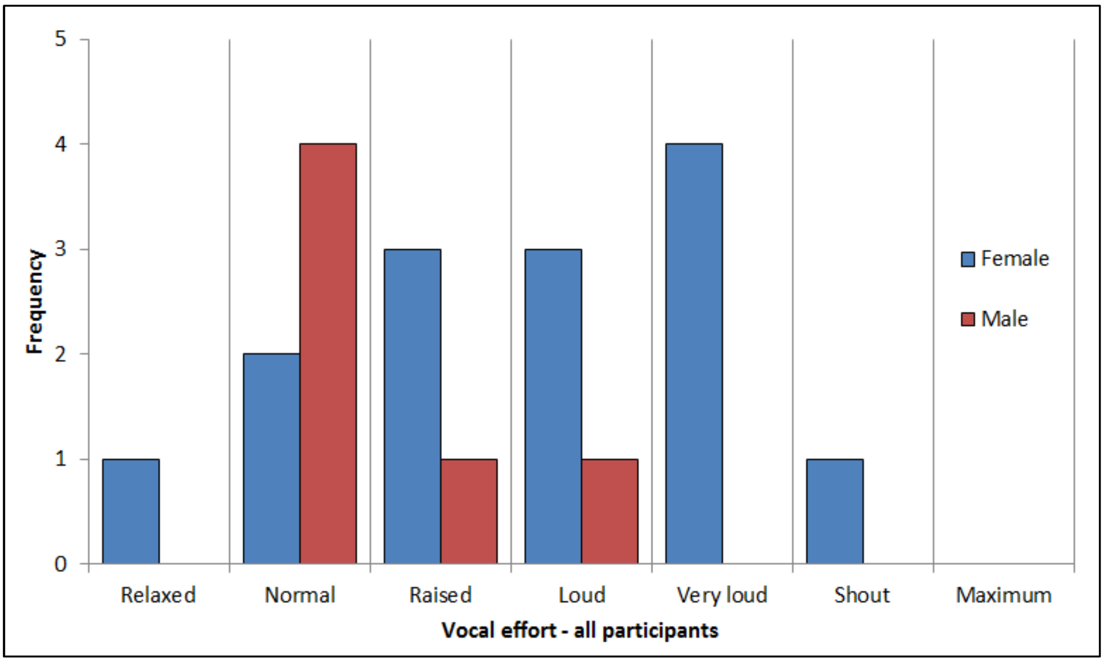


Figure 11.5: Vocal effort categories by gender

Figure 11.5 indicates that among the female participants some had mean voice levels in the ‘very loud’ (n = 4) and ‘shout’ (n = 1) categories. There were a greater proportion of the male participants (compared with female participants) in the ‘normal’ voice level category despite the small number of male participants.

The participants’ voice levels have been considered alongside the participant questionnaire. The responses were considered based on two voice level groupings – those with voice levels ‘relaxed’ to ‘loud’ and those covering ‘very loud’ to ‘shout’.

The louder voiced group reported having to talk over background noise more often (100% compared with 87%) which indicates higher classroom noise levels. Interestingly the higher voice level group did not report often having to shout (0% compared with 33%). This may mean that a high voice level has become normal for these individuals and could indicate permanent changes in voice behaviour or function. The higher voice level group reported often having a feeling of a lump in the throat (20% compared with 0%) and a constricted feeling in the throat (20% compared with 13%) both of which may be symptoms of damage or changes to the voice system.

More of the higher voice level group had received voice training of some type (60% compared with 47%) though the nature of training varied considerably. There were insufficient numbers of participants in the group to undertake statistical tests between these questionnaire responses and the voice data.

The data was further subdivided based on the school type. Figure 11.6 shows the vocal effort categories for the participants who taught in primary schools.

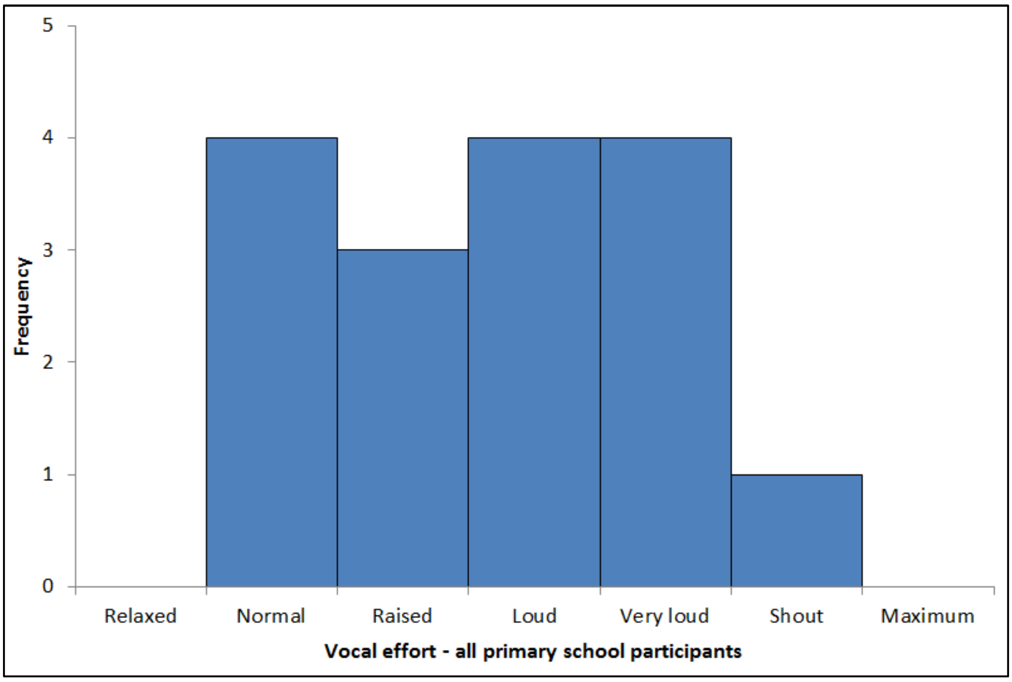


Figure 11.6: Vocal effort categories – all primary school teachers

Figure 11.6 shows that for the primary school teachers 25% (*n* = 4) had a mean voice level categorized as 'normal' and 75% (*n* = 12) had mean voice levels higher than 'normal' category with one classified in the 'shout' category.

Figure 11.7 shows the primary school participants classified by gender. The participants with mean voice levels in the 'very loud' and 'shout' categories were all female. None of the male participants were included in these vocal effort categories.

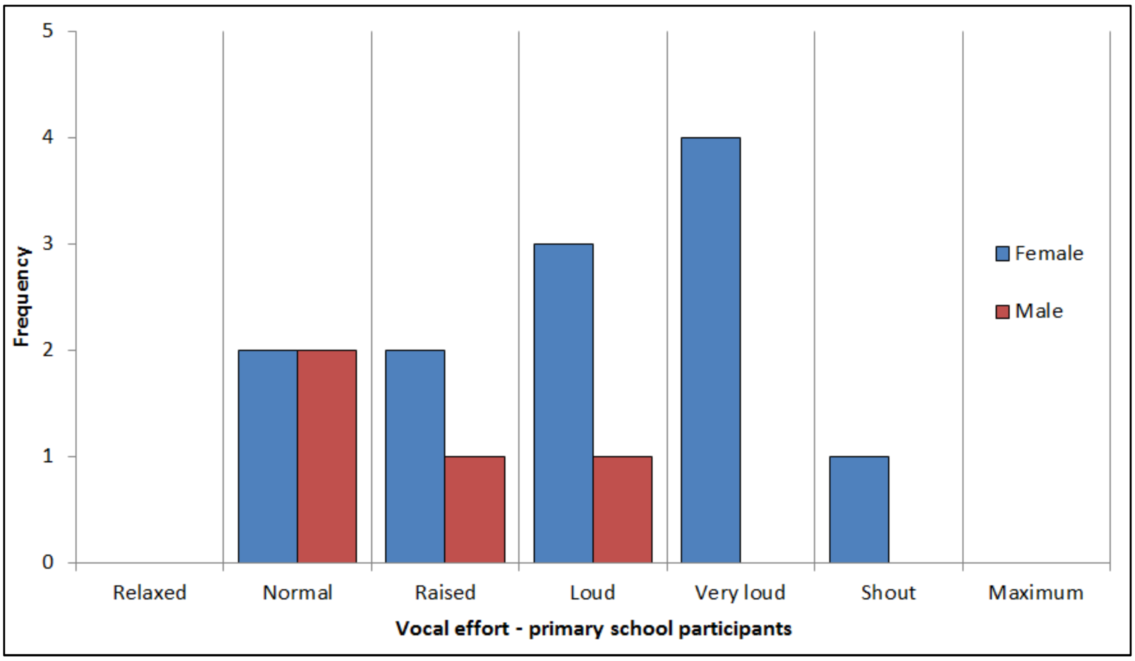


Figure 11.7: Vocal effort categories - primary school teachers by gender

Analysis in Figure 11.8 of participants who taught in secondary schools showed a lower mean voice level (albeit for a small sample size) with no participants having a mean voice level classified in the 'loud' or higher ranges. There were not sufficient numbers of participants to allow analysis by gender.

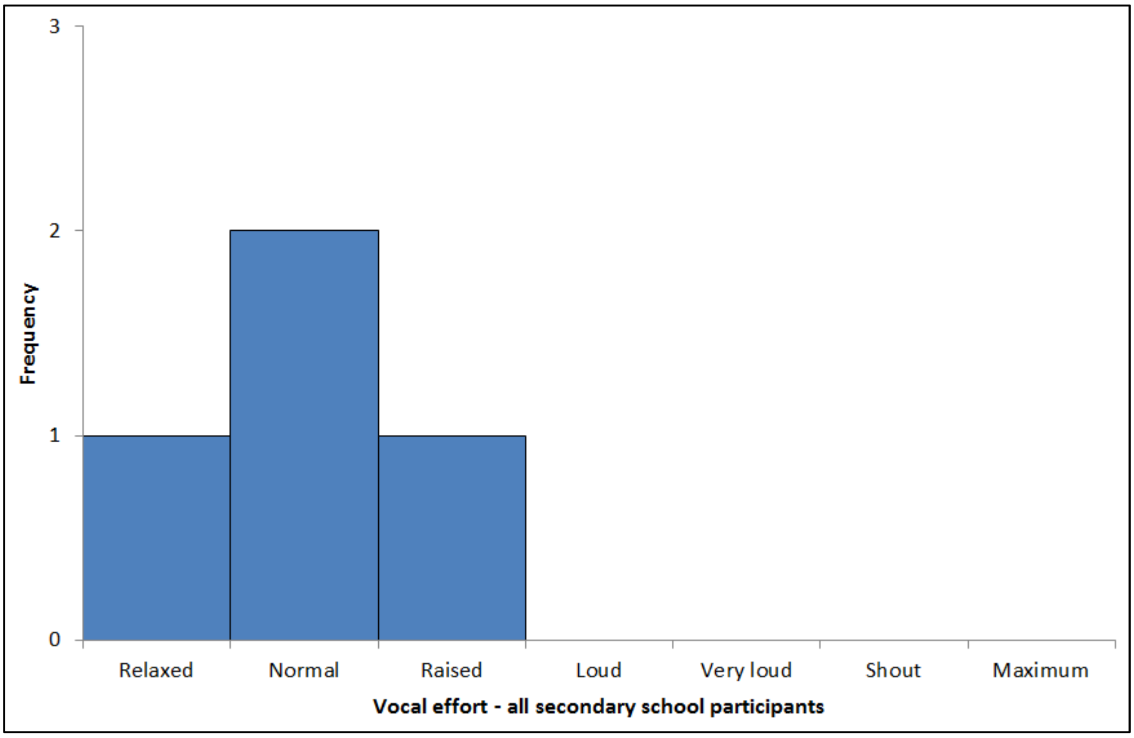


Figure 11.8: Vocal effort categories – all secondary school teachers

11.4 Fundamental frequency (SF_0)

The SF_0 values are displayed in Figure 11.9. All values quoted in this section are mean SF_0 values.

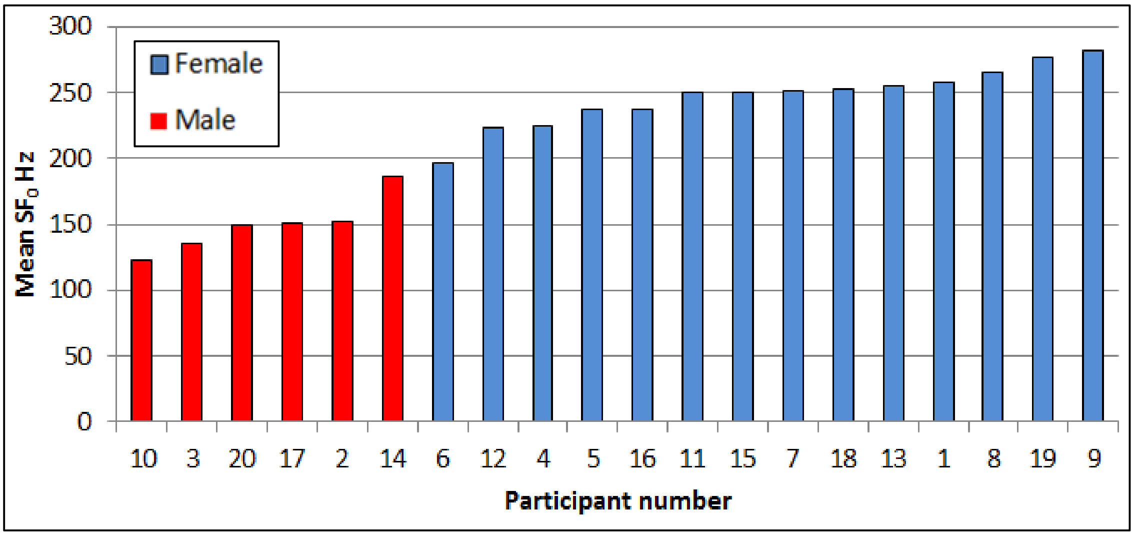


Figure 11.9: SF_0 for all participants

The values were within the expected ranges for both genders. The range of SF_0 data for the participant group and referred to in the literature is shown in Table 11.4.

Table 11.4: SF_0 mean values and range

Gender	SF_0 Hz			
	Minimum	Maximum	Mean	Literature mean [6]
Male	123	187	150	128
Female	197	282	247	225

Table 11.4 shows that the mean SF_0 values for the participants were higher for both genders than the literature means for the general population.

For male participants the mean value was 150 Hz (*SD* 19.7 Hz) with the most frequent mean SF_0 values in the band 151-160 Hz. There were a relatively small number of male participants (n = 6) and therefore this may not be representative of the wider teacher population.

For female participants the mean value was 247 Hz (*SD* 21.6 Hz) with the most frequent values in the 251-260 Hz band. The frequency histogram for SF_0 in the female participants is shown in Figure 11.10.

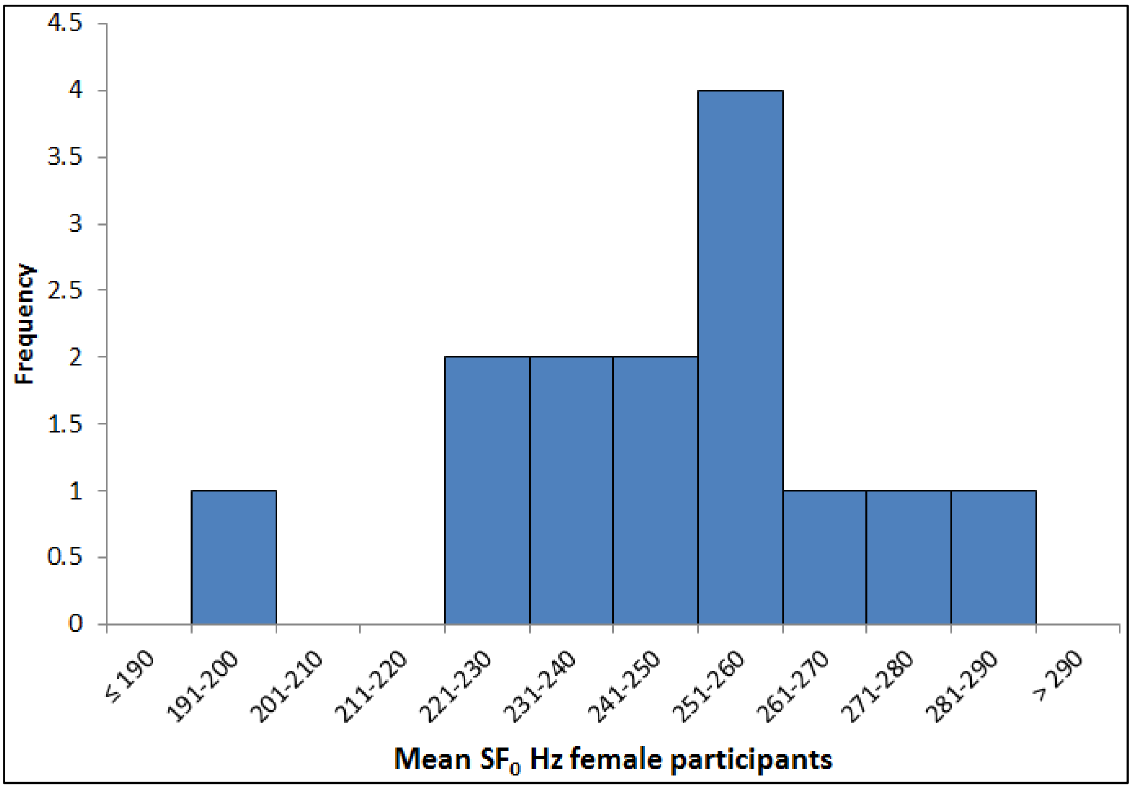


Figure 11.10: SF_0 female participants

The data analysed for both gender and school type is summarised in Table 11.5.

Table 11.5: SF_0 by gender and school type

Gender	School type	*n*	SF_0 Hz				
			Min	Max	Range	Mean	*SD*
Female	Primary	12	197	282	85	248	22.1
	Secondary	2	225	258	33	242	16.5
Male	Primary	4	123	187	64	153	22.7
	Secondary	2	135	152	17	144	8.5

This showed that for both male and female participants the mean SF_0 values were higher in primary compared with secondary school teachers and that the range was greater.

In order to look at differences between male and female participants in the different school types it is necessary to compare the mean SF_0 values between the gender groups. This is complicated by the different expected mean SF_0 values for males and females in the general population (see section 2.2.1).

The approach used was to normalise the SF_0 values based on the expected difference ratio between males and females in the general population to allow direct comparison between genders. This was carried out by adjusting the female SF_0 values using the mean male to female SF_0 gender ratio of 1:1.75; the results are summarised in Table 11.6.

Table 11.6: SF_0 normalised by gender

Gender	School type	Mean SF_0	SF_0 normalised for gender
Female	Primary	248	142
	Secondary	242	138
Male	Primary	153	153
	Secondary	144	144

This showed that the male participants had a higher normalised SF_0 in both primary (+11 Hz) and secondary (+6 Hz) schools compared with their female counterparts. The sample sizes of the respective groups are small and therefore limit the conclusions that can be drawn, but this may warrant further investigation with a wider data set.

11.5 Phonation time and percentage

The phonation time varied considerably between the participants by up to 50% of the overall mean value. This can be accounted for by the range of teaching sessions which the participants had on the day of measurement.

The overall mean phonation time was 5545 seconds (1.5 hours) of continuous speaking during a working day (excluding pauses between words).

The secondary school teacher group (n = 4) had a lower mean phonation time of 2961 seconds (*SD* 623.1 s) compared with the primary school teachers (n = 16) mean of 6191 seconds (*SD* 2414.3 s). The small sample size means it is not possible to determine if this is representative of a general difference in the wider teaching population.

When considered by school type and gender, for primary school teachers the female teachers had a greater mean phonation time than male primary school teachers. The inverse applied for secondary school teachers; however the number of participants was small in this group and any differences may not be representative.

The reasons why there may be differences in phonation time between genders in the same teaching types are not clear. There may be differences in pedagogy or the interactions between teachers and pupils such as discipline, or it may be related to a need to repeat speech due to signal to noise challenges for the female teachers.

The results are summarised in Table 11.7.

Table 11.7: Phonation time by gender and school type

Gender	School type	n	Phonation time (seconds)				
			Min	Max	Range	Mean	*SD*
Female	Primary	12	4501	13146	8645	6786	2437.8
	Secondary	2	1981	3241	1260	2611	630.0
Male	Primary	4	3111	5867	2756	4404	1108.6
	Secondary	2	2942	3678	736	3310	368.0

The phonation percentage is potentially a more useful metric for relative comparisons as it is not influenced by the measurement time.

The phonation percentage values are shown in Figure 11.11 for all participants and in a histogram (Figure 11.12).

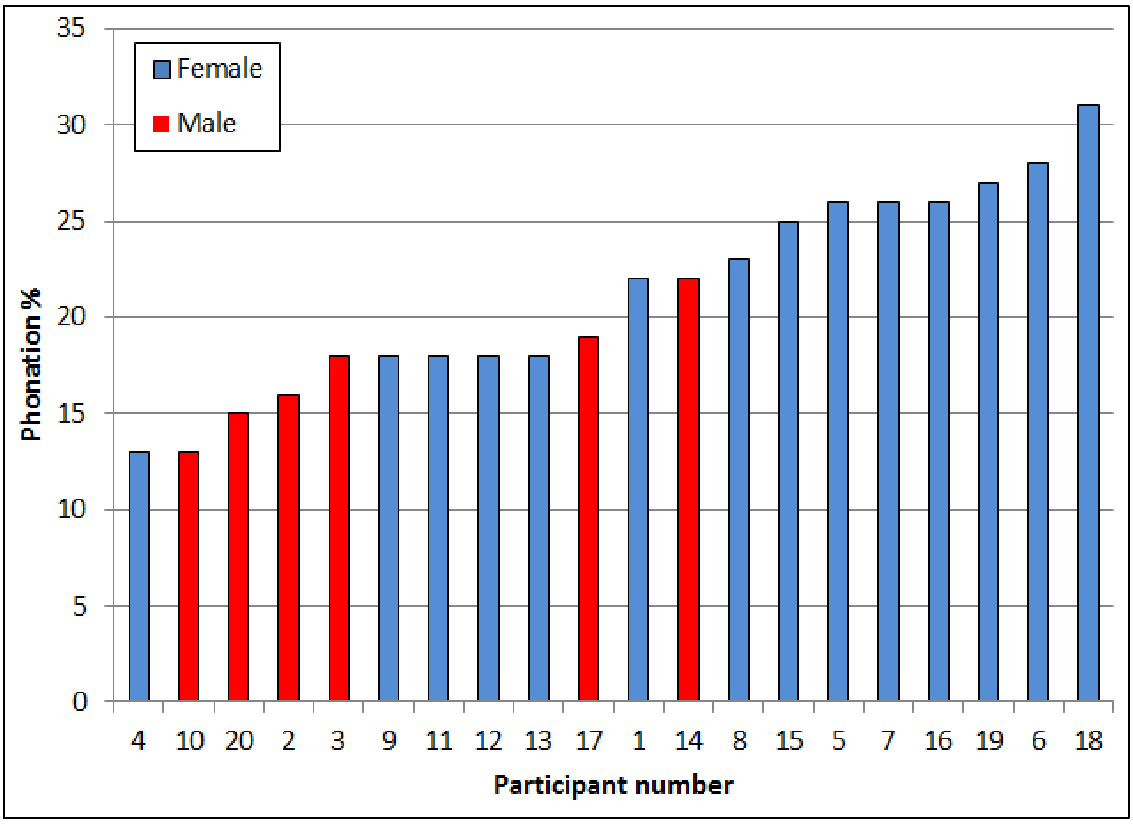


Figure 11.11: Phonation percentage

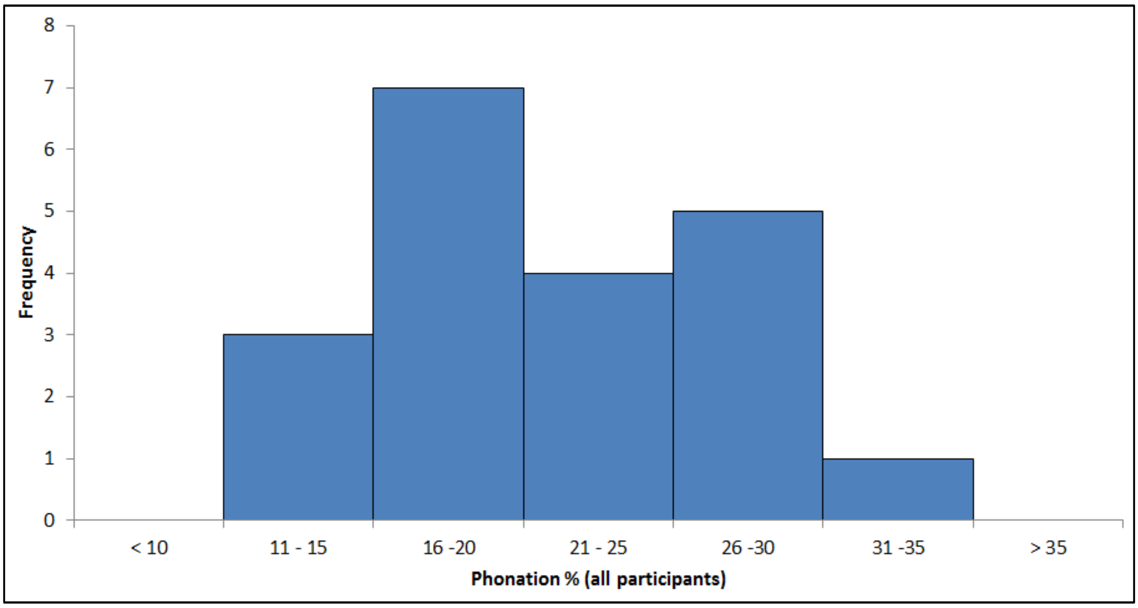


Figure 11.12: Phonation percentage - all participants

The phonation percentages ranged from 13 to 31% with a mean value of 21% (*SD* 5.1%) for all participants. This was within the literature range of 21 to 40% [10, 11, 12, 13, 14].

The lower range values in the data may indicate teachers who have had teaching periods where less oral instruction is required. This underlines the practical difficulties of measuring comparable working days in the field as teaching activities vary constantly between participants on different days. This is shown by the ranges reported in the literature.

When the participants are considered by school type, the primary school teachers had a significantly higher mean phonation percentage of 22% (n = 16, *SD* 5.0%) compared with the secondary school teachers with a mean value of 17% (n = 4, *SD* 3.3%).

This may be due to longer periods of oral instruction being required when teaching younger children for perhaps pedagogical or disciplinary reasons.

In terms of school type and gender the analysis is detailed in Table 11.8.

Table 11.8: Phonation percentage by gender and school type

Gender	School type	*n*	Phonation %				
			Min	Max	Range	Mean	*SD*
Female	Primary	12	18	31	13	24	4.4
	Secondary	2	13	22	9	18	4.5
Male	Primary	4	13	22	9	17	3.5
	Secondary	2	16	18	2	17	1.0

This data showed that there was no difference in the mean phonation percentages in male teachers between secondary and primary schools. For female teachers the mean percentage was higher in the primary school teachers but the secondary school participant group was small and therefore this may not be significant.

For the primary school teachers the mean value of phonation percentage was 22% (*SD* 5.0%) in line with the overall value. The frequency histogram is shown in Figure 11.13 for primary school teachers only.

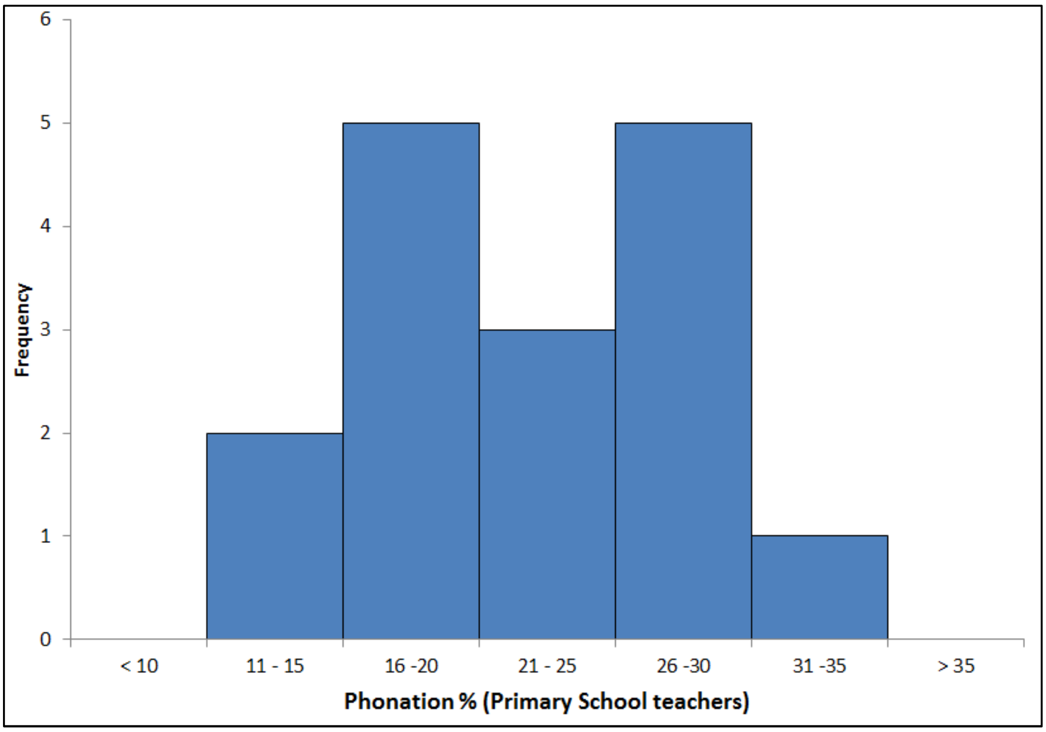


Figure 11.13: Phonation percentage - primary school teachers

The participant questionnaire included a number of questions relating to patterns and perceptions of voice use. The responses have been compared with the respective phonation times and percentages for the participants. The number of participants involved meant that robust statistical analysis was not possible.

In those who had phonation percentages or times above the mean value there was no increased reporting of having to speak for long periods without rest. This may indicate that individuals do not perceive high phonation times or percentages.

There was a greater proportion in phonation percentage terms who agreed that their voice sometimes felt tired, with 80% in those above the mean value agreeing compared with 50% below. A greater percentage also reported that they felt they used their voice too much, with 80% in those above the mean value and 70% below. This may indicate that the effects of speaking for a larger proportion of the working day were impacting on those individuals.

Teachers with phonation times above the mean value did not report using their voice too much but did report that their voice sometimes felt tired, with 56% agreeing compared with 45% of those below the mean.

The phonation percentage may be a better parameter than phonation time for relative comparison between individuals as it is independent of measurement time. This may explain why the phonation percentage aligned with the reporting of voice tiredness or excessive voice use in the questionnaire results, but phonation time did not.

A larger data set would be required to determine if these indications are important.

11.6 Vocal loading indices

Mean vocal fold distance (VFD) and vocal loading index (VLI) values (see 2.2.4) have been calculated and are shown in Table 11.9.

Table 11.9: Vocal loading index by gender and school type

Gender	School type		Vocal fold distance m	Vocal loading index
M	Primary	Mean	3798	705
		SD	905.6	258.3
	Secondary	Mean	1780	479
		SD	905.0	82.0
	Overall	Mean	3125	630
		SD	1313.2	240.9
F	Primary	Mean	7252	1485
		SD	2650.4	304.9
	Secondary	Mean	2127	619
		SD	833.0	109.0
	Overall	Mean	6520	1361
		SD	3055.6	416.1

The results in Table 11.9 indicate that the female participants had higher VFD and VLI values; this may result from differences in SF_0 by gender. The ratio between mean SF_0 for males and females is 1:1.75. The ratios between male and female loading parameters are shown in Tables 11.10.

Table 11.10: VFD and VLI ratios by gender and school type

Parameter	Male : female ratios		
	All	Primary	Secondary
Vocal fold distance (m)	1:2.1	1:1.9	1:1.2
Vocal loading index	1:2.2	1:2.1	1:1.3

Table 11.10 shows that in the primary school teachers the differences between the VFD and VLI values are what would be expected due to the SF_0 differences by gender. In the secondary school participants the ratio was smaller than would be expected due to SF_0 alone.

To investigate the differences between participants of the same gender in different school types the ratios were calculated and are shown in Table 11.11.

Table 11.11: VFD and VLI ratios for school type within genders

Parameter	Primary : secondary ratios	
	Male	Female
Vocal fold distance (m)	2.1:1	3.3:1
Vocal loading index	1.4:1	2.5:1

The variations in phonation time between participants and the relatively small number of subjects mean that further investigations would be needed to examine potential differences in VLI and VFD. However the ratios indicate that primary school teachers within the study had higher VLI and VFD values than those in secondary schools and that the differences were greater for females than for males.

The VFD values were considered in relation to the responses to the participant questionnaire which asked if participants felt they used their voice too much. The data were divided into two groups either side of the mean VFD value. Below the mean VFD value 67% reported using their voice too much, compared with 50% above the mean. With VLI those participants with values below the mean point reported using their voice too much at a higher rate (67%) compared with those above the mean point (55%). Therefore those participants with high vocal loading were not necessarily aware of this factor.

11.7 Further analysis of voice data

The data has been statistically analysed to investigate differences found between participant subgroups. These investigations are summarised in this section.

Statistical analyses were carried out using IBM SPSS Statistics version 21.0.0.0 64-bit for Windows running on a HP EliteBook 840 G2 laptop running Windows 7 Professional.

The analyses have been carried out for the full data set as well as considering sub-groups by gender, school type and other factors. To study the differences between groups of participants independent-samples t-tests were used for two groups. There were insufficient participant numbers to undertake some analysis types on certain sub-groups.

Differences were considered significant at the p = <0.05 level. The sample sizes in the study were small; therefore these results must be treated with caution and are not considered conclusive but in some instances may indicate trends and areas for future research and expansion. The significant differences are summarised in the following sections and the significant correlations in Chapter 12.

11.7.1 Voice level and gender

An independent-samples t-test was conducted to compare the voice levels by gender and showed a significant difference in the voice levels for males (n = 6, m = 63 dBZ, SD = 3.2 dB) and females (n = 14, m = 69 dBZ, SD = 7.0 dB), t (17) = -2.30, p = 0.034 two-tailed. The mean voice level was 5.6 dB higher in the female participants than the males.

This is the opposite to the mean voice levels for the general population (see section 2.3) and placed the mean male voice level between 'normal' and 'raised', and the mean female voice level between 'raised' and 'loud'.

A study [35] which measured relative voice levels between male and female teachers also found higher mean voice levels in female teachers but with a smaller, 3 dB, difference. This may result from different SNR requirements for female speakers due to different SF_0 values or may relate to pupil behaviour and other pedagogical factors.

11.7.2 Voice level and school type

An independent-samples t-test was conducted to compare voice levels by school type. There was a significant difference between primary (n = 16, m = 69 dBZ, SD = 6.4 dB) and secondary school participants (n = 4, m = 61 dBZ, SD = 3.3 dB) with t (18) = 2.14, p = 0.05 two-tailed. This indicated that the primary school teachers had a mean voice level 7.5 dB higher than the secondary school teachers. This difference is comparable with other studies (see section 2.3), and may be due to factors such as higher occupied noise levels or different pedagogy. The primary school subgroup had a greater proportion of female participants (75%) compared with the secondary school subgroup (50%) and the gender differences in voice level may mean the groups are not directly comparable.

For primary schools there was no statistically significant difference between voice levels for male (n = 4, m = 65 dBZ, SD = 3.9 dB) and female participants (n = 12, m = 70 dBZ, SD = 6.9 dB) with t (14) = -1.54, p = 0.15 two-tailed.

For secondary schools there was no statistically significant difference between voice levels for male (n = 2, m = 61 dBZ, SD = 1.4 dB) and female participants (n = 2, m = 61 dBZ, SD = 1.4 dB) with t (2) = -1.08, p = 0.92 two-tailed.

There were also no statistically significant differences between school types within the same gender groups. For female participants there was no statistically significant difference between voice levels for those teaching in primary schools (n = 12, m = 70 dBZ, SD = 6.9 dB) and secondary schools (n = 2, m = 62 dBZ, SD = 6.4 dB) with t (12) = 1.67, p = 0.12 two-tailed. This lack of significance may result from the very small numbers in the respective groups; a larger sample size would allow further investigation into the two variables.

For male participants the same applied; there was no statistically significant difference between voice levels for those teaching in primary schools (n = 4, m = 65 dBZ, SD = 3.9 dB) and secondary schools (n = 2, m = 61 dBZ, SD = 1.4 dB) with t (4) = 1.18, p = 0.30 two-tailed. The same limitations due to the small numbers in the respective groups apply as per the female participants.

11.7.3 Voice level and voice training

There was no statistically significant difference for voice levels between those who have had voice training (n = 10, m = 67 dBZ, SD = 7.1 dB) and those who have not (n = 10, m = 68 dBZ, SD 6.9 dB) based on an independent-samples t-test.

This was also the case by gender; for male participants there was no statistically significant difference between those who had voice training (n = 3, m = 65 dBZ, SD = 4.7 dB) and those who had not (n = 3, m = 62 dBZ, SD = 2.0 dB). For female participants there was also no difference; voice training (n = 7, m = 68 dBZ, SD = 8.0 dB) and no voice training (n = 7, m = 70 dBZ, SD = 6.9 dB).

It was not possible to analyse the secondary school participants as a group for voice training due to the small sample size.

For the primary school participants, although not statistically significant, those who had received voice training had a 1 dB lower mean voice level (n = 8, m = 68 dBZ, SD = 7.0 dB) than those who had not (n = 8, m = 69 dBZ, SD 6.8 dB).

The voice training reported covered a range of levels, types and durations which also complicated analysis and means that participants with comparable voice training would be required to investigate differences between the groups in greater detail.

11.7.4 Phonation percentage, phonation time and gender

An independent-samples t-test was conducted to compare the phonation percentages for males and females. There was a significant difference in the phonation percentages for males (m = 17%, SD = 3.2%) and females (m = 23%, SD = 5.1%; t (18) = -2.48, p = 0.02, two-tailed) with males having a lower mean phonation percentage.

A larger proportion of the female participants taught in primary schools (75%) compared with the male participants (50%). Primary school teachers would be expected to have a higher phonation percentage compared with secondary school teachers (see section 2.2.2), and this may be one explanation for the difference in phonation percentages in the data. However the relatively low number of male participants means that the indications must be treated with caution. Further analysis with a larger sample size would be needed to investigate this relationship further.

When phonation time was analysed, there were indications of a possible difference, with female participants having a higher phonation time, with the difference at a nearly significant level between males (m = 4039 s, SD = 1164.6 s) and females (m = 6190 s, SD = 2801.0 s; t (18) = -1.79, p = 0.09, two-tailed). A larger sample size would be required to confirm the significance of this indicated difference.

11.7.5 Phonation percentage, phonation time and school type

An independent-samples t-test was undertaken to compare the phonation percentages for different school types. There was not a statistically significant difference in the phonation percentages for participants in primary schools (m = 22%, SD = 5.2%) and secondary schools (m = 17%, SD = 3.8%; t (18) = 1.73, p = 0.10, two-tailed). This may be related to the low number of participants in the secondary school group. Further investigations with larger participant numbers in both groups would be needed to determine if there was any statistically significant difference between phonation percentages in different school types.

When phonation time was analysed by school type there was a significant difference between phonation time for those participants in primary schools (m = 6191 s, SD = 2493.5 s) and in secondary schools (m = 2961 s, SD = 719.5 s; t (18) = 2.52, p = 0.02, two-tailed), with those in primary schools having longer phonation times. This is likely to be due to the pedagogical differences, with the teaching of younger children involving more oral instruction.

When considering these phonation time differences by gender there was a significant difference among the female participants, with those in primary schools having longer phonation times (m = 6786 s, SD = 2546.2 s) compared with those in secondary schools (m = 2611 s, SD = 891.0 s; t (12) = 2.23, p = 0.05, two-tailed).

Among the male participants there was no significant difference in phonation times between those in primary schools (m = 4404 s, SD = 1280.1 s) and secondary schools (m = 3310 s, SD = 520.0 s; t (4) = 1.11, p = 0.33, two-tailed).

Differences related to pedagogy would be expected to apply to both male and female participants, however, the small sample size may be a factor in a similar relationship not being indicated in the male participants.

11.7.6 Phonation percentage, phonation time and voice training

There was no statistically significant difference for phonation percentage between those who had received voice training (*m* = 20%, *SD* = 4.6%) and those who had not (*m* = 22%, *SD* = 26.0%; *t* (18) = -0.59, *p* = 0.56, two-tailed).

Further analysis by gender sub groups also showed no significant differences. There was no statistically significant difference in the phonation percentage for males based on voice training (*n* = 3, *m* = 19%, *SD* = 3.5%) or no voice training (*n* = 3, *m* = 16%, *SD* = 2.5%). The same applied for female participants based on voice training (*n* = 7, *m* = 21%, *SD* = 5.0%) and no voice training (*n* = 7, *m* = 24%, *SD* = 5.0%).

For the primary school participants no statistically significant difference was noted between those who had received voice training (*n* = 8, *m* = 21%, *SD* = 4.2%) and those who had not (*n* = 8, *m* = 23%, *SD* 6.1%). This lack of difference may indicate that phonation percentage is essentially a fixed requirement of the teacher’s role and that although voice training may, for instance, improve the efficiency of voice use, it cannot reduce the amount of speaking that teaching demands.

There was no statistically significant difference in phonation time between those who had received voice training (*m* = 5405 s, *SD* = 2342.5 s) and those who had not (*m* = 5684 s, *SD* = 2952.1 s; *t* (18) = -0.23, *p* = 0.82, two-tailed).

This also applied within gender groups. Among the male participants there was no significant difference in phonation times between those who had received voice training (*m* = 4834 s, *SD* = 1159.5 s) and those who had not (*m* = 3244 s, *SD* = 385.5 s; *t* (4) = 2.23, *p* = 0.09, two-tailed).

For the female participants there was also no significant difference in phonation times between those who had received voice training (*m* = 5649 s, *SD* = 2747.7 s) and those who had not (*m* = 6730 s, *SD* = 2961.0 s; *t* (12) = -7.01, *p* = 0.49, two-tailed).

Similarly, there was no significant difference in phonation time by school type between those primary school teachers who had received voice training (*m* = 6103 s, *SD* = 2038.0 s) and those who had not (*m* = 6278 s, *SD* = 3025.3; *t* (14) = -0.14, *p* = 0.89, two-tailed) or for secondary school teachers who had received voice training (*m* = 2611 s, *SD* = 891.0 s) and those who had not (*m* = 3310 s, *SD* = 520.4 s; *t* (2) = -0.96, *p* = 0.44, two-tailed).

Thus, within the groups with and without voice training, there was no statistically significant difference in the phonation times.

In addition, for those without voice training, there was no significant difference between phonation times for males (*m* = 3244 s, *SD* = 385.5 s) and females (*m* = 6730 s, *SD* = 2961.0; *t* (8) = -1.97, *p* = 0.09, two-tailed). Similarly, for those with voice training there was no significant difference between phonation times for males (*m* = 4834 s, *SD* = 1159.5 s) and females (*m* = 5649 s, *SD* = 2747.7; *t* (8) = -0.48, *p* = 0.64, two-tailed).

11.7.7 SF_0 and gender

An independent-samples t-test was conducted to compare the SF_0 for males and females. There was a significant difference between the SF_0 for males (*m* = 150 Hz, *SD* = 21.6 Hz) and females (*m* = 247 Hz, *SD* = 22.4 Hz; *t* (18) = -9.04, *p* = 0.00, two-tailed) with males having a lower mean SF_0 as would be expected due to physical differences (see section 2.2.1).

The analysis was repeated with the female SF_0 values normalised based on the expected gender difference ratio (see Table 11.7). This showed no significant difference between the $SF_{0,\ normalised}$ for males (*m* = 150 Hz, *SD* = 21.6 Hz) and females (*m* = 141 Hz, *SD* = 12.7 Hz; *t* (18) = 1.09, *p* = 0.29, two-tailed). The normalisation ratio is based on the typical values in the literature and may not be applicable to this small group of participants, therefore a larger group would be needed to investigate the relative SF_0 values for males and females with more certainty.

11.7.8 SF_0 and school type

An independent-samples t-test was conducted to consider SF_0 differences by school type. The primary school teachers had a higher mean SF_0 value of 225 Hz compared with that of secondary school teachers of 193 Hz. This may be explained by the greater proportion of female participants in the primary school group who had higher SF_0 values than their male counterparts.

To control for these gender differences the analysis was carried out with the SF_0 values normalised based on the expected gender difference ratio (see Table 11.7). This showed no significant difference between the $SF_{0,\ normalised}$ for primary (*m* = 145 Hz, *SD* = 17.0 Hz) and secondary school participants (*m* = 141 Hz, *SD* = 10.6 Hz; *t* (18) = 0.43, *p* = 0.67, two-tailed). As in section 11.7.7 the normalisation ratio is based on the typical values in the literature and may not be applicable to this small group of participants.

Analysis was carried out of gender groups by school type. Both the male and female primary school teachers had higher mean SF_0 values compared with their counterparts who taught in secondary schools. However these differences were not at a significant level between females teaching in primary (*m* = 248 Hz, *SD* = 23.1 Hz) and secondary schools (*m* = 242 Hz, *SD* = 23.3 Hz; *t* (12) = 0.39, *p* = 0.70, two-tailed). Similarly the differences were not at a significant level between males teaching in primary (*m* = 153 Hz, *SD* = 26.3 Hz) and secondary schools (*m* = 144 Hz, *SD* = 12.0 Hz; *t* (4) = 0.45, *p* = 0.67, two-tailed).

Therefore, the data suggest a difference in SF_0 by school type, but extending the research with a bigger sample size would be necessary to examine these differences further.

11.7.9 SF_0 and training

Analysis was undertaken to investigate differences in SF_0 values based on voice training. 50% of participants had received voice training and this training was evenly distributed by gender, with 50% of both the male and female participants having received voice training.

The group with voice training had a higher mean SF_0 value with a lower standard deviation, though there was not a statistically significant difference between those with voice training (*m* = 224 Hz, *SD* = 46.0 Hz) and those without (*m* = 212 Hz, *SD* = 56.9 Hz; *t* (18) = 0.54, *p* = 0.60, two-tailed).

When analysis was undertaken using $SF_{0,\ normalised}$, values no significant difference was found between those with voice training (*m* = 149 Hz, *SD* = 15.9 Hz) and those without (*m* = 139 Hz, *SD* = 14.5 Hz; *t* (18) = 1.55, *p* = 0.14, two-tailed).

For the gender groups there was no significant difference in SF_0 for males with voice training (*m* = 163 Hz, *SD* = 21.1 Hz) and without (*m* = 137 Hz, *SD* = 14.6 Hz; *t* (4) = 1.76, *p* = 0.15, two-tailed). There was also no difference in SF_0 for females with voice training *m* = 251 Hz, *SD* = 17.6 Hz) and without (*m* = 244 Hz, *SD* = 27.4 Hz; *t* (12) = 0.53, *p* = 0.60, two-tailed).

11.7.10 Vocal loading indices and gender

An independent-samples t-test was conducted to compare the vocal loading indices for males and females.

For the vocal loading index (VLI) there was a significant difference in the values for males (*m* = 630, *SD* = 263.9) and females (*m* = 1361, *SD* = 431.9; *t* (18) = -3.82, *p* = 0.001, two-tailed) with males having a lower mean VLI as would be expected based on the difference in SF_0 values which are used in the calculation of VLI (see section 2.2.4). The ratio between the male and female mean VLI values is 1:2.16 compared with the expected SF_0 ratio of 1:1.75 (see Table 11.7). This indicates that the female participants had higher VLI values than would be expected from the typical gender SF_0 differences alone.

This is also shown by comparison of the vocal fold distance (VFD) values. These showed a significant difference in the values for males (*m* = 3125 m, *SD* = 1438.5 m) and females (*m* = 6520 m, *SD* = 3170.9 m; *t* (18) = -2.49, *p* = 0.023, two-tailed) with males having a lower mean VFD value. This gives a ratio of 1:2.09 for male to female VFD compared with the expected SF_0 value difference alone of 1:1.75. One possible reason for this indicated difference in vocal loading parameters may be the female participants having to repeat themselves due to the different SNR demands related to their typical voice spectrum and the relative spectrum of the children's voices (see section 2.3) which may not apply to the male participants.

The relatively low number of male participants and the unequal gender balance within the primary and secondary school participant groups mean that these findings are indicative only, but would warrant further investigations with a larger participant group.

11.7.11 Vocal loading indices and school type

The vocal loading index (VLI) and vocal fold distance (VFD) were analysed by school type. The mean VFD and VLI values were higher in the primary school participants compared with those in secondary schools.

There was a significant difference between the VFD for primary school (m = 6388 m, SD = 2867.9 m) and secondary school participants (m = 1954 m, SD = 1024.1 m; t (18) = -2.99, p = 0.01, two-tailed). For VLI there was also a significant difference between the VLI for primary school (m = 1290, SD = 462.5) and secondary school participants (m = 549, SD = 137.6; t (18) = 3.11, p = 0.01, two-tailed).

The gender balance of the primary and secondary school groups was not the same and therefore the differences in SF_0 with gender may have contributed to this difference. Further analysis was undertaken to investigate this.

For the female participants there was a significant difference for VFD between those teaching in primary school (m = 7252 m, SD = 2768.3 m) and secondary school participants (m = 2127 m, SD = 1178.0 m; t (12) = 2.51, p = 0.03, two-tailed). This may relate to the higher phonation time in primary school participants (see Table 11.8) which would have a direct effect on the VFD value. This higher phonation time may result from differences in pedagogy between teaching younger and older children but may also result from more onerous speech intelligibility requirements in younger children leading to the need for the teacher to repeat instructions.

For the male participants the differences were not significant. Based on the analysis of the female participants, if the pedagogical differences explained the differing VFD values entirely in the different school types, this would be expected to also apply to the male participants. However the data showed no significant difference for VFD in males between those teaching in primary school (m = 3798 m, SD = 1045.7 m) and secondary schools (m = 1780 m, SD = 1279.9 m; t (4) = 2.10, p = 0.10, two-tailed). This lack of significance may be a result of the small sample size and would warrant further investigations with a larger participant group.

When considering VLI by school type for the female participants there was a significant difference between VLI for those teaching in primary schools (m = 1485, SD = 318.4) and secondary schools (m = 619, SD = 154.1; t (12) = 3.68, p = 0.003, two-tailed).

For the male participants there was not a significant difference in VLI between those teaching in primary schools (m = 705, SD = 298.2) and secondary school participants (m = 479, SD = 116.0; t (4) = 0.99, p = 0.38, two-tailed). As with VFD this lack of significance may be a result of the small sample size and would warrant further investigations with a larger participant group.

11.7.12 Vocal loading indices and training

Analyses were undertaken to examine relationships between voice training and both VFD and VLI.

For all participants considered together there was no significant difference for VFD between those with voice training (m = 5310 m, SD = 2933.1 m) and without (m = 5693 m, SD = 3516.6 m; t (18) = -0.27, p = 0.79, two-tailed). There was also no significant difference for VLI between those with voice training (m = 1089, SD = 433.1) and without (m = 1194, SD = 603.6; t (18) = -0.45, p = 0.66, two-tailed).

When considered by gender there was no significant difference for female participants in terms of VLI between those with voice training (m = 1208, SD = 452.7) and without (m = 1514, SD = 380.1; t (12) = -1.37, p = 0.20, two-tailed).

For male participants there was a close to significant difference for VLI between those with voice training (*m* = 812, *SD* = 253.7) and without (*m* = 447, *SD* = 99.0; *t* (4) = 2.32, *p* = 0.08, two-tailed) however, the sample size was small so this result may not be important.

A similar pattern is shown in the analysis for VFD. For the female participants there was no significant difference in terms of VFD between those with voice training (*m* = 3444 m, *SD* = 1301.9 m) and without (*m* = 7263 m, *SD* = 2938.2 m; *t* (12) = -0.87, *p* = 0.40, two-tailed). For male participants there was a significant difference in VFD between those with voice training (*m* = 4219 m, *SD* = 757.5 m) and without (*m* = 2031 m, *SD* = 1004.0 m; *t* (4) = 3.01, *p* = 0.04, two-tailed). As with VLI, the sample size was small so this result may not be of importance.

11.8 Summary of analysis

There was a statistically significant difference between the mean voice levels of male and female subjects. The female participants had a higher mean voice level of $L_{pZ,\ 1\ m}$ 69 dB compared with that of the male participants at $L_{pZ,\ 1\ m}$ 63 dB. This is different to the general population [34] where males have louder voices, but is in line with other teacher studies which showed females with voice levels higher by around 3 dB [35] rather than the 6 dB in this data.

There was also a statistically significant difference between secondary and primary school teachers: secondary school teachers had a mean voice level of $L_{pZ,\ 1\ m}$ 61 dB compared with $L_{pZ,\ 1\ m}$ 69 dB for primary school teachers. Among the primary school teachers the female participants had a mean voice level of $L_{pZ,\ 1\ m}$ 70 dB compared with $L_{pZ,\ 1\ m}$ 65 dB for the males though this difference was not statistically significant.

The SF_0 values were within the expected ranges, there was a lower mean SF_0 for both male and female secondary school teachers compared with primary schools. The difference was smaller in females representing a smaller proportional change as the mean SF_0 was higher in the female participants as would be expected due to physical differences. However these differences were not at a statistically significant level between genders based on normalised SF_0 values or between school types.

The mean phonation time was 1.5 hours with an overall phonation percentage of 21% which is comparable to studies in the literature. There was a statistically significant difference in phonation time by gender, although this may not be important and may be due to the small sample size. The phonation percentage varied by school type with a mean of 17% in the secondary school teachers and 22% in the primary school teachers although the difference was not statistically significant.

The female teachers had a larger difference in phonation percentage between primary (higher) and secondary (lower) compared with the male teachers, and had a higher phonation percentage than male participants in both school types.

The VLI and VFD differences between males and females were higher than the expected mean SF_0 ratio between genders (see section 2.2.4). This indicated that there were additional factors involved. This difference is due to the primary school participants having a higher ratio whereas the secondary school participants had a lower ratio than the typical SF_0 ratio would suggest.

The primary school teachers had higher VLI and VFD values than their respective counterparts in secondary schools with the same gender, but this difference was greater in the female teachers, with a ratio of 3.3:1 between the primary and secondary school VFD values.

There were no statistically significant differences in voice parameters due to voice training although the nature of training was not consistent between participants.

11.9 Conclusions

This chapter has considered the voice measurements results which showed differences in voice parameters by participant gender and school type, with female participants speaking at higher levels. Participants of both genders in primary schools had higher voice levels, SF_0 values and phonation percentages indicating that vocal loading is likely to be significant for this cohort, however the differences were not statistically significant based on the data set. More than half of all the participants (65%) spoke at mean voice levels which would be classified as above ‘normal’ level.

The next chapter will give details of the analyses that have been carried out on the voice and acoustic measurement results and indications of potential relationships between different voice parameters and room acoustic properties.

Chapter 12 Relationships between voice and acoustic data

12.1 Introduction

This chapter presents the results of statistical analyses undertaken to identify correlations between the voice and acoustic parameters measured.

The sample sizes in the study were small; therefore these results must be treated with caution and are not considered conclusive. Where correlations have been indicated this does not necessarily equate to causality but may indicate trends and areas for future research and expansion

Bivariate correlation analyses were carried out using Pearson's correlation coefficient for all variables. The interpretation of correlation values has been based on the categories in Table 12.1.

Table 12.1: Correlation coefficient values [159]

Sign of correlation coefficient	Very strong	Strong	Moderate	Weak	Weak/none
Positive	0.8 to 1.0	0.6 to 0.8	0.4 to 0.6	0.2 to 0.4	0.0 to 0.2
Negative	-1.0 to 0.8	-0.8 to -0.6	-0.6 to -0.4	-0.4 to -0.2	-0.2 to 0.0

Correlations were considered significant at the $p < 0.05$; level. However other significance values have been reported where the small sample sizes may have affected the significance value but there are suggestions of a possible trend.

The analyses have been carried out for the full data set as well as considering sub-groups by gender, school type and other factors. To study the differences between groups of participants, independent-samples t-tests were used for two groups. There were insufficient participant numbers to undertake some analysis types on certain sub-groups.

The significant correlations are summarised and discussed in the following sections.

12.2 Comparison of voice parameters and unoccupied noise levels

12.2.1 Voice level

Correlation analyses were undertaken to investigate relationships between voice levels and unoccupied noise levels. The significant correlations between voice levels and a range of parameters in both dBA and octave band levels are summarised in Table 12.2. In this table *p* values ≤ 0.07 are included as these are close to significant and may indicate a trend which could be investigated with a greater sample size.

Table 12.2: Correlations between unoccupied noise levels and voice levels for all participants

Parameter	Voice level mean $L_{pZ,\,1\,m}$ dB - all participants (*n* = 20)	
	r	*p*
UANL L_{Aeq}	0.43	0.06
UANL L_{eq} 125 Hz	0.48	0.03
UANL L_{eq} 250 Hz	0.42	0.07
UANL L_{eq} 500 Hz	0.43	0.06
UANL L_{eq} 1 kHz	0.45	0.05
UANL L_{A90}	0.43	0.06
UANL L_{90} 125 Hz	0.51	0.02
UANL L_{90} 250 Hz	0.53	0.02
UANL L_{90} 500 Hz	0.45	0.05
UANL L_{90} 1 kHz	0.41	0.07

There were moderate positive correlations between voice levels and UANL L_{Aeq} (r = 0.43) and L_{A90} (r = 0.43) which were both close to significant (p = 0.06). This data is plotted along with regression lines in Figures 12.1 and 12.2.

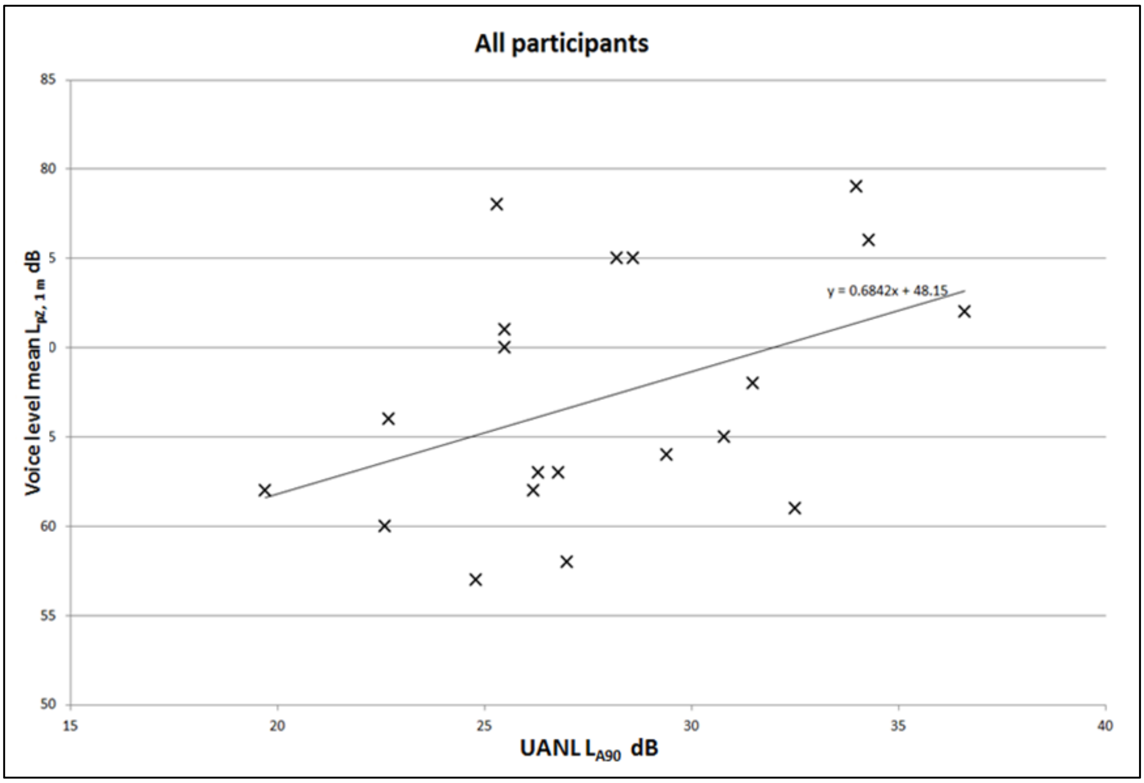


Figure 12.1: Voice level and UANL L_{A90}

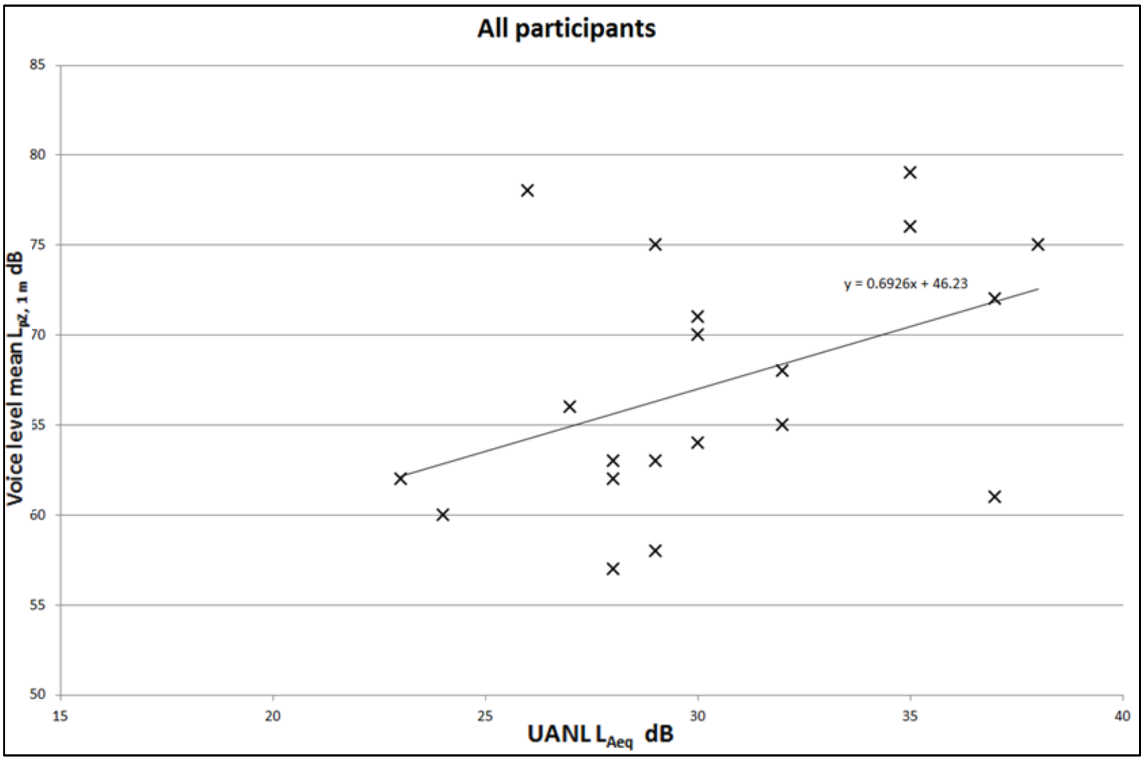


Figure 12.2: Voice level and UANL L_{Aeq}

The regression lines show that the mean voice levels increased by 0.7 dB per dB increase in UANL for both L_{A90} and L_{Aeq}.

The strongest correlations between voice levels and UANLs were with the 125 and 250 Hz L_{90} octave bands. The L_{90} UANL values tended to have a stronger correlation both in dBA and octave band terms than the L_{eq} values. The L_{90} value is likely to be a better representation of the true UANL as it is not affected by short term noise events.

Due to the differences (see section 2.2.1) in the typical SF_0 values between the genders, correlations have been analysed separately for male and female participants.

The significant internal noise level correlations for male and female teachers are shown in Table 12.3. There were only significant correlations for the female participants, however for information the corresponding values for the male participants are included irrespective of significance. The small number of male participants may have limited the significance of correlations for that group.

Table 12.3: Significant correlations between unoccupied internal noise levels and voice level by gender

Parameter	Voice level mean $L_{pZ,\,1\,m}$ dB			
	Male n = 6		Female n = 14	
	r	p	r	p
UANL L_{eq} 125 Hz	0.45	0.38	0.47	0.09
UANL L_{eq} 250 Hz	0.02	0.97	0.56	0.04
UANL L_{eq} 1 kHz	0.30	0.56	0.50	0.07
UANL L_{90} 125 Hz	0.66	0.15	0.43	0.13
UANL L_{90} 250 Hz	0.17	0.75	0.61	0.02

Table 12.3 indicates that the voice levels of female teachers were significantly correlated with UANL L_{eq} 250 Hz and UANL L_{90} 250 Hz. Scatter plots are shown in Figures 12.3 and 12.4, together with the regression lines.

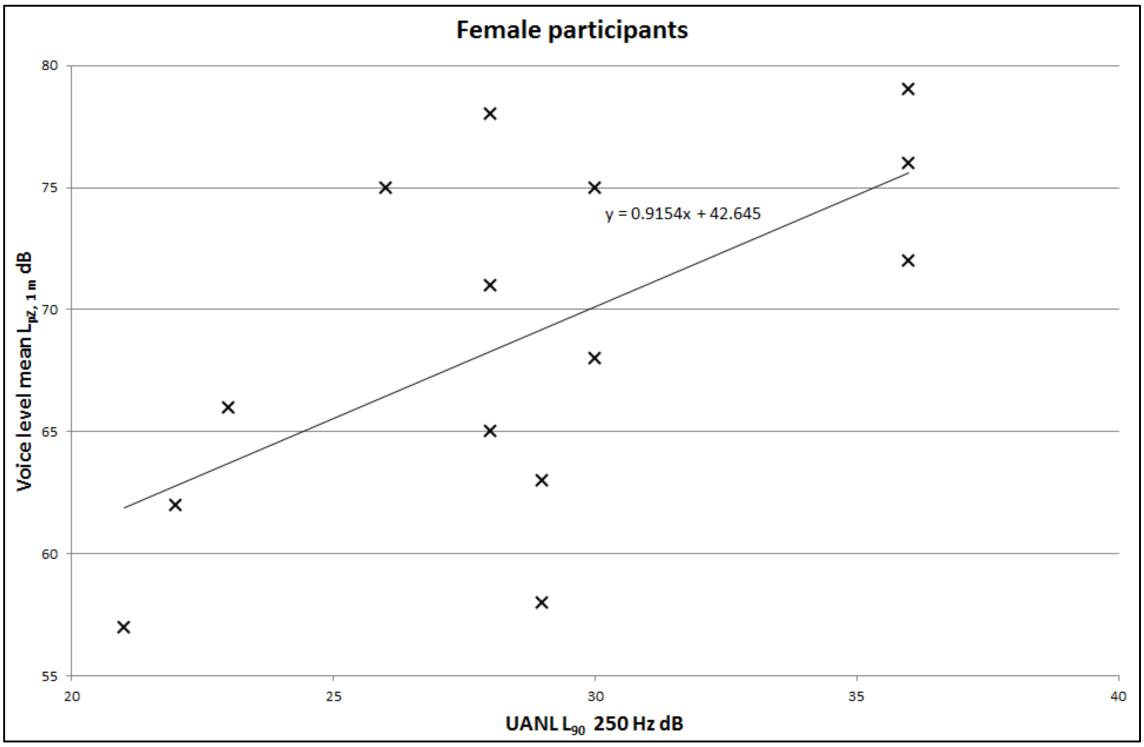


Figure 12.3: Female participants - voice level and UANL 250 Hz L_{90}

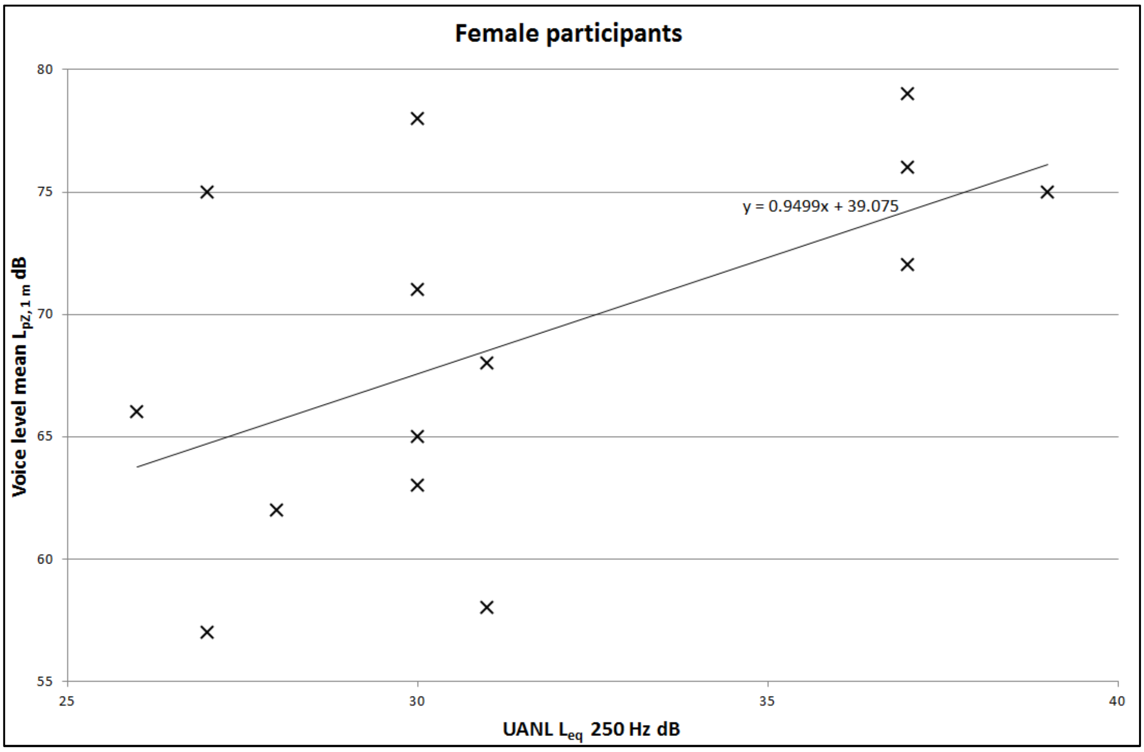


Figure 12.4: Female participants - voice level and UANL 250 Hz L_{eq}

It is notable that the 250 Hz band covers the mean SF_0 for females of 225 Hz (see Table 2.1). It is therefore possible that the Lombard effect [28] caused these teachers to speak louder due to ambient noise in the same frequency band as the primary output of their voices.

If the same effect applied to male participants then a similar correlation would be expected to occur in the 125 Hz band to correspond with the mean SF_0 for males of 128 Hz (see Table 2.1). The correlation between voice level in males and UANL L_{eq} 125 Hz was moderate (r = 0.45) with a strong correlation for UANL L_{90} 125 Hz (r = 0.66), however neither of these correlations were statistically significant, possibly due to the small sample size. Nevertheless the relatively strong correlation in the 125 Hz frequency band compared with other frequencies suggests a similar phenomenon to that observed in the female teachers. A larger number of participating male teachers would be necessary to investigate this further.

The plots of the male participants' voice levels and UANL 125 Hz octave band values are shown in Figures 12.5 and 12.6.

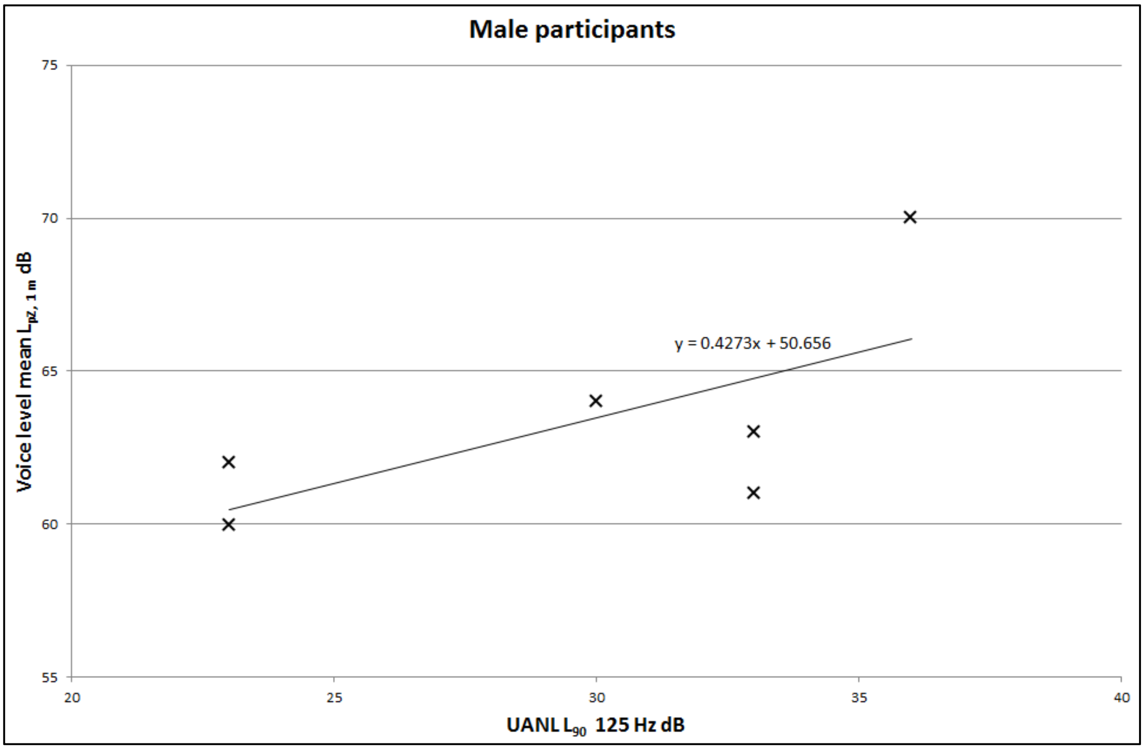


Figure 12.5: Male participants - voice level and UANL 125 Hz L_{90}

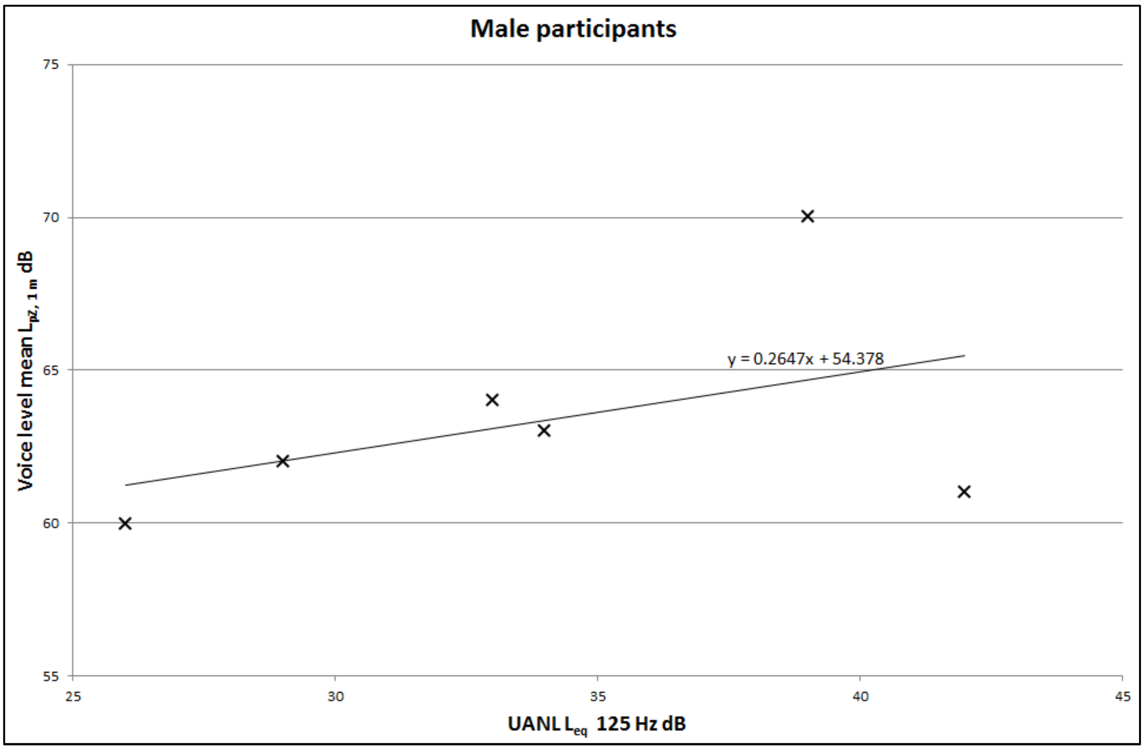


Figure 12.6: Male participants - voice level and UANL 125 Hz L_{eq}

The regression lines (not considering significance for males) equate to the following mean voice level increases:

- Females: 0.9 dB per dB increase in the UANL 250 Hz band for both L_{90} and L_{eq}.
- Males: 0.3 dB per dB increase in the UANL 125 Hz band L_{eq} and 0.4 dB per dB for the 125 Hz L_{90}.

This indicates that the voice levels for female participants had a greater increase relative to UANL than the male participants in the octave bands related to the respective mean SF_0 values.

The relatively small number of participants meant that is was not possible to further analyse this rate of increase by subgroups with different UANLs. With a larger data set it may be possible to investigate if the correlations are consistent throughout a typical range of UANL values or if the correlation is more significant at lower or higher ambient noise levels. Similarly there was not sufficient data to look at potential variation in this correlation between primary and secondary school participants.

12.2.2 Phonation percentage and time

There were some significant and almost significant correlations for the male participants between phonation time and UANL values in certain octave bands as shown in Table 12.4. There were no corresponding significant correlations in the female participants.

Table 12.4: Significant correlations between phonation time and UANL by gender

Parameter	Phonation time (s)			
	Male n = 6		Female n = 14	
	r	p	r	p
UANL L_{eq} 125 Hz	0.90	0.02	0.30	0.29
UANL L_{eq} 500 Hz	0.82	0.05	0.02	0.94
UANL L_{eq} 1 kHz	0.77	0.07	-0.12	0.68

This did not apply to the phonation percentage values which, being independent of the duration of teaching on a given day, allows direct comparison between participants. Therefore these correlations should be interpreted with caution and may not be important.

When considering male primary school teachers only, the correlation of UANL L_{eq} 125 Hz with phonation percentage (r = 0.99, p = 0.01) was significant and very strong. The sample size (n = 4) limits the implications that can be drawn from this. The correlation in the 125 Hz band does however align with the mean SF_0 of male voices which may be important and would warrant further investigation as it could indicate a need to repeat speech due to SNR challenges in the spectral domain when the teacher's SF_0 and classroom UANL coincide.

12.2.3 Vocal loading indices

The VLI is calculated using the phonation time and therefore the correlations tracked those of the phonation time. Vocal fold distance also aligned with VLI and was not analysed separately as a result. The significant VLI correlations were for male participants with UANL L_{eq} 125 Hz (r = 0.85, p = 0.03) and 500 Hz (r = 0.83, p = 0.04).

There was no significant correlation for female participants, and therefore as with phonation time this may not be important.

12.2.4 SF_0

A strong, significant correlation was noted between mean SF_0 ($r = 0.97$, $p = 0.03$) and UANL L_{eq} 250 Hz levels in male primary teachers ($n = 4$). This did not manifest itself in male teachers generally or in female teachers and therefore may be an anomalous result.

12.2.5 Participant questionnaires

The participant questionnaire responses were analysed alongside the corresponding UANL and occupied noise level data. In terms of UANL, more of those participants who taught in classrooms with UANL values above the mean than those below the mean reported often having to talk over background noise (100% above the mean, 80% below the mean) and being in a difficult acoustic environment (56% above the mean, 40% below).

12.3 Comparison of voice parameters and occupied noise levels

12.3.1 Voice level

Correlation analyses were undertaken to investigate relationships between voice levels and occupied noise levels. The significant correlations are summarised in Table 12.5. The occupied noise levels were the arithmetic averages of the 1 hour measurements during teaching. In this table p values ≤ 0.07 are included as these are close to significant and may indicate a trend which could be investigated if the sample sizes were greater.

Table 12.5: Correlations between occupied internal noise levels and voice levels for all participants

Parameter	Voice level mean $L_{pZ,\ 1\ m}$ dB - all participants (*n* = 20)	
	r	*p*
Occupied $L_{Aeq,\ arith.\ av.}$	0.63	0.00
Occupied $L_{eq,\ arith.\ av.}$ 500 Hz	0.56	0.01
Occupied $L_{eq,\ arith.\ av.}$ 1 kHz	0.59	0.01
Occupied $L_{eq,\ arith.\ av.}$ 2 kHz	0.67	0.00
Occupied $L_{eq,\ arith.\ av.}$ 4 kHz	0.64	0.00
Occupied L_{Afmax}	0.46	0.04
Occupied L_{fmax} 2 kHz	0.59	0.01
Occupied L_{fmax} 4 kHz	0.55	0.01

In Table 12.5 there were moderate to strong positive correlations between voice levels and a number of occupied noise level parameters. These occupied noise level correlations may be a result of the teacher's voice level being a contributory component of the overall occupied noise level along with activity noise from children.

When analysis was carried out by gender sub-groups the apparent significant correlations for all participants were as a result of significant correlations for the female participants. There were no significant correlations for the males. This may be a result of female speakers being more affected by occupied noise levels than males, or could be that due to their louder voice levels (see section 11.3) they had more contribution to the overall classroom noise levels, or there may be other less-apparent explanations. The correlations calculated for gender subgroups are shown in Table 12.6.

Table 12.6: Correlations between occupied internal noise levels and voice levels by gender

Parameter	Voice level mean $L_{pZ,\ 1\ m}$ dB			
	Male *n* = 6		Female *n* = 14	
	r	*p*	*r*	*p*
Occupied $L_{Aeq,\ arith.\ av.}$	0.62	0.19	0.58	0.03
Occupied $L_{eq,\ arith.\ av.}$ 1 kHz	0.63	0.18	0.55	0.04
Occupied $L_{eq,\ arith.\ av.}$ 2 kHz	0.69	0.13	0.65	0.01
Occupied $L_{eq,\ arith.\ av.}$ 4 kHz	0.61	0.20	0.59	0.03
Occupied L_{fmax} 2 kHz	0.72	0.11	0.51	0.06

There was a correlation between occupied noise levels in dBA and voice levels for the participants as a whole, and there were some correlations with specific spectrum bands (see Table 12.5). When the data were further analysed by gender the significant correlations were in the female participants, however this may be a result of the relatively small number of male participants. The occupied L_{Aeq} noise levels and voice levels are shown in Figure 12.7 for information.

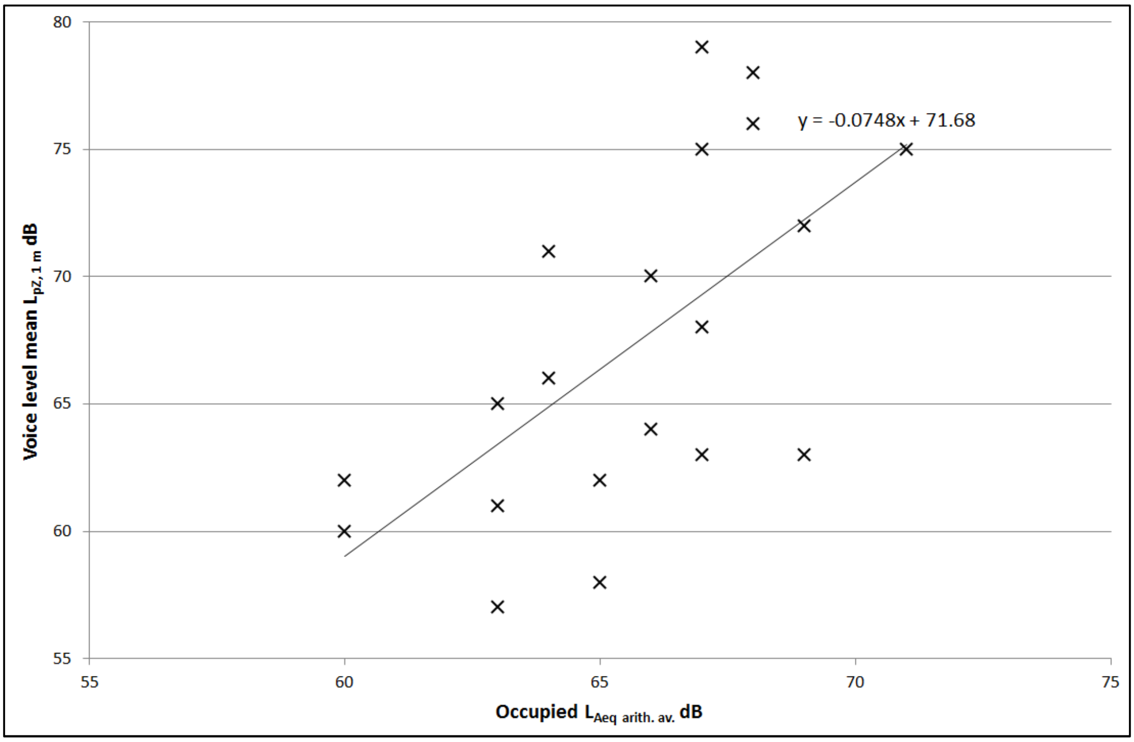


Figure 12.7: All participants - voice level and occupied $L_{Aeq,\ arith,\ av.}$

In the participant questionnaires, those participants who taught in occupied noise levels above the mean value reported being in a difficult acoustic environment more frequently (50% above the mean, 20% below) as well as reporting that they spoke over background noise at a higher rate (100% above the mean, 80% below). The small number of participants represented in the questionnaire data limit what can be inferred from the results but the findings may indicate a link between occupied noise levels and how the participants subjectively consider their acoustic environment and voice use in their classrooms.

12.3.2 Phonation percentage and time

There were some significant correlations between phonation time, phonation percentage and occupied noise levels in terms of the $L_{eq,\ arith.\ av.}$ values in the 500 Hz to 4 kHz octave band range, L_{Aeq} and L_{Afmax} as shown in Table 12.7. When considered by gender the correlations were significant in the female participants but not the male participants which may be a result of the small numbers.

Table 12.7: Significant correlations between occupied noise levels and phonation percentage and time

Parameter	Phonation %		Phonation time (s)	
	r	*p*	*r*	*p*
Occupied $L_{Aeq\ arith.\ av.}$	0.63	0.00	0.48	0.00
Occupied $L_{eq\ arith.\ av.}$ 500 Hz	0.44	0.05	0.63	0.00
Occupied $L_{eq\ arith.\ av.}$ 1 kHz	0.47	0.04	0.6	0.01
Occupied $L_{eq\ arith.\ av.}$ 2 kHz	0.36	0.11	0.53	0.02
Occupied $L_{eq\ arith.\ av.}$ 4 kHz	0.49	0.03	0.52	0.02
Occupied L_{Afmax}	0.46	0.04	0.48	0.03

This may indicate that the voices of participants were significant in the overall measured noise levels. It does not necessarily imply that teachers spoke for a greater percentage or for a longer time in higher occupied noise conditions.

12.3.3 Vocal Loading Index

The SF_0 value is used in the calculation of Vocal Loading Index and therefore the inherent difference in SF_0 by gender means that correlations with occupied noise levels have been examined separately for male and females. There were no significant correlations for male or female participants between VLI and occupied noise level parameters, although for female participants there were moderate positive correlations between VLI and occupied L_{eq} levels in the 1 kHz ($r = 0.47$, $p = 0.09$) and 4 kHz ($r = 0.49$, $p = 0.08$) octave bands.

12.3.4 SF_0

As with VLI the inherent difference in SF_0 by gender means that correlations with occupied noise levels have been examined separately for male and females. There were no significant correlations for male or female participants between SF_0 and occupied noise level parameters.

12.4 Comparison of voice parameters and room acoustic data

Analyses were undertaken to examine relationships between voice parameters and room acoustic parameters including EDT_{mf}, T_{mf}, A_{mf} and room radius, as well as values at specific frequencies.

12.4.1 Voice level

There were no statistically significant correlations between room acoustic parameters and voice levels for all participants or for females and males considered separately.

12.4.2 Phonation percentage and time

There were no statistically significant correlations between room acoustic parameters and phonation time and percentage for the participants as a whole, or for male and female subjects analysed separately.

12.4.3 Vocal loading indices

There were significant moderate correlations for female teachers between VLI and the total absorption A_{mf} ($r = 0.53$, p = 0.05) and room radius ($r = 0.56$, $p = 0.04$). A possible explanation is that more absorption in a room means that there is less reinforcement for the teacher's voice by way of sound reflections and therefore the speaker may speak differently to compensate for a perceived lack of room support.

In male teachers there was no corresponding correlation with the total absorption in the room.

12.4.4 SF_0

For SF_0 there were no statistically significant correlations with room acoustic parameters.

12.5 Summary

The absence of significant correlations between voice and room acoustic parameters indicated that in this particular data set, room parameters related to reverberation time and absorption did not have a measurable influence on voice parameters. The interaction between, for instance, UANL or occupied noise levels and reverberation time, means there may be influences which are masked due to the combined effects.

Partial correlation analyses were undertaken to control for UANL effects on correlations between voice and reverberation time parameters.

There were no significant correlations found between voice parameters and reverberation time parameters when controlling for L_{eq} or L_{90} in the relevant octave bands e.g. RT_{60} at 125 Hz with L_{eq} UANL at 125 Hz.

The responses to the participant questionnaire indicated that, subjectively, reverberation times may contribute to perceived difficulties. The participants were asked if there were times during the week when they were in a difficult acoustic environment. Dividing the responses according to T_{mf} values, showed that below the mean 20% agreed rising to 50% above the mean, the same split in responses applied above and below the mean EDT_{mf} values.

This may indicate a link between longer reverberation times and a perception of difficult acoustic conditions. A larger data set would be needed to determine if these indications were important.

12.6 Conclusion

In summary there were moderate positive correlations identified between voice levels and UANLs which were close to significant. There was a significant correlation for female participants with the UANL values in the 250 Hz band which corresponds to the typical female SF_0 value. There were indications of a similar effect in male participants at the lower 125 Hz band though the small sample size may have limited the significance. The calculated Lombard effects [28] in these bands were higher for females compared with males. This indicates that low frequency UANL values may have an effect on the voice levels of teachers, though current school UANL criteria are expressed in dBA only and hence do not consider low frequencies.

Comparison of the measured data and participant questionnaires showed that those teaching in higher UANLs reported talking over noise more frequently, and more of those in higher occupied noise levels reported a difficult acoustic environment.

There were no significant correlations between reverberation times and associated room acoustic properties and voice parameters.

There were moderate correlations for female teachers between VLI and the total absorption A_{mf} and room radius. There were indications of a similar correlation, though not at statistically significant levels, between these same factors and phonation time.

The sample sizes for both male and female participants were relatively small and therefore further investigations with a larger sample size would be necessary to determine conclusively whether there is a relationship between voice level and noise for both male and female teachers.

The statistical analyses undertaken were limited by a number of factors including the APM accuracy, and the many variations between participants and classrooms that are present in non-laboratory conditions. The main factor is that the UANL values are based on unoccupied measurements at a different time to the voice measurements and therefore may not accurately represent those that occurred during the voice measurement period.

The next chapter will detail the online survey element of the research in terms of the questionnaire development and initial pilot survey to develop the survey structure.

Chapter 13 Design of online survey and pilot survey

13.1 Introduction

The project also included an online survey for teachers, which was developed to gather additional information on teachers' experiences of voice strain and other voice-related problems, as well as their perceptions of general noise and acoustics in schools.

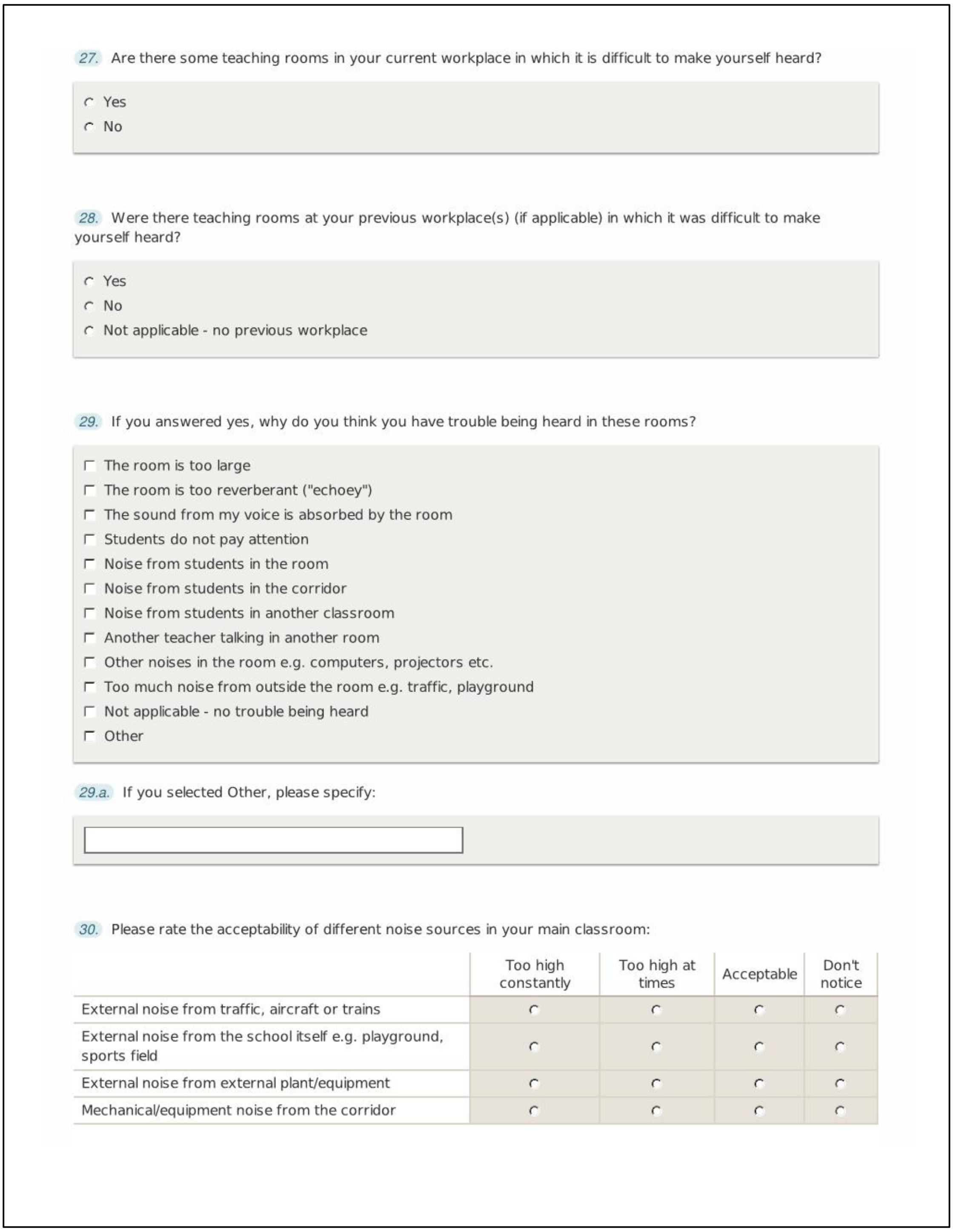
The survey was undertaken in two stages: a pilot study to develop the methodology and survey questions, and then a larger scale survey. This chapter will give details of the survey design and a summary of the pilot study results.

13.2 Design of survey

The survey was undertaken using the Bristol Online Survey platform [160], an online survey tool intended for academic research purposes. The system enabled different question structures to be used including multiple choice and free response answers and included analytical tools and a dashboard showing the responses to date.

The survey was accessed via a web address link and QR code which took respondents firstly to an information page through a consent agreement and then to the main questions. Respondents were automatically allocated an individual identity number which enabled responses for each individual to be cross referenced and gave respondents the option to save their answers and return to complete the survey at a later time. All responses were anonymous. Ethical approval was obtained for the survey as detailed in section 9.2.

The pilot survey comprised 58 questions organised into a number of sections, Figure 13.1 shows a typical question section as it appeared to the respondents.



27. Are there some teaching rooms in your current workplace in which it is difficult to make yourself heard?

- Yes
- No

28. Were there teaching rooms at your previous workplace(s) (if applicable) in which it was difficult to make yourself heard?

- Yes
- No
- Not applicable - no previous workplace

29. If you answered yes, why do you think you have trouble being heard in these rooms?

- The room is too large
- The room is too reverberant ("echoey")
- The sound from my voice is absorbed by the room
- Students do not pay attention
- Noise from students in the room
- Noise from students in the corridor
- Noise from students in another classroom
- Another teacher talking in another room
- Other noises in the room e.g. computers, projectors etc.
- Too much noise from outside the room e.g. traffic, playground
- Not applicable - no trouble being heard
- Other

29.a. If you selected Other, please specify:

30. Please rate the acceptability of different noise sources in your main classroom:

	Too high constantly	Too high at times	Acceptable	Don't notice
External noise from traffic, aircraft or trains	○	○	○	○
External noise from the school itself e.g. playground, sports field	○	○	○	○
External noise from external plant/equipment	○	○	○	○
Mechanical/equipment noise from the corridor	○	○	○	○

Figure 13.1: Example question section

The first section concerned personal details such as age, gender and number of teaching years, information on the type of school, subject taught and the physical properties of the classroom.

There then followed questions on experiences of voice problems and health in general. To ensure that the gathered data was technically robust, these questions were based on established clinical questionnaires, primarily The Voice Impact Profile by Martin and Lockhart [161] which was amended to suit the specific requirements of this study. For the general health section the initial proposal was to incorporate a proprietary health questionnaire; however this proved prohibitively expensive, and an alternative was developed independently.

Finally, participants were also asked to rate different noise types in the classroom and experiences of acoustic issues.

13.3 Pilot survey distribution

The survey was piloted in October and November 2013 at two state, academy-status schools in South East England. These schools participated in the voice measurements; a primary school with approximately 20 teachers (School S3) and a secondary school (School S1) with approximately 40 teachers.

For the pilot study the link was distributed by senior staff members directly to teachers. The direct-to-school distribution method gave a relatively low response rate. The anonymous nature of the survey, as required by the University's ethical code, meant that it was not possible to identify and follow up individuals who had not responded.

The primary role of the pilot study was to check the effectiveness of the survey structure for any operational issues ahead of the main survey.

Participants were made aware that they were helping to test the survey ahead of a larger scale version and were asked to give comments and feedback which were incorporated into the final survey version where appropriate.

The results are summarised in the following section.

13.4 Results of pilot survey

Not all questions were answered by all respondents, therefore the results given are the percentage of valid responses to the individual questions. Where erroneous answers have been given or free text answers align with one of the multiple choice answers these have been discounted or reassigned in the analyses respectively. All percentages are rounded to the nearest whole number which may produce cumulative totals above 100% in some cases.

The results from the pilot study are discussed separately to the main study as the method of recruiting participants was different and the range of schools involved relatively narrow.

The relatively small number of respondents means that statistically robust analyses were not possible on a number of questions.

13.4.1 Profile of respondents

There were 15 respondents, 27% male (n = 4) and 73% female (n = 11), which compared well with the gender balance of the profession as a whole in England where 74% of teachers are female [53].

The average age was 44 years (SD 12.2) with 20% (n = 3) being under 30; all respondents were of working age. Nationally 25% of teachers are under 30. The over 50s are 18% of the national teaching population but formed 53% (n = 8) of the pilot survey respondents. Therefore the age distribution of respondents was different to that of the profession generally.

In terms of the number of years teaching only one respondent had taught for less than a year and the greatest number of respondents (n = 7) had taught for over 25 years.

Eleven respondents taught in secondary schools, three in infant/primary school and one was a special needs teacher (school type unknown).

13.4.2 Classroom information

Respondents were asked about the features of their classrooms. The respondents taught in classrooms constructed in a range of periods from the Victorian-era to the 2000s. The two schools in the pilot study were constructed in the 1890s and 1950s but in common with many schools had been extended during different periods resulting in a range of construction eras in the same school. This was reflected in the questions about classroom finishes which showed a range of materials.

The main classroom layout types were tables in clusters (n = 6) and rows (n = 7).

Respondents were asked about their teaching in open plan areas. The majority (86%) did not teach in open plan rooms. Of those who did (n = 2) these were for 12 and 19 hours per week respectively.

The majority of respondents (80%, n = 12) taught classes of 21 to 30 pupils, with the remainder teaching smaller classes.

13.4.3 Classroom acoustics

Respondents were asked about their experiences of how the acoustics in classrooms affected their voice and their impressions of different noise sources in their classrooms. They were also asked how their main teaching room made their voice sound. Of the valid responses 62% (n = 8) reported that they could hear themselves clearly, and 45% (n = 6) that the room supported their voice. 15% (n = 2) reported that their voice sounded 'echoey' or reverberant in the classroom.

60% (n = 9) reported that there were rooms in their current workplace in which it was difficult to make themselves heard, with the three most frequently given reasons being that the room was too reverberant or 'echoey' (60%, n = 9), the room being too large (33%, n = 5) and external noise such as traffic (27%, n = 4).

Respondents were asked to rate various different noise sources in their main classrooms in terms of acceptability.

The main sources that were reported as being too high were:

- External noise from the school itself, e.g. playground, too high at times (36%, *n* = 5).
- External noise from plant and equipment too high at times (15%, *n* = 2).
- People noise from corridors too high at times (36%, *n* = 5) and constantly too high (7%, *n* = 1).
- Pupil noise from other classrooms too high at times (23%, *n* = 3).
- Equipment noise in own classroom too high at times (15%, *n* = 2) and constantly too high (8%, *n* = 1).
- Pupil noise in own classroom too high at times (31%, *n* = 4).

Other noise sources were generally rated as acceptable or not noticeable by the majority of respondents.

Thus the noise sources being reported at too high levels most frequently were people noise from corridors and pupil noise in the teachers' own classrooms.

13.4.4 Voice use and problems

Respondents were asked about their experiences of voice loss. 33% (*n* = 5) had experienced voice problems during their teaching career. These problems included partial voice loss occasionally, partial voice loss frequently, total voice loss occasionally, and changes in voice quality or characteristics.

Of the respondents who reported voice problems two did not seek help despite experiencing significant voice problems, while others had sought help from their GP and others. Voice rest was the most often advised measure which was reported as helping with voice problems in many cases.

None of the respondents had taken time off from work in the previous two years due to voice problems, compared with 60% (*n* = 9) who had had time off for other health reasons in the same period. 80% (*n* = 4) of those who had experienced voice problems had remained at work despite problems with their voice.

47% (n = 7) stated that their voice felt tired at the end of the day and 47% (n = 7) frequently had to raise their voice when teaching.

In relation to voice training, 27% (n = 4) of the respondents had received voice training, with two individuals having received informal training or guidance, one having had a one-off session during teacher training and one having attended a short course. 93% (n = 14) of respondents felt that voice training should be included in teacher training courses. 46% (n = 6) felt that voice problems were a significant issue for teachers.

13.4.5 Hearing loss and tinnitus

One respondent had hearing loss, wore two hearing aids and stated that some rooms were more difficult to hear in. This would be expected given the more onerous acoustic conditions needed by those who are hearing impaired. The same respondent experienced tinnitus constantly and stated that this was on occasion made worse by teaching. Four other respondents reported occasional tinnitus.

13.4.6 General health

Participants were asked a number of questions related to general health. These underwent further refinement following the pilot study. 86% (n = 12) of respondents considered themselves to be in good or very good health. 44% (n = 6) reported feeling calm and peaceful only some or little of the time, indicating that stress may have affected some of the respondents.

13.5 Conclusions

The pilot survey indicated that teachers were concerned about voice problems and a significant proportion of the respondents (more than 30%) had experienced these.

Following the pilot study some minor adjustments were made to the main survey including adding a small number of additional questions and some simplification of the general health questions section. In addition the order of the questions was revised to follow a more logical order.

The pilot survey was followed by a large scale online survey publicised with the help of two UK teaching unions. The survey details and results are summarised in the next chapter.

Chapter 14 Results of online survey

This chapter details the results of the main online survey for teachers. The methodology for distributing the survey is described along with results sections grouped by question type.

14.1 Distribution of survey

Following the pilot survey the main survey was prepared for issue. To reach the maximum number of teachers the researcher held meetings with two UK teacher unions. The National Union of Teachers (NUT) and Voice: *The union for educational professionals* generously agreed to publicise the survey.

The NUT is the UK's largest teaching union with approximately 372,000 members [162] representing 37% of teachers who are union members [163]. The NUT included an article in their journal *The Teacher* in January 2014 as well as a tweet on the official NUT Twitter feed.

Voice [164] has approximately 20,000 members [165] and represents 2% of teachers who are union members [163]. *Voice* included an article in their journal *The Voice* in January 2014 and on their online blog. The survey was also promoted on the Institute of Acoustics group on LinkedIn.

In addition, details of the survey were given to participants in the voice measurements (see Chapter 9). The author also distributed details of the survey via family and friends to reach as many teachers as possible.

The survey was open from January 2014 until December 2015 to maximise opportunities for responses. It comprised 57 questions including a section on general health and wellbeing and took participants around 15 minutes to complete. The publicity details and copies of the survey questions are contained in Appendix H.

14.2 Survey respondents

The main online survey had 153 responses. Not all respondents completed all questions. Data is reported based on the valid responses for each question. All percentage values are rounded to the nearest whole number which may result in cumulative values greater than 100 percent. Where respondents were able to select more than one answer the quoted percentages are the proportion of respondents to that question who selected each option unless otherwise stated.

Some questions included free text answer sections. Where these answers aligned with answer options presented in the question, these responses have been included in the relevant answer category or additional categories added in the results to highlight the free responses.

The survey received a relatively small number of responses given the potential number of respondents that were reached. This is often a challenge with surveys, particularly when there is no mechanism for following up potential respondents. It is possible that prospective participants did not complete the survey due to concerns about the anonymity of their responses. It is felt that these concerns were allayed with clear reference to how data would be used anonymously in the Participant Information Sheet which was the first page of the online survey (see p. 303). This was also highlighted in the publicity wording (see Figure H.1 and H.6).

The respondents were self-selecting and therefore may not represent the wider teaching population. The number of responses does, however, allow for statistically valid analysis. For the basis of statistical analysis it has been assumed that there are 506,000 full time teachers in the UK [47, 48, 49, 50, 51] and if this is the total population 153 responses would give a ±8% margin of error at the 95% confidence level [166]. The main results are summarised in the following sections.

14.3 Survey results

The survey questions were grouped into a number of sections on different topics. The results are also subdivided into a number of sections; section 14.4 on personal information, 14.5 on classroom details, 14.6 on voice problems, 14.7 on classroom acoustics, 14.8 on the implications of voice problems and 14.9 on hearing and other health issues.

14.4 Personal information

14.4.1 Gender (Q1)

The respondents to the main survey were 72.5% female and 27.5% male (n = 142) which is very similar to the overall teaching population [53]. One potential source of bias in the data could be that some of those who responded did so because of having suffered from voice problems personally. As there is an apparent greater prevalence of voice problems in female teachers [59, 60, 73] the respondent gender profile may be a result of that.

14.4.2 Age (Q2)

The respondents were asked to give their age. The highest age bracket was over 67 years. For analysis purposes respondents in this bracket were classified as being aged 68. The age profile of the respondents is summarised in Table 14.1.

Table 14.1: Age profile

Group	Mean	*SD*	Min	Max	*n*
All	43	12.5	22	68	142
Male	46	12.0	25	68	39
Female	42	12.2	22	68	103

Table 14.1 shows that the male respondents had a higher mean age than the female respondents. The greatest proportion of respondents was in the 35-39 age bracket. The age distribution of the participants has been compared with that of the profession as a whole [167], this is shown in Figure 14.1.

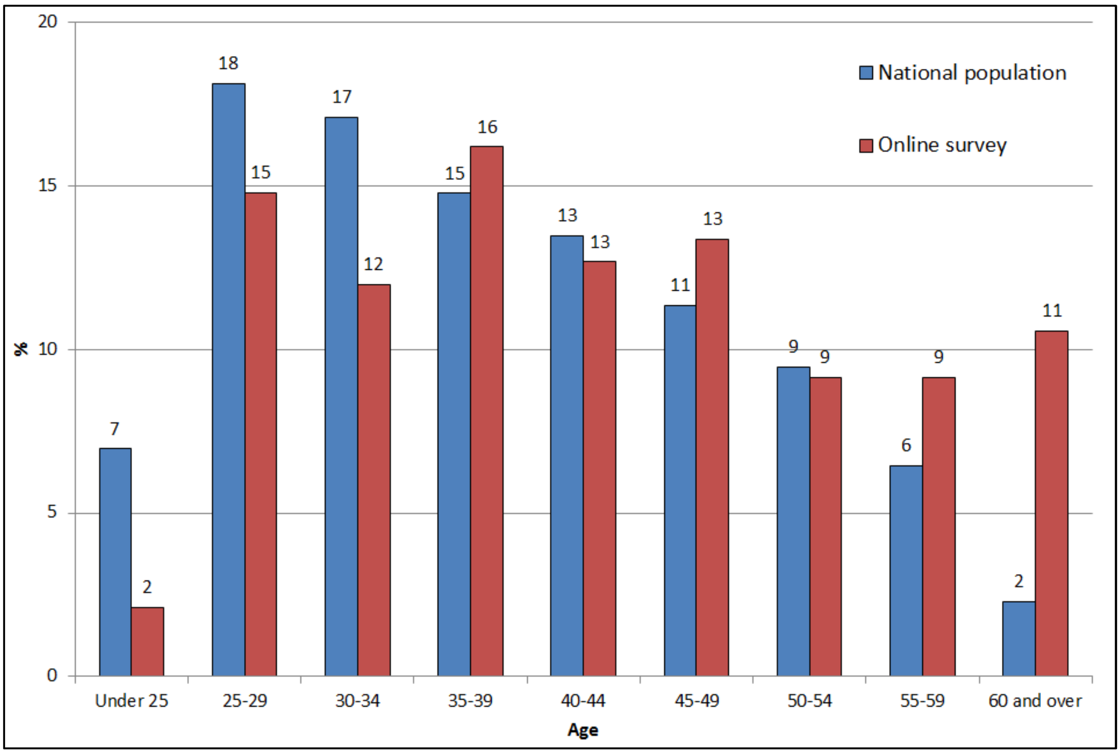


Figure 14.1: Age profile of the teaching profession and survey respondents

Nationally 25% of teachers are under 30; of the survey respondents of working age (under aged 65) 18% were under 30. 18% of the national teaching population is over 50 years of age but 23% of the working age survey respondents.

The distribution by gender and age is shown in Figure 14.2.

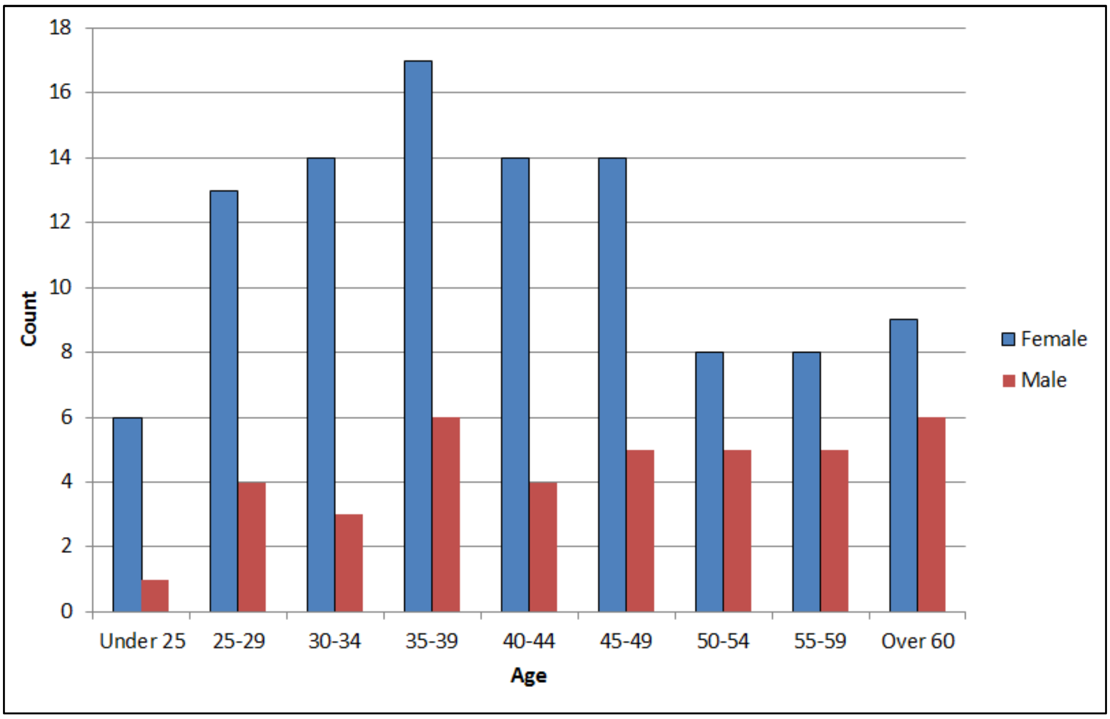


Figure 14.2: Age profile by gender

By gender the largest proportion of male respondents were in the 35-39 and over 60 age brackets, while for females the largest proportion was in the 35-39 age bracket. This means that the majority of respondents were of working age and their answers reflected current teaching conditions and experiences.

14.4.3 English as first language (Q3)

Respondents were asked if English was their first language. Of those that responded (n = 140) 99% had English as their first language. This was considered important as speech intelligibility requirements can be more onerous for non-native speakers and listeners [94].

14.4.4 Teaching status (Q4)

Respondents were asked if they were current, former or retired teachers. The valid responses (n = 139) are detailed in Figure 14.3.

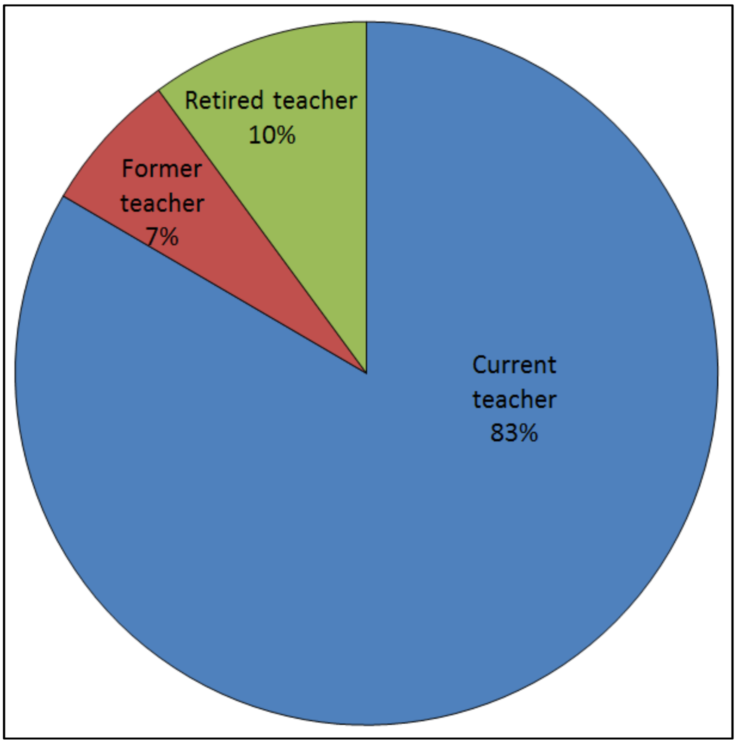


Figure 14.3: Employment status

The majority of respondents were teaching at the time of the survey, meaning that primarily the data gathered related to contemporary school conditions and pedagogy.

14.4.5 Length of teaching career (Q5)

Respondents were asked how many years they had been teaching. The valid responses (*n* = 140) are shown in Figure 14.4.

There was a range of experience levels ranging from newly qualified teachers to those with more than 25 years of teaching. In terms of voice problems this had the potential to include those who had experienced the initial demands of teaching on the voice in the early stages of their careers, as well as those who may have experienced voice problems due to the cumulative effects of long term voice loading.

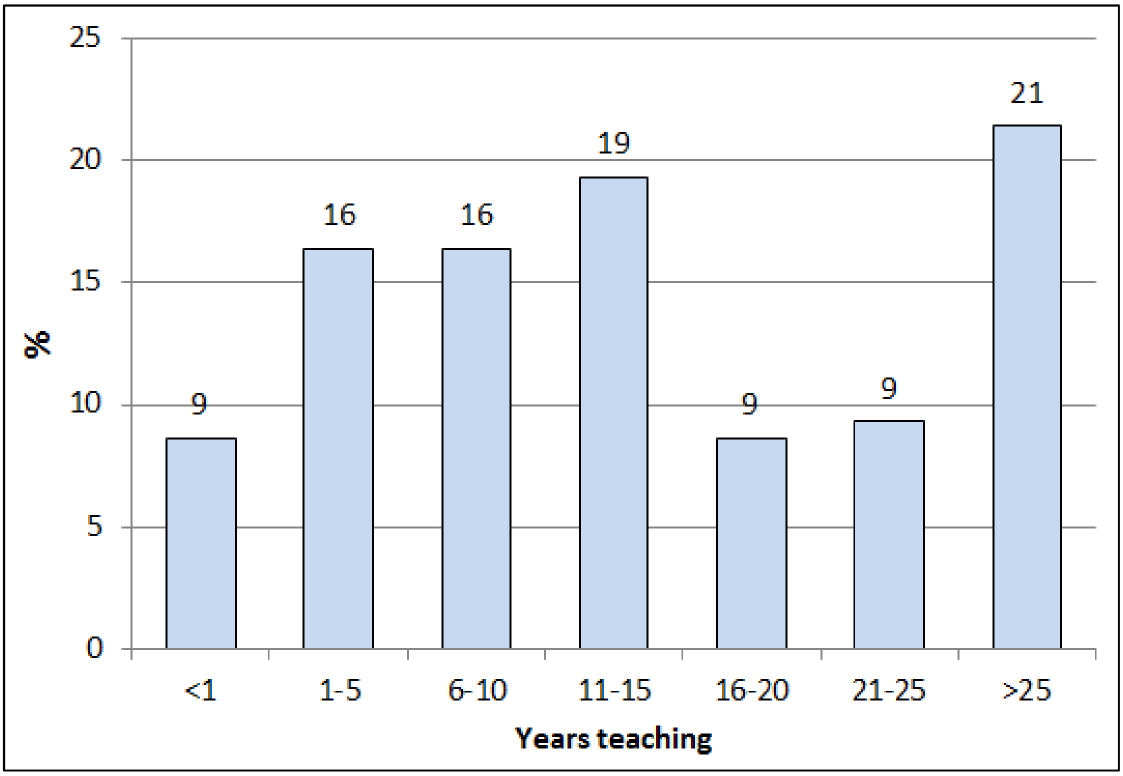


Figure 14.4: Number of years teaching

14.4.6 Location (Q6)

Of the valid responses (*n* = 141) 97% taught in England. This was relevant to the voice measurements in Chapter 9 and the guidance and legislation reviewed in Chapter 5 related to England. The results are summarised in Figure 14.5.

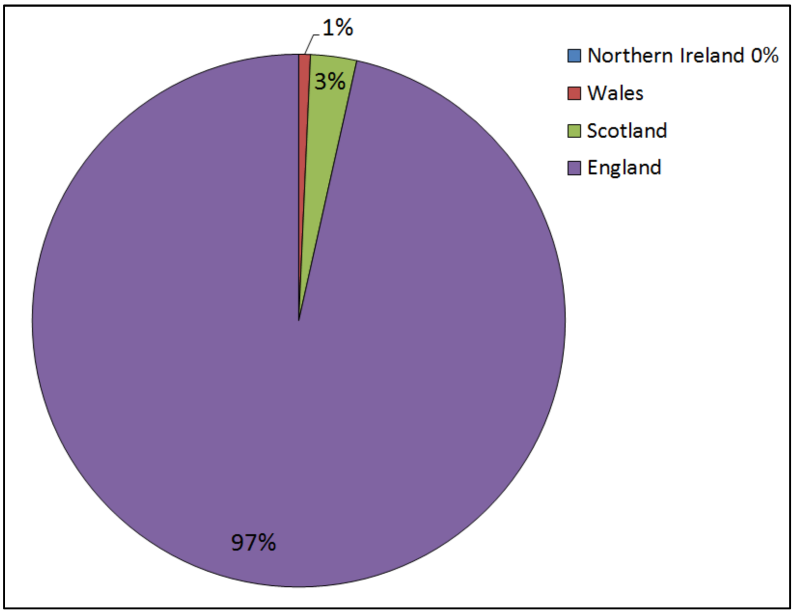


Figure 14.5: Location of teaching

14.4.7 Type of teaching (Q7)

Participants were asked what type of teaching they did. The valid responses (*n* = 143) are shown in Figure 14.6.

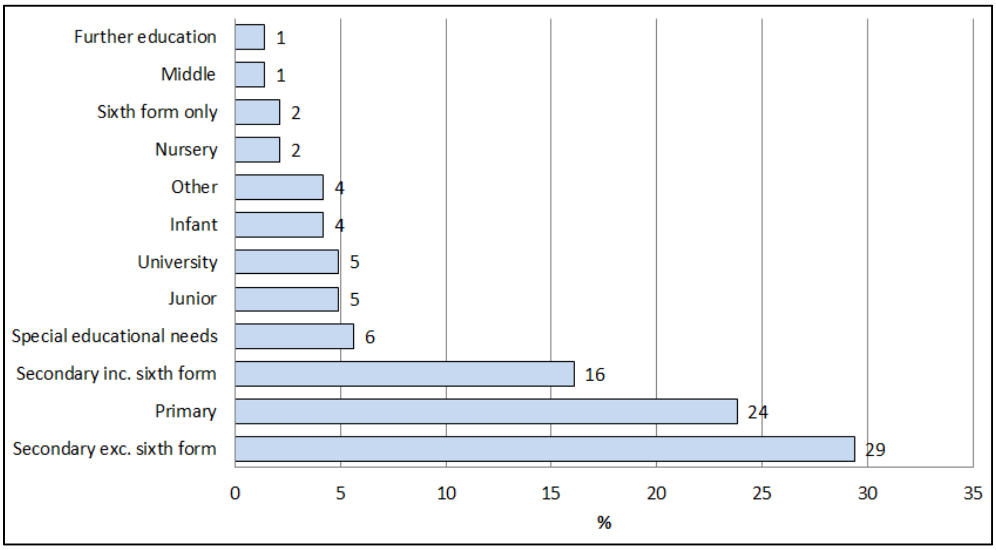


Figure 14.6: Teaching type

Of the respondents 24% taught in primary schools and 45% taught in secondary schools (with and without sixth forms). This is relevant to this project as a whole as the focus has been on building types for which there are mandatory acoustic requirements (i.e. schools). The relatively small number of respondents from the other groups meant that valid statistical analyses could not be carried out on those groups.

14.4.8 Subject taught (Q8)

Respondents were asked the main subject they taught. The valid responses (*n* = 139) are shown in Figure 14.7.

A majority of the respondents taught in primary schools and therefore taught all subjects. There were relatively small numbers among those who taught specific subjects which meant it was not possible to analyse other factors based on the subjects taught.

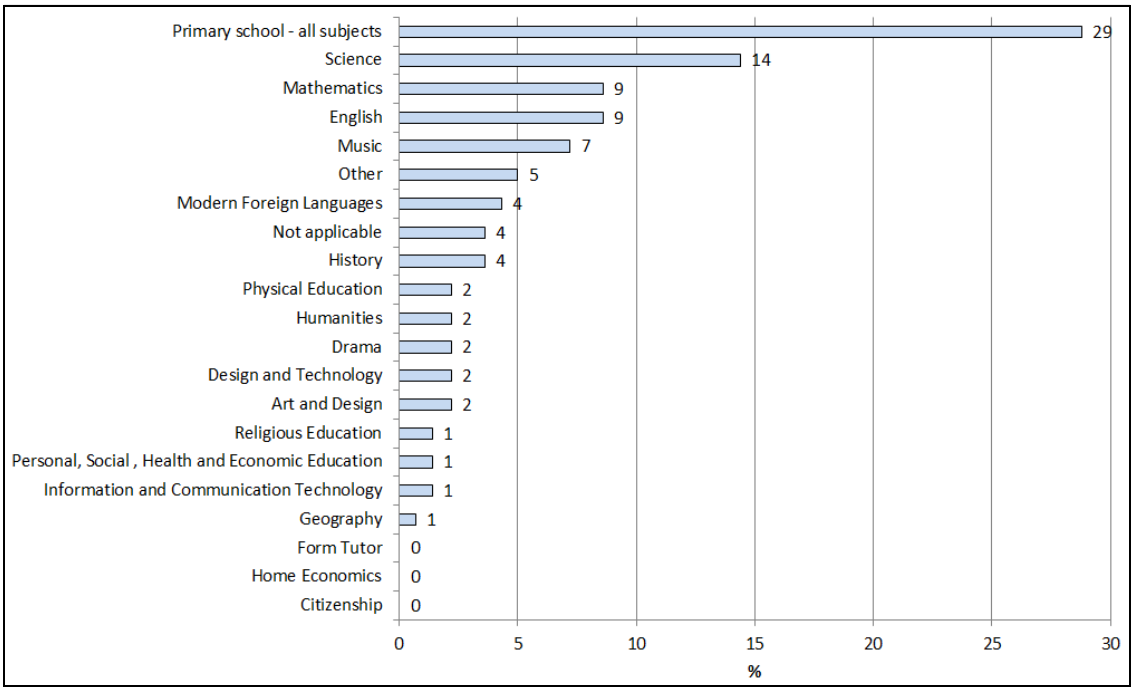


Figure 14.7: Subject taught

14.4.9 Private or state sector (Q9, Q10)

There were 138 valid responses, 95% of respondents worked in the state sector with 5% in the private sector. This aligns with the voice measurements detailed in Chapter 9 which were undertaken in state schools.

Those respondents in the state sector were asked about the status of their schools. The results are summarised in Figure 14.8 for the valid responses (*n* = 131). The majority were local authority schools, with a smaller proportion being academy-status schools. There were 1% of respondents who taught in free schools. The 'other' category answers included Church of England and voluntary aided schools.

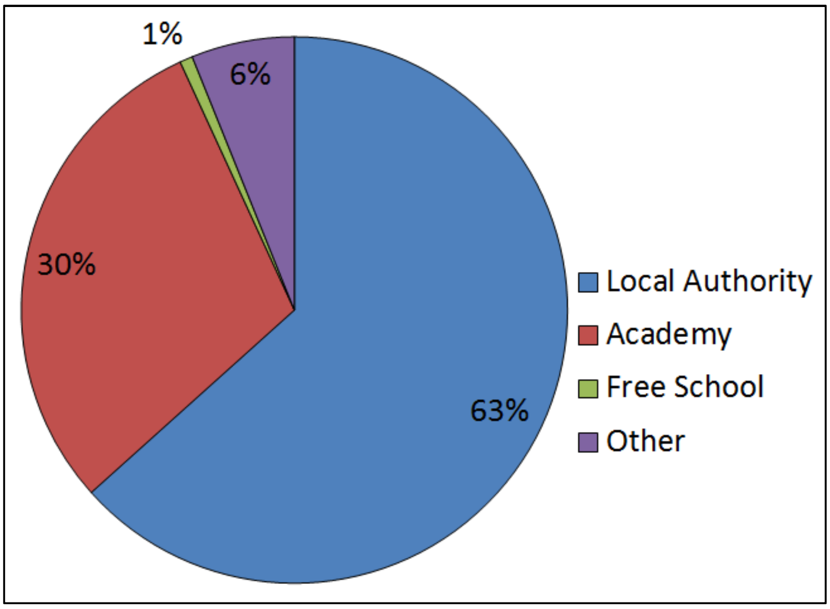


Figure 14.8: Status of state sector schools

14.5 Classroom details

14.5.1 Classroom layout (Q11)

Respondents were asked to describe the normal layout of their classrooms. The responses from the individual respondents (*n* = 142) are summarised in Figure 14.9. Respondents were able to select multiple options on this question; therefore the percentages quoted are the proportion of respondents who selected each option.

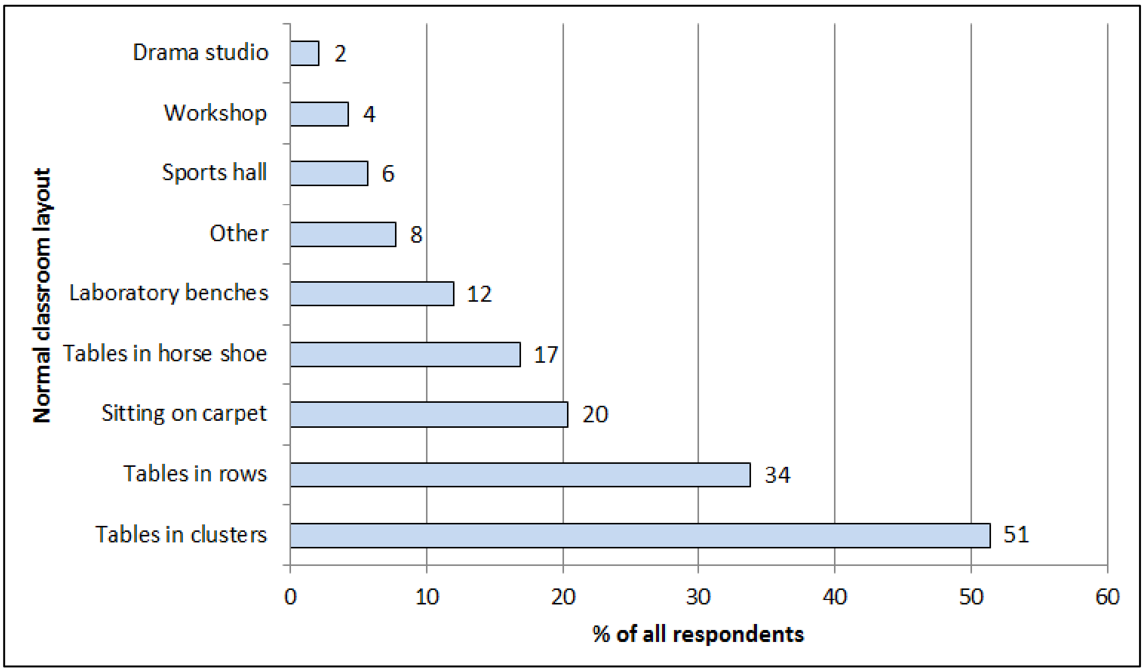


Figure 14.9: Classroom layout

The most frequent classroom arrangements were tables in clusters and rows, which indicated that the majority of pupils would be at some distance from the teacher and listening in the reverberant field. A small number taught in sports halls, workshops or drama studios which may have different acoustic conditions from typical classrooms and may place different demands on the voice as a result.

14.5.2 Period of classroom construction (Q12)

Respondents were able to select more than one answer if they taught in more than one classroom type. The percentages quoted are a proportion of the total number of valid answers (n = 167), the results are summarised in Figure 14.10.

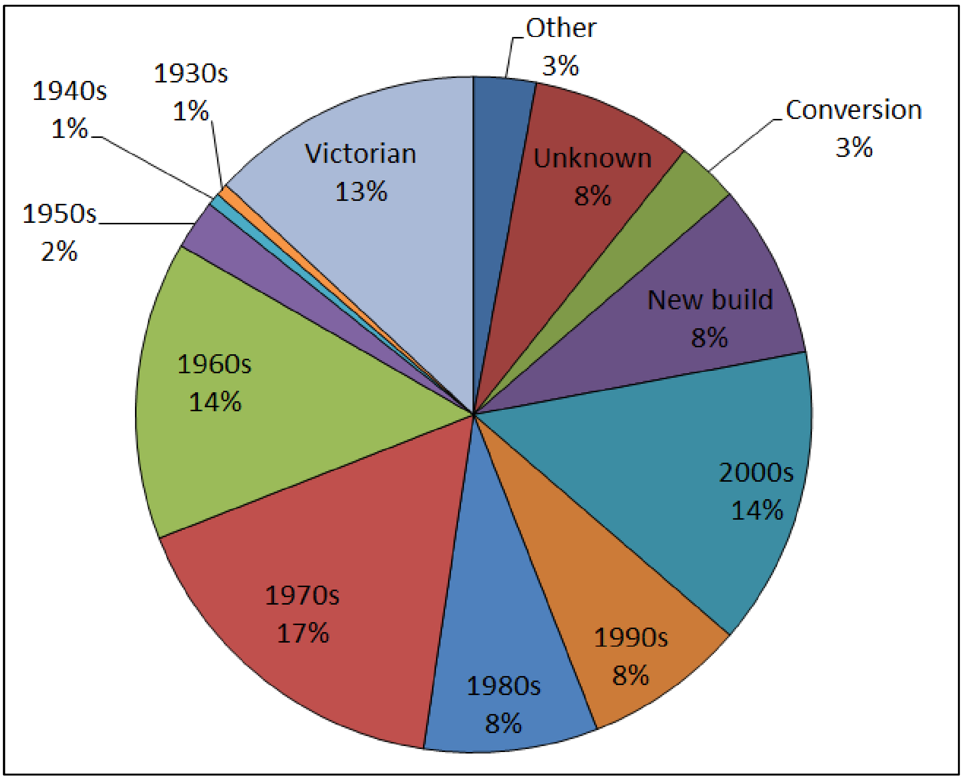


Figure 14.10: Period of classroom construction

The greatest proportion taught in 1970s era rooms. 22% of the rooms taught in were constructed in either the 2000s or more recently. Classrooms constructed from 2004 onwards would have been under the remit of BB93:2003 [121] and may be expected to have better acoustic conditions than early classrooms. The older classrooms may however have been refurbished to better acoustic standards since their initial construction, which would not be accounted for in the data.

14.5.3 Open plan spaces (Q13, Q13A)

Open plan classrooms may well present alternative voice challenges due to acoustic qualities that are different from those of enclosed classrooms. The differences are primarily noise intrusion from other teaching groups in the same space plus differing sound absorption treatments intended to reduce noise transfer within the space.

Of the valid respondents (*n* = 141), 20% taught in open plan classrooms. These respondents were then asked how many hours per week this was for. There were 22 responses to this question. The results are included in Figure 14.11. 9% of these 22 respondents (n = 2) taught in open plan spaces for more than 25 hours per week.

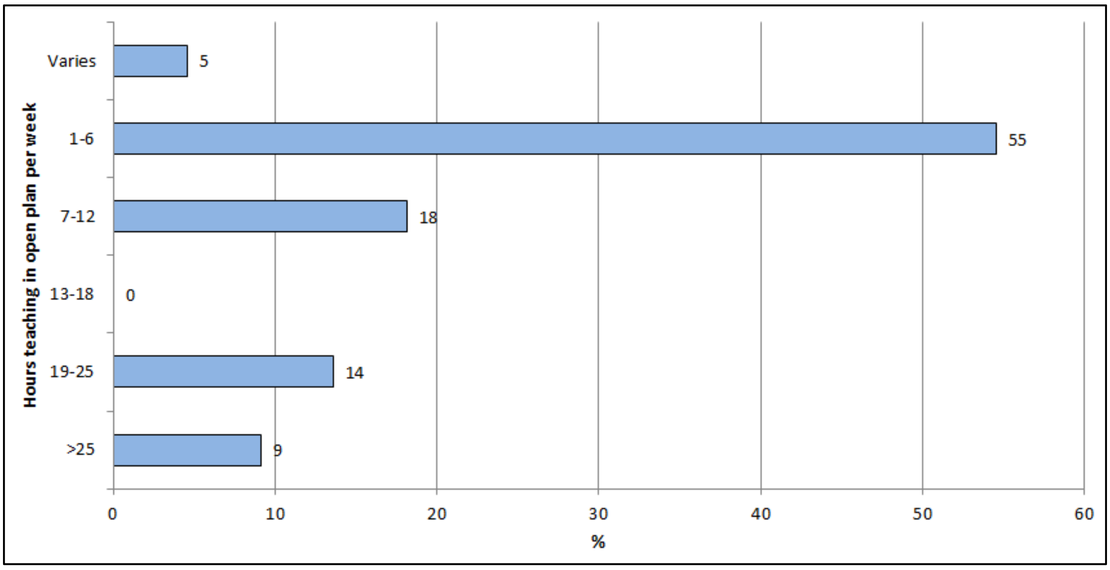


Figure 14.11: Teaching hours per week in open plan spaces

14.5.4 Class size (Q14)

Respondents were asked how many pupils were normally in their classes. The results for the valid answers (n = 139) are shown in Figure 14.12. This indicated that the majority had class sizes of 21-30 which aligns with the teachers in the voice measurements in Chapter 9 where classes were all of 33 or less pupils.

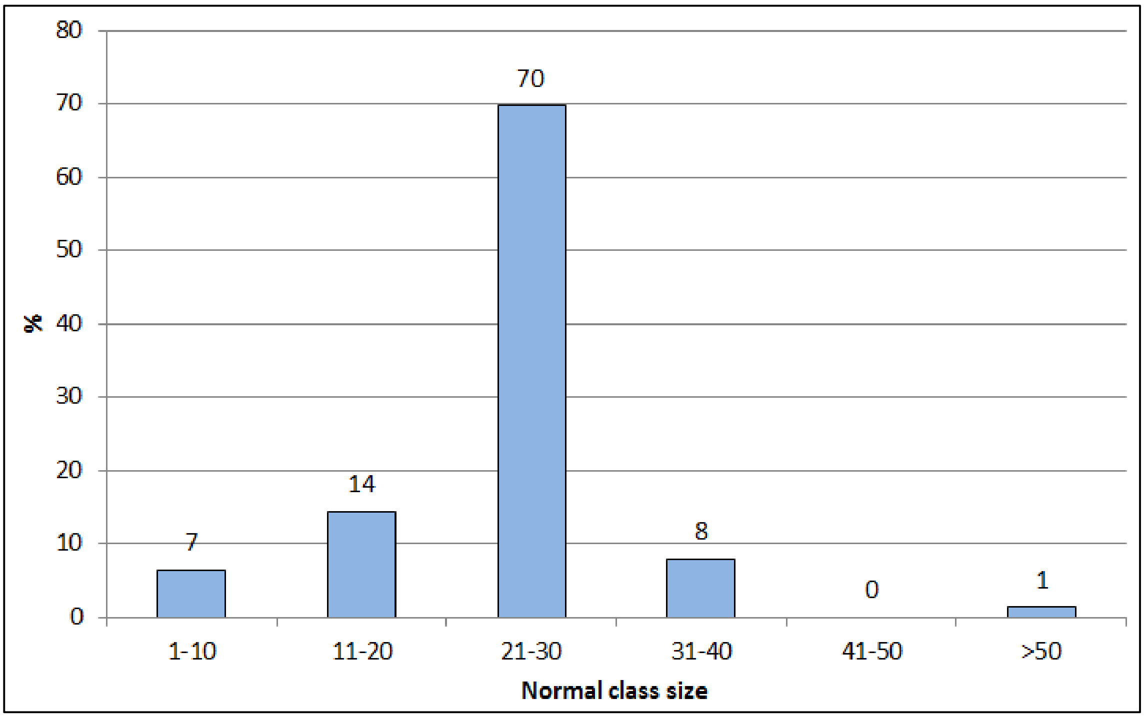


Figure 14.12: Class sizes

The teachers in the larger class sizes of 31-40 included secondary and primary. One respondent who taught in a university, taught class sizes of over 50 people. Those who taught in class sizes of 10 or less were predominantly special needs teachers.

14.5.5 Classroom finishes (Q15)

Respondents were asked to give details of the surface finishes of the walls, ceiling and floor of their normal teaching room. Multiple options could be selected to allow for a variety of finishes on one surface. The responses are summarised in Figure 14.13.

4% of the classrooms had sound absorbent wall panels, 69% had plastered walls and 32% brick or block walls. 70% had carpeted floors, 39% vinyl and 10% wood. 60% had ceiling tiles (these are assumed to be sound absorbent tiles) and 32% had plasterboard ceilings.

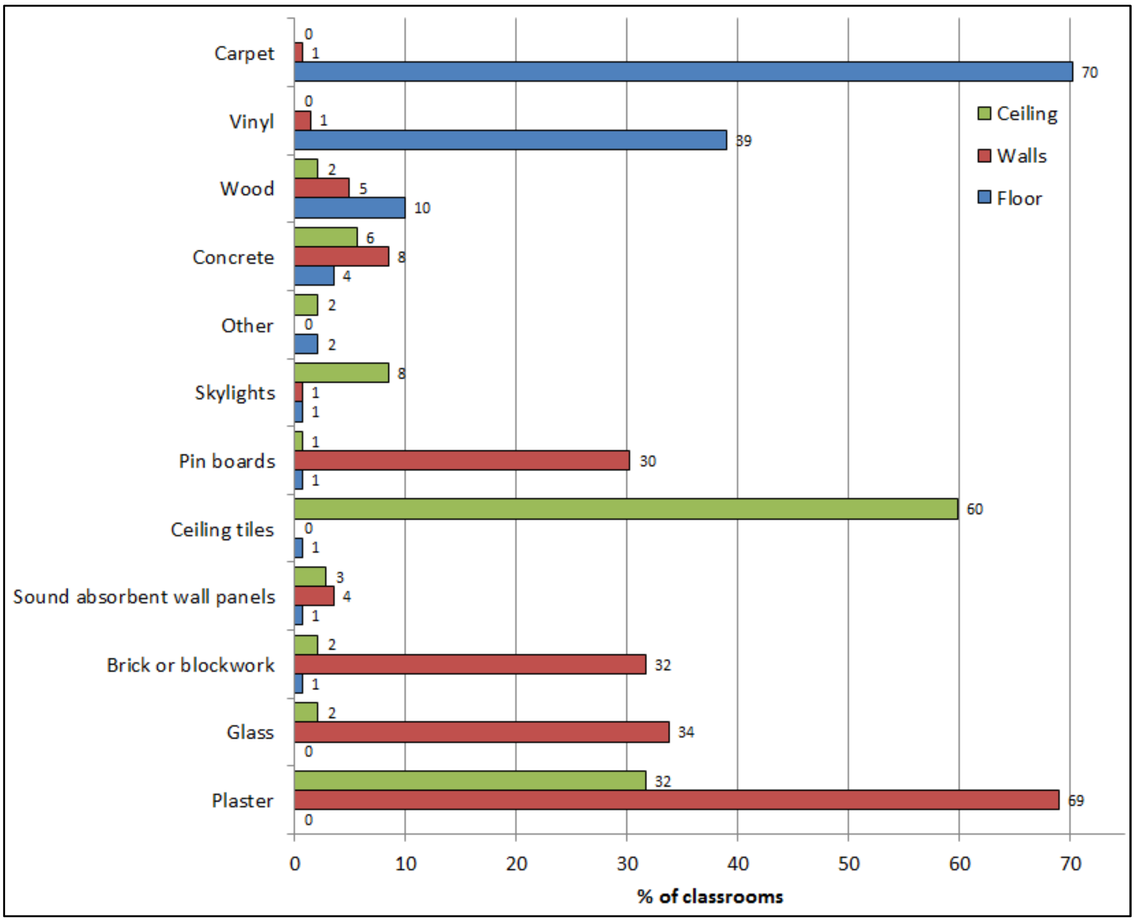


Figure 14.13: Surface materials of classroom

The presence of some form of ceiling tile in 60% of classrooms indicated a potentially significant amount of sound absorption in these rooms. This would still leave at least 40% without significant sound absorption which may mean that reverberation times would be above guidance values in these classrooms.

14.6 Voice problems

14.6.1 Experience of voice problems (Q16-Q17)

Participants were asked if they had experienced voice problems during their teaching career. There were 140 valid responses of which 66% reported having experienced voice problems.

The voice problem prevalence rate reported in this survey was higher than in those questionnaire studies by others detailed in the literature [59, 61, 62]. This could indicate a potential bias due to the recruitment method in this study. Those who are interested in voice problems due to having experienced them may respond in greater proportions than those who have not, which may make the sample unrepresentative.

If they had experienced significant voice problems, participants were asked to describe these in Q17. The answers from the respondents (n = 94) are summarised in Figure 14.14, more than one option could be selected.

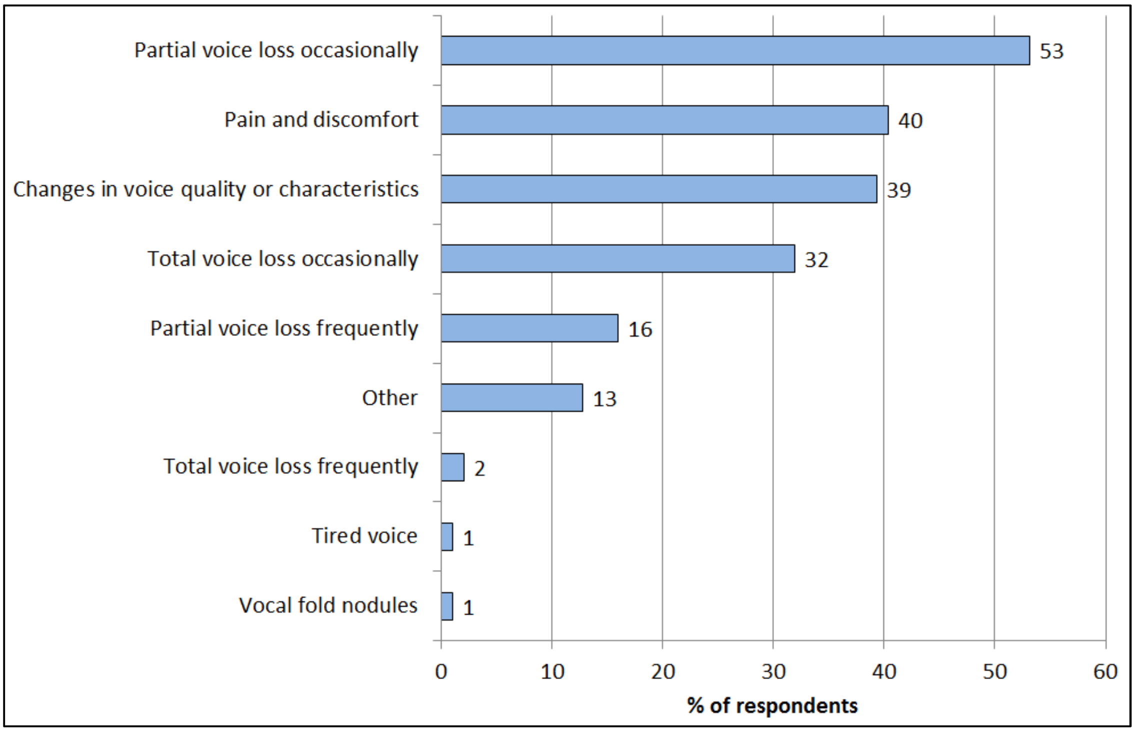


Figure 14.14: Description of voice problems

The main points from Figure 14.14 are that over 50% of respondents had experienced voice loss occasionally, though this may not be related to occupational voice use. However, 16% reported partial voice loss frequently and 2% total voice loss frequently, which would have a significant impact on the ability to teach and may indicate a pattern that differs from that of the general population. In addition 40% reported pain and discomfort, and 39% reported changes in their voice quality or characteristics which could indicate significant underlying voice issues associated with long term vocal loading (see 2.2.3).

14.6.2 Help with voice problems (Q18, 19, 20)

Respondents were asked, if they had voice problems, where they had sought help or advice. The proportion of respondents who selected each option (n = 82) is shown in Figure 14.15, respondents could select more than one answer.

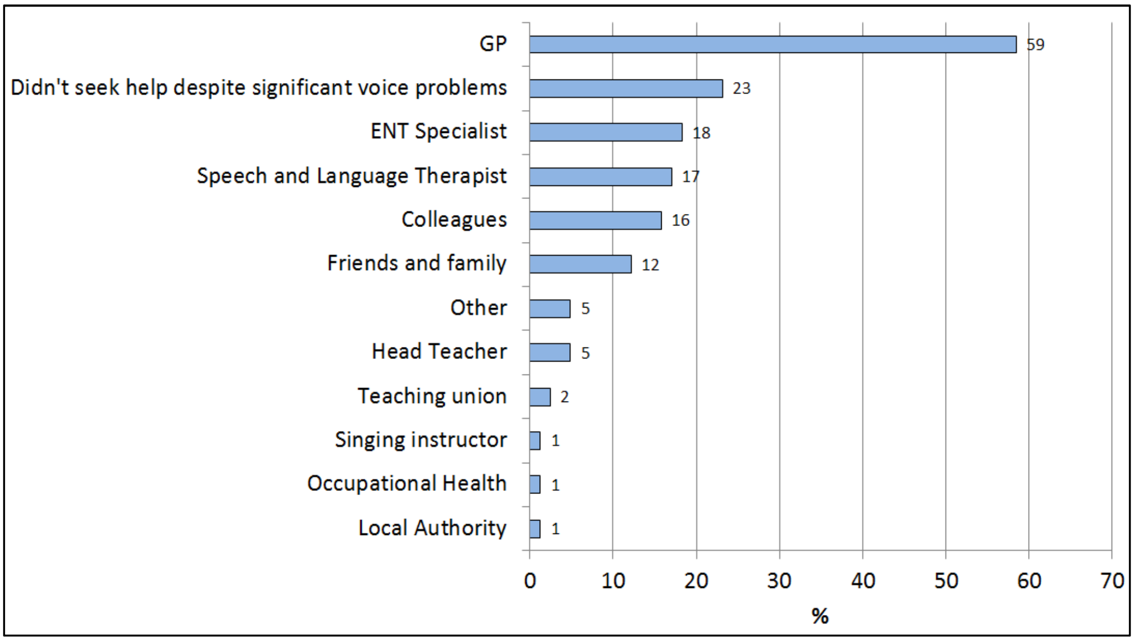


Figure 14.15: Help and advice sources for voice problems

Of those who had sought help, a significant proportion consulted a General Practitioner (59%), Ear Noise and Throat Specialist (18%) or Speech and Language Therapist (17%), all of which indicate a significant level of concern to seek such advice.

It is notable that 23% did not seek help despite significant problems which is worrying. It would not be considered sensible to continue to use (and potentially damage) other parts of the body which were injured or not functioning normally.

Respondents were asked, if they sought help, what measures, if any, were advised. The respondents (n = 60) were able to select more than one option, the percentage that selected each option is shown in Figure 14.16.

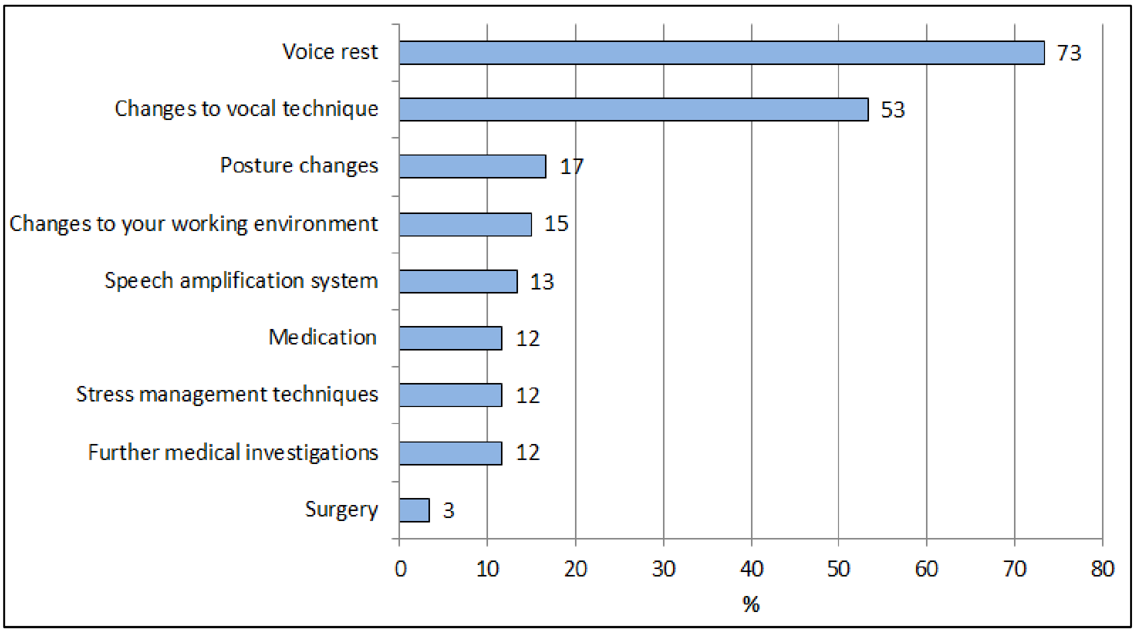


Figure 14.16: Measures advised for voice problems

In practical terms, voice rest would be difficult to achieve without absence from work. Changes to voice techniques were advised in 53% of cases, indicating that many would benefit from voice training. Although only 15% were advised to change their working environment, this may underestimate the contribution of this factor; those advising may not be best qualified to determine any contribution from acoustic factors.

Of those respondents who had followed the advice, 80% reported that this had helped with their voice problems, and 20% that it had not.

14.6.3 Variations in voice problems (Q21)

Respondents were asked, if they had voice problems, when these were most pronounced. The valid responses (n = 88) are detailed in Figure 14.17.

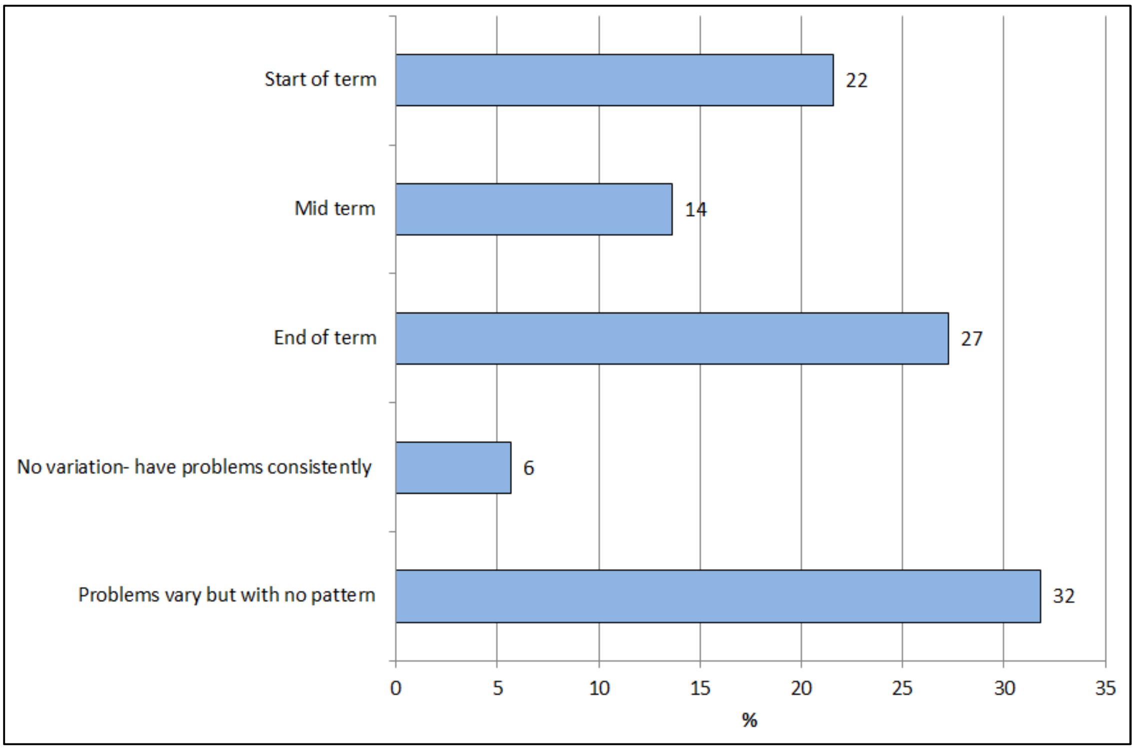


Figure 14.17: Variation of voice problems with time

The majority of respondents could not identify a pattern when their voice problems were most pronounced. Of those who did see a pattern, the problems appeared to be worst at the start and end of term. This may relate to the effects of transitioning from a 'normal' pattern of voice use during holidays to an occupational voice pattern, with the associated implications for vocal loading. The effects at the end of term may result from the cumulative, attritional effects of vocal loading over the teaching period.

14.6.4 Time off work due to voice and other health reasons (Q22, 23)

Respondents were asked how much time they had taken off during the previous two years due to voice problems. The results for the valid responses (n = 82) are shown in Figure 14.18.

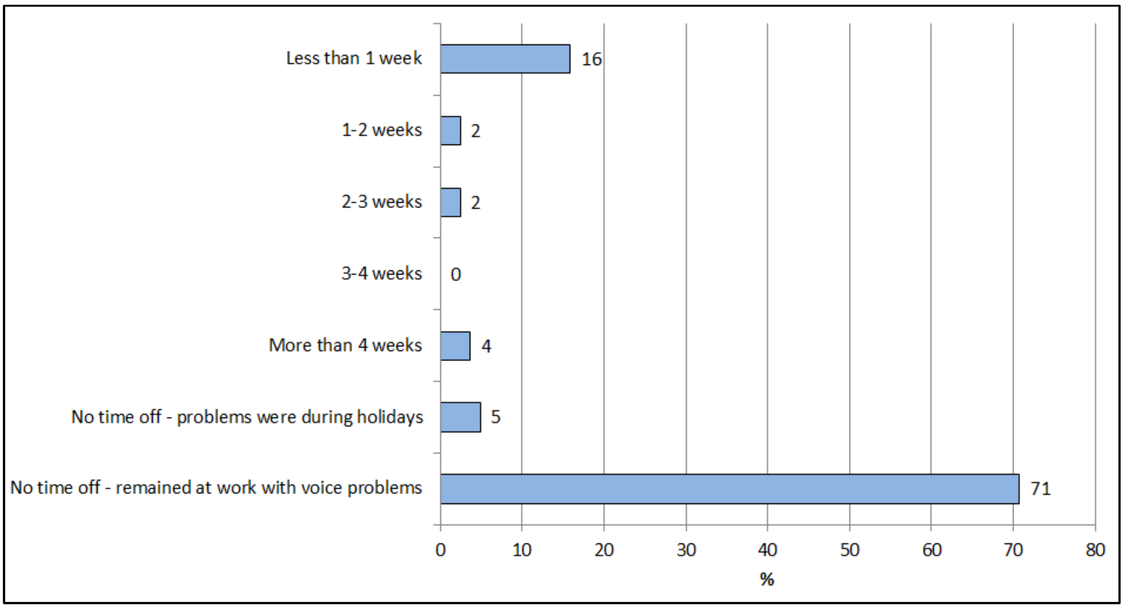


Figure 14.18: Time off work due to voice problems in the last 2 years

Of those who had time off due to voice problems, the majority were absent for periods of less than one week. This may be due to the problems being short term, or may reflect the pressure to return to work, and the lack of seriousness with which voice problems are treated by the sufferer and colleagues or managers. A small number (4%) had more than 4 weeks off indicating that these problems were significant in some cases.

Of potential concern from an occupational health point of view, 71% of those who had experienced voice problems had remained at work, continuing high vocal loading despite voice problems, which may have the potential to extend and exacerbate problems.

Respondents were also asked how much time they had had off in the previous two years for other health reasons. The valid responses (n = 113) are summarised in Figure 14.19.

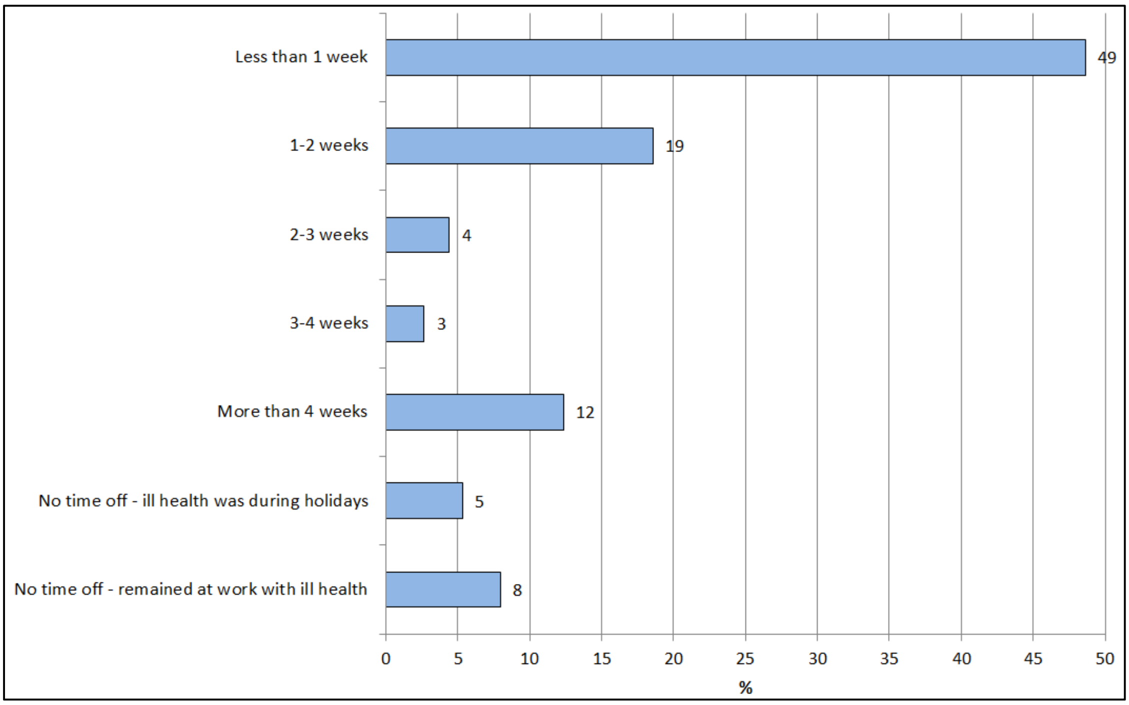


Figure 14.19: Time off work due to other health reasons in the previous 2 years

The majority that had time off work did so for less than one week indicating that these were short term problems. The percentage that remained at work with general ill health appeared significantly lower than for voice problems, perhaps reflecting the relative seriousness with which different health issues are treated.

14.6.5 Voice tiredness (Q25)

Of the valid responses (n = 140) 64% responded that their voice often felt tired at the end of the day. This may suggest that, even after many years of teaching experience, the voice cannot adapt to the demands and may suffer from attritional effects from sustained vocal loading.

14.6.6 Voice training (Q26, 26a, 27)

Participants were asked about their experience of voice training. Of the valid responses (n = 141) 59% had never received any voice training. Of those who had received training, participants were asked about the frequency and nature of the training. The valid responses (n = 53) are summarised in Figure 14.20.

Figure 14.20: Voice training type

Given what would seem to be the inherent risks to the voice from teaching at high voice levels for long durations, this dearth of training is surprising and troublesome. The potential economic, social and personal costs related to voice problems in teachers have been discussed in section 3.4. The provision of voice training for all as a precaution would seem to be an obvious, prudent measure that should be adopted universally for many reasons.

It is also surprising from a health and safety perspective (see Chapter 5) that educational bodies do not provide this as a method of demonstrating that they are meeting their statutory obligations in a straightforward manner. Instead there seems to be a reliance on personal, piecemeal, reactive responses with no overall consistency.

The results in Figure 14.20 indicate that voice training provision is poor. Only 41% of respondents had received any voice training, and of these the majority (53%) had received only a single session. The majority of the remaining respondents had arranged their own training.

Participants were asked if they felt that voice training should be included in all teacher training courses, 93% agreed, which indicated strong support for this approach among the survey respondents.

14.6.7 Voice training (Q28)

In question 28, respondents were asked if they had any further experiences or comments on voice problems or voice training.

Selections of the comments are included below:

‘There is a macho attitude to voice use in schools and teachers believe that they mustn't make a fuss. [There is a] Culture of just putting up with it and that it doesn't really matter anyway. I was teased by colleagues for using [a] voice amplification system’.

‘Your voice is your most important tool; you need to know how to use it effectively and how to protect it’.

‘All teachers should have regular voice training offered. Music departments need to be proactive in supporting and protecting their employees’ voices. It needs to be taken much more seriously!’

‘Voice problems are not treated seriously enough by the profession. Although 'voice rest' was advised by my doctor/specialist, this was impossible….ultimately, my voice appears to be permanently damaged. As a singer, and music, dance and drama teacher, this has been very difficult to cope with’.

‘Most school days I lost my voice totally (apart from a whisper) at lunchtime’.

‘I believe training is less needed working with younger children as you are in smaller groups & need to use your voice less. In older [age group], bigger classes my voice can sometimes not be heard very clearly and can feel strained’.

‘We had it [voice technique] mentioned a little on our PGCE and I think that this is important. More would be good though as I have drawn on personal experience of singing to help’.

‘Effective classroom management has helped enormously with voice problems’.

‘I often experience problems at the start of term when my voice needs to adapt to be used every day. Throat infections can be more prolonged due to the need to use the voice continuously’.

‘Some working days are excessively long e.g. 8 am start then teaching all day, then parents’ evenings / open evenings until 9 pm. This is a very long time to be using your voice’.

‘I have no idea when or how the problem started but the voice I have now is entirely different to the one I started with’.

‘I have training in acting so this is of great help with voice projection without strain’.

‘I always lose my voice in September’.

‘I know a lot of teachers during their NQT year lost [their voices] or had voice problems’.

‘It would be helpful for TAs [teaching assistants] to receive voice training also as they often cover classes and interventions in larger rooms’.

‘I was disappointed by the lack of training in this area’.

The free comments section provided a poignant insight into the first-hand experiences of teachers and highlighted the human dimension to voice problems which can sometimes be lost when the issues are looked at in a purely objective way. A number of common strands emerged:

The central role of the voice as the most important tool in teaching was emphasised, as well as the need for voice training for both teachers and teaching assistants. There was a sense that neither schools nor colleagues were taking the issues seriously. One respondent described being teased by colleagues for needing to use a voice amplification system. If voice amplification systems were to be substituted in that context for hearing aids or a wheelchair, the perception may be very different and perhaps the teasing behaviour would be considered bullying or discrimination.

There appears to be a section of society, including within the teaching community, which diminishes and trivialises voice issues, perceiving speaking as part of the job and considering that those who have voice problems should accept them or leave the profession. If occupational voice problems were substituted for hearing loss in factory worker, asbestosis in builders or musculoskeletal conditions in occupations with manual handling, this view would seem out of kilter with how society views these other risks.

One respondent mentioned being advised to rest their voice as a measure to counter voice problems and commented how unrealistic this was when continuing to teach.

Two distinct patterns of voice problems seemed to be referenced: firstly voice problems related to vocal loading manifesting at the start of term, or in response to long phonation times (such as a school day followed by a parents' evening), and secondly, permanent negative voice changes and apparent damage due to occupational use.

The responses to this question indicate that for the respondents voice problems are a significant issue which cannot be solved on an individual, unilateral basis as they result from some of the intrinsic demands of the teacher's role. The impression is that once voice problems are serious enough to be disruptive then irreversible changes may have already taken place. This emphasises the need for voice training as a preventative measure and for reducing other risk factors, such as those associated with the working environment, as far as possible.

14.7 Classroom acoustics

14.7.1 Problems being heard (Q29)

Participants were asked if there were rooms in their current or previous workplaces in which it was difficult to make themselves heard. This question was intended to identify experiences of adverse acoustic conditions.

57% (valid responses *n* = 136) reported that there were such rooms in their current workplace and 57% (valid responses n = 114) reported that this was the case in their former workplaces.

Respondents were asked what they thought the reason for this was. The valid responses (n = 92) are summarised in Figure 14.21. Respondents could select more than one option as appropriate therefore the quoted percentages are the proportion of respondents selecting each option.

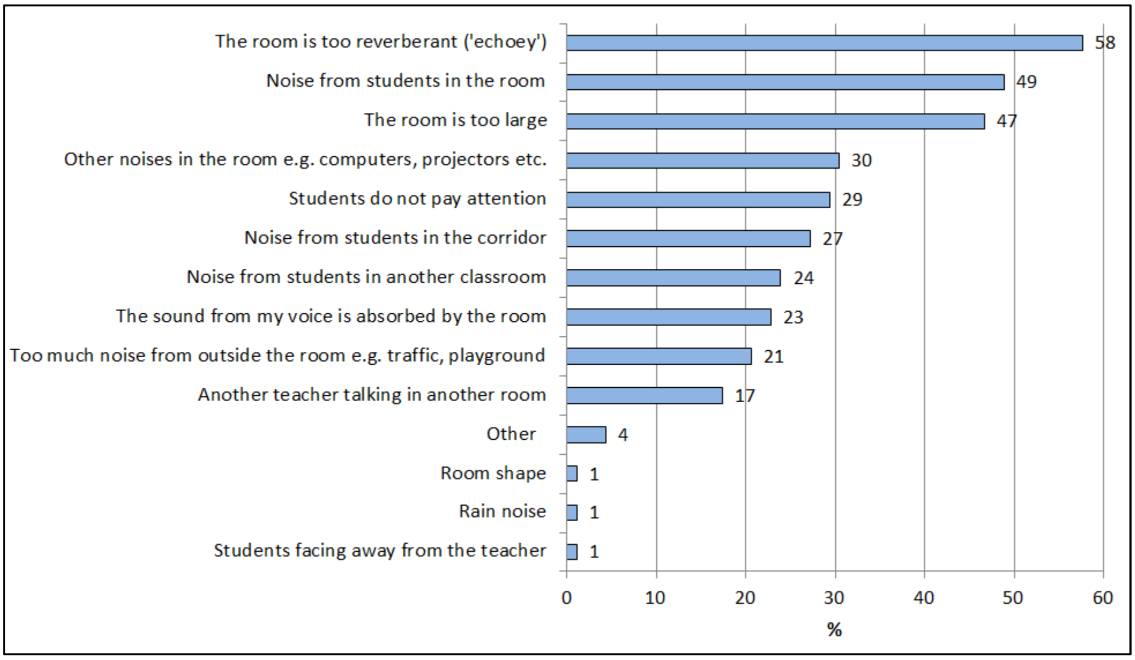


Figure 14.21: Reasons for difficulty being heard in rooms

Of those who gave further information, 58% considered that this was due to the room being too reverberant, with 23% considering the problems were due to the room absorbing too much sound from their voice. This indicates that a large proportion of respondents taught in rooms without sufficient sound absorption, whereas a smaller number may have had too much sound absorption or insufficient early reflections to gauge their voice level and get voice support from the room.

When asked about internal noise levels affecting their voice in the classroom, the primary difficulty was perceived to be caused by internally generated noise in terms of noise from pupils in the same classroom (49%), pupils in the corridors (27%) and in other classrooms (24%) or classroom equipment such as projectors (30%).

The disturbance from noise elsewhere in the buildings indicates potentially poor internal sound insulation of walls, floors and doors. The perceived high noise level of sources within the classroom itself may also be related to long reverberation times increasing the noise of internal sources. There may also be variation due to the pedagogy affecting activity noise levels or in equipment selections such as video projectors or similar.

In relation to externally generated noise, both in terms of activity noise from the school itself and underlying ambient noise sources such as traffic, neither type were perceived as a reason for not being heard. It is possible however, based on the indications in Chapter 12, that these factors influence voice parameters on a subconscious level which the participants may not be aware of.

14.7.2 Acceptability ratings of different noise sources in classrooms (Q32)

Respondents were asked to rate the acceptability of noise in their main teaching classroom from different sources separately. For each source the following rating could be selected:

- Too high constantly.
- Too high at times.
- Acceptable.
- Don’t notice.

The percentage of valid responses for each noise source are shown in Figure 14.22.

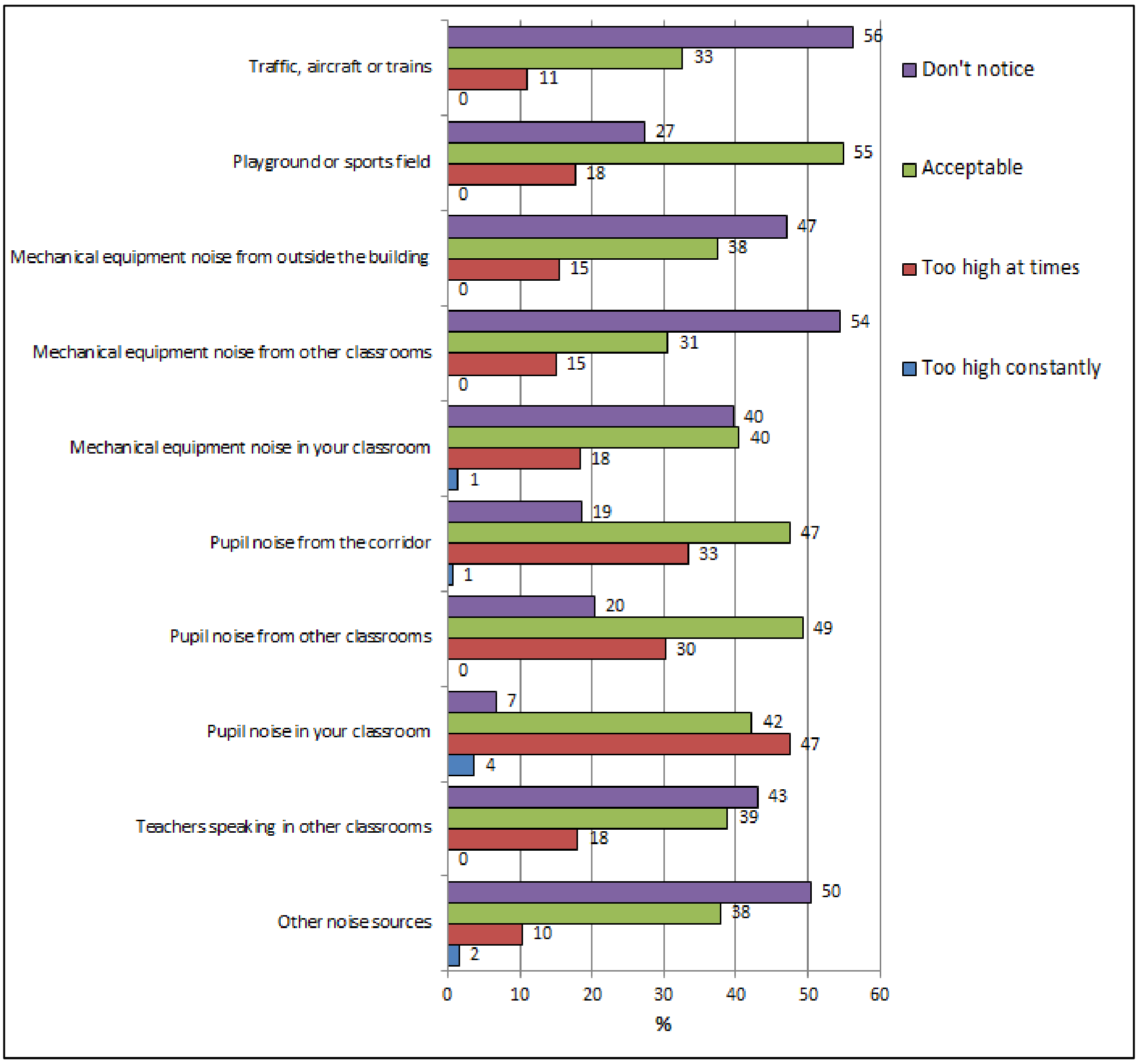


Figure 14.22: Acceptability of different noise sources in main teaching rooms

Very few respondents reported sources that were too high constantly. A significant proportion reported pupil noise in their classrooms, other classrooms or corridors to be too high at times. This may indicate issues with internal sound insulation as per question 29. Other sources were rated significantly better in terms of acceptability.

It is notable that underlying ambient noise sources (such as traffic) were either not noticed or acceptable to 89% of respondents which indicates that subjectively these sources were not an issue. As suggested by the data in Chapter 12 participants may still be affected by these sources on a subconscious level without being aware.

14.7.3 Effect of teaching rooms on voice sound (Q33)

Respondents were asked how their main teaching room made their own voice sound. The valid responses (n = 138) are summarised in Figure 14.23. Respondents could select more than one answer.

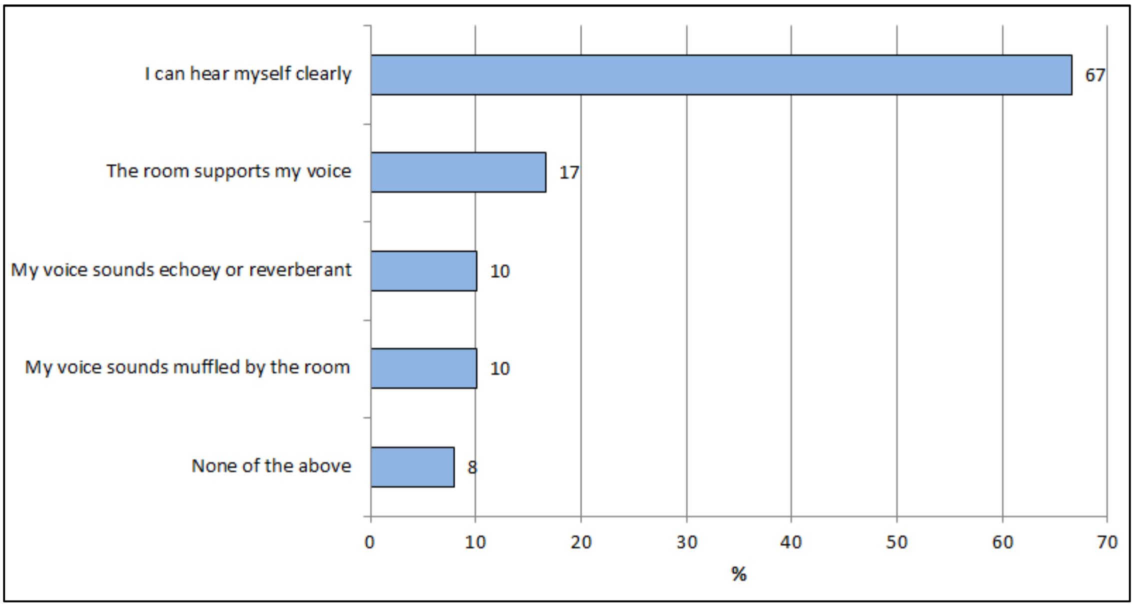


Figure 14.23: Sound of respondents' voices in their teaching rooms

The majority of respondents stated that they could hear themselves clearly in their classroom (67%), with a further 17% reporting that their classroom supported their voice.

One in ten respondents reported that their classroom made their voice sound reverberant and the same proportion that their voice sounded muffled. This indicated that acoustic conditions were not well suited to speech for 20% of the respondents.

14.7.4 Strategies for being heard (Q34)

Respondents were asked, if they had difficult speaking or being heard, what strategies they used. The valid responses (n = 138) are summarised in Figure 14.24. Respondents could select more than one answer.

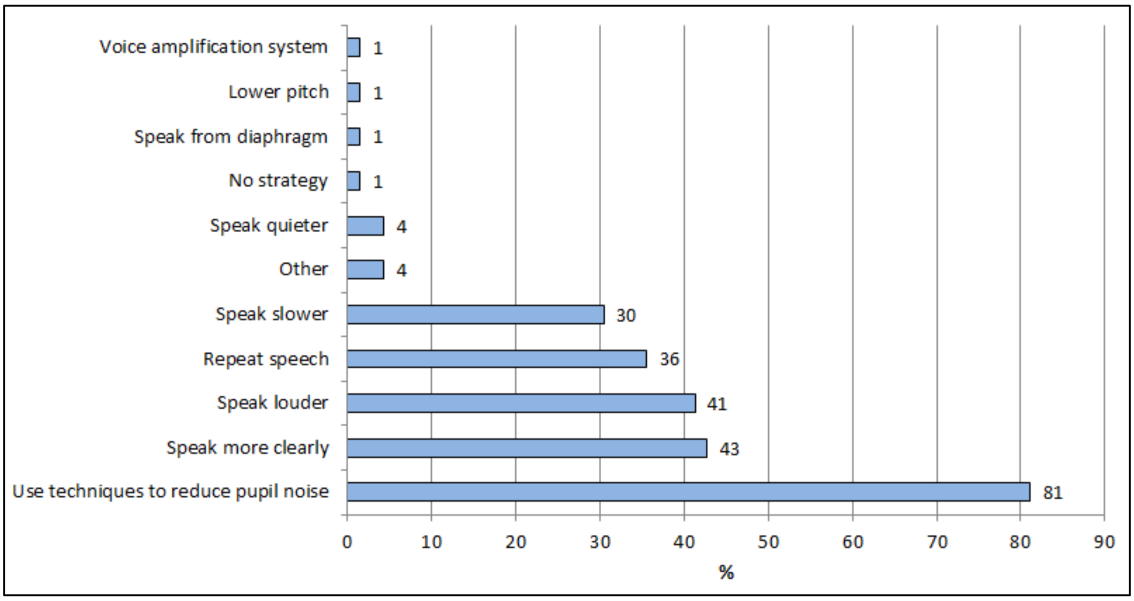


Figure 14.24: Strategies used when there is difficulty speaking or being heard

The most frequent answer was to use techniques to reduce pupil noise, which are assumed to include pedagogical methods. 41% reported speaking louder and 43% speaking more clearly to compensate; both of these responses would require changes to the natural speaking style and may have consequences for voice loading. It was noted that only 1% had used voice amplification systems as a strategy.

14.7.5 Voice use (Q35)

Respondents were asked if they frequently used their voice in particular ways. Respondents could select multiple options; the percentages shown in the summary in Figure 14.25 are the proportion of respondents (n = 121) that selected each option.

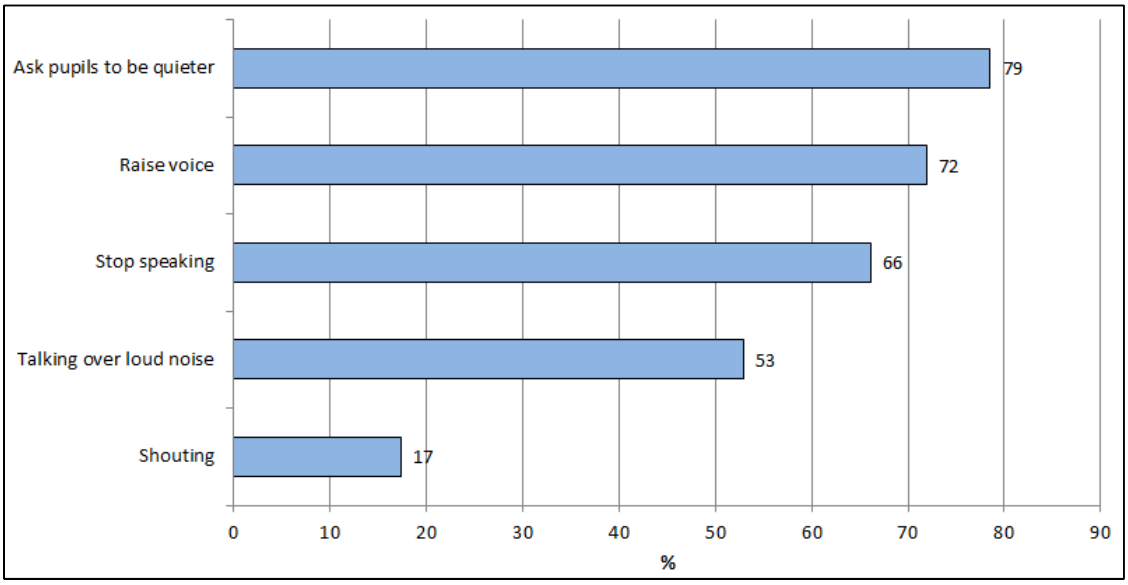


Figure 14.25: Voice use patterns

72% of respondents reported raising their voice and 17% shouting frequently, which indicated potentially harmful patterns of voice use. 53% found that they had to talk over loud noise (the noise type was not specified). There were also pedagogical approaches in terms of asking pupils to be quieter and stopping speaking (presumably to prompt a change in pupil behaviour).

14.8 Implications of voice problems

14.8.1 Significance of voice problems for teachers (Q36)

Question 36 asked if the respondents felt that voice problems were a significant issue for teachers.

Of the valid responses (*n* = 139) a majority of 78% considered that voice problems were significant, although the sample may not be representative of the wider teacher population.

14.8.2 Retirement or career change related to voice problems (Q37)

Respondents were asked whether voice problems had contributed to their stopping teaching if they were a former or retired teacher.

There were twenty valid responses of which 3% reported that voice problems had been a contributing factor. These consisted of two retired teachers and one former teacher. These respondents gave further details which are provided below:

'I sing and perform. It is impossible to do this and teach classroom children in the daytime'. – Former teacher.

'Early retirement awarded on recommendation of ENT specialist'. – Retired teacher.

'I developed dysphonia and industrial asthma at my last place of work'. – Retired teacher.

These three responses indicated that voice problems were a factor in some individuals stopping teaching. Further research would be needed to explore the extent of this in the wider teaching population.

14.8.3 Voice amplification systems (Q39, 40, 41)

Respondents were asked if they had used a voice reinforcement system in the classroom. Of the valid responses (n = 136) 13% had used a voice reinforcement system.

Given the number of respondents who reported having to speak louder or shout in questions 34 and 35, more individuals may benefit from the use of voice amplification systems. However these systems may actually decrease intelligibility as shown by Backus *et al.* [168] in rooms with long reverberation times (see section 6.3) or other unsuitable acoustic qualities. Given the extent of such room acoustics issues reported in question 29, these would also need to be addressed if amplification systems were to be used effectively.

Question 40 asked, if respondents had used a voice amplification system, whether this helped to reduce their voice problems. The valid responses (*n* = 17) are summarised in Figure 14.26.

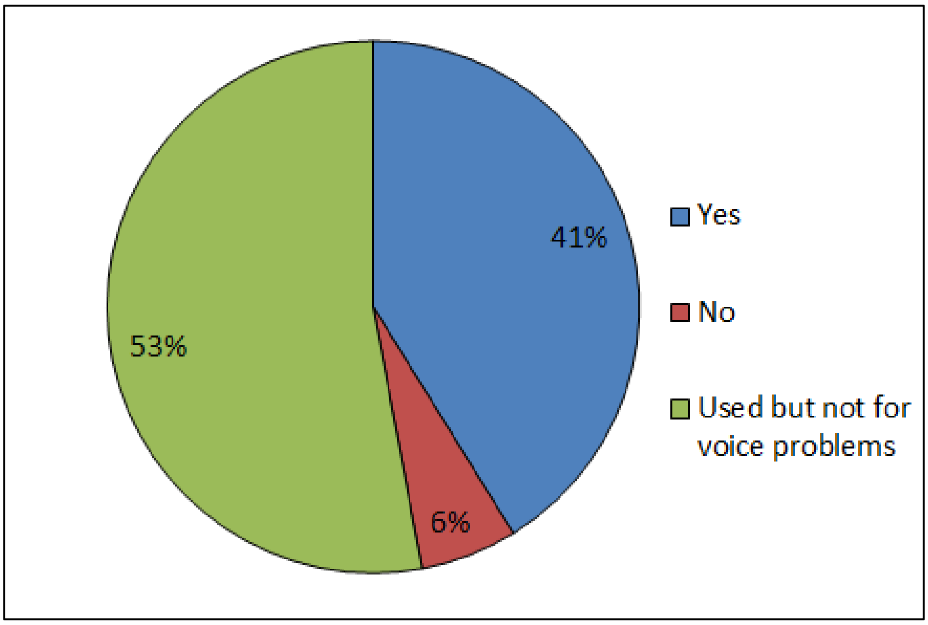


Figure 14.26: Reduced voice problems with voice amplification

Figure 14.26 indicates that the majority of those who used voice amplification systems found this helped.

Those respondents who had used speech reinforcement systems (*n* = 17) were asked (Q41) if they had received any training on these. The valid results (*n* = 17) are summarised in Figure 14.27.

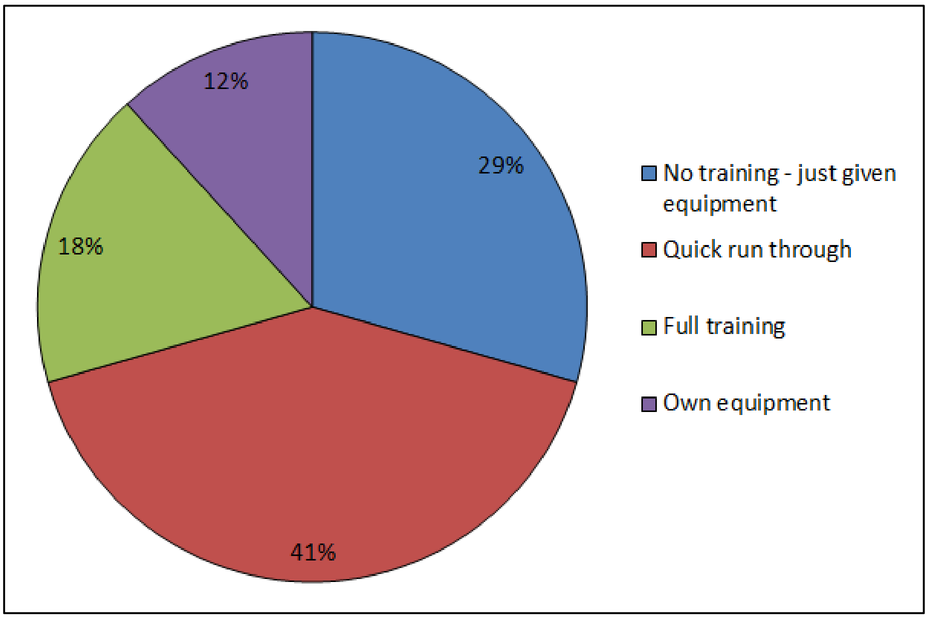


Figure 14.27: Voice amplification system training

This emphasises the importance of proper training. If voice amplification systems are to be effective, then those using them must be confident in their operation to ensure that they are used well over the long term. Almost one third of the respondents had received no instruction, and only one in five had full training. A lack of instruction may reinforce a perception that voice amplification systems are not effective due to bad experiences with their use.

14.9 Hearing and other health issues

14.9.1 Hearing loss (Q42-45)

Respondents were asked if they had any hearing loss (Q42). Of the responses (*n* = 137) 16% reported some hearing loss. Those respondents who had some hearing loss were asked (Q43) about hearing aid use. The valid responses (*n* = 20) are summarised in Figure 14.28.

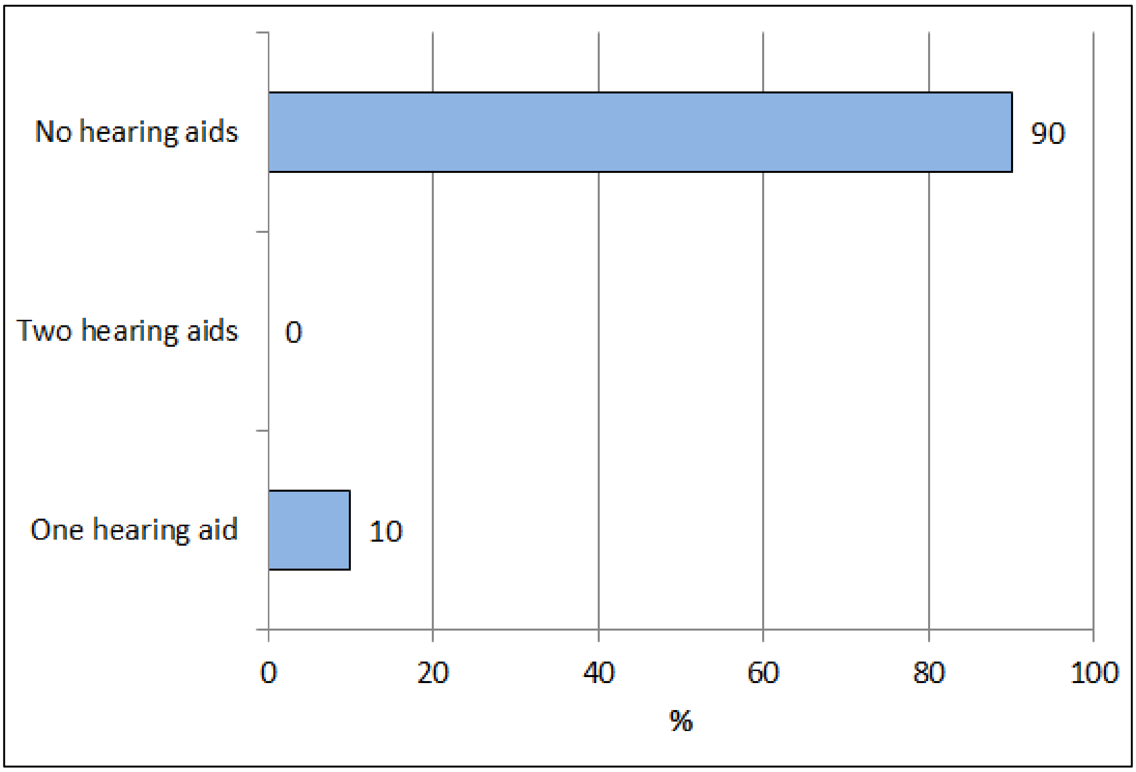


Figure 14.28: Hearing aid use in those with hearing loss

Respondents with hearing loss were asked (Q44) if they found some teaching rooms more difficult to hear in than others. For the valid responses (n = 20) 40% said yes and 60% no.

Respondents with hearing loss were asked if they believed this was made worse by teaching (Q45). The valid responses (n = 20) are summarised in Figure 14.29.

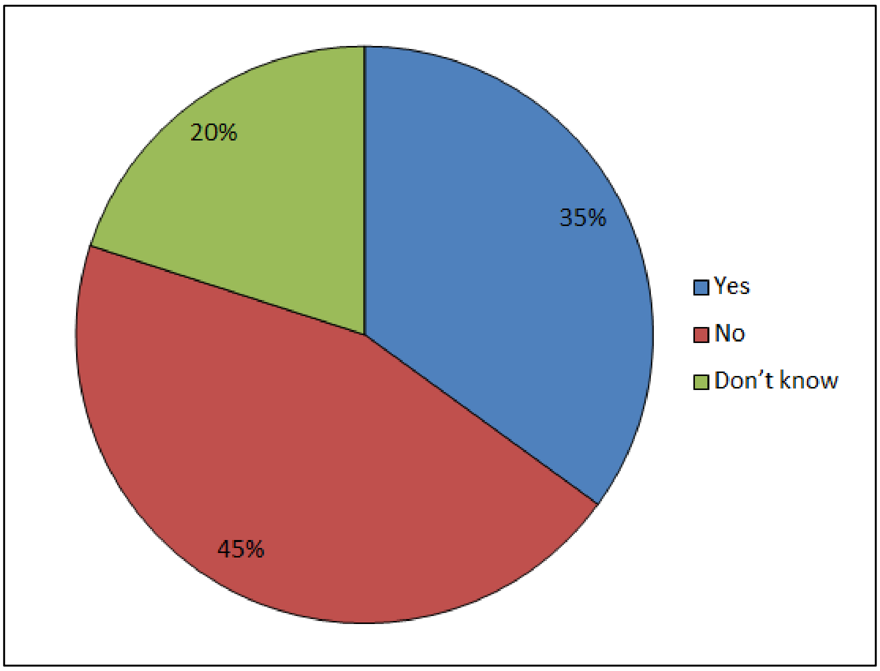


Figure 14.29: Hearing loss made worse by teaching

This indicates that a small number of respondents experienced hearing loss but the majority did not use hearing aids. This has similar implications for the acoustic design of classrooms as for hearing impaired children who have more onerous acoustic requirements [123]. Some of the teachers reported that teaching made their hearing loss symptoms worse.

14.9.2 Tinnitus (Q46-48)

In the survey section related to tinnitus, respondents were asked if they ever experienced tinnitus. There were n = 135 valid responses which are summarised in Figure 14.30.

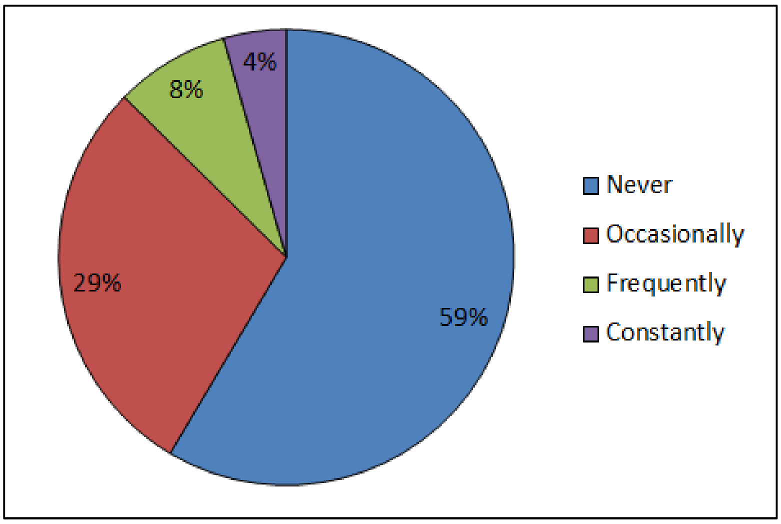


Figure 14.30: Experience tinnitus

Figure 14.30 shows that 41% of respondents experienced tinnitus at times and 12% experienced it frequently or constantly. Respondents who experienced tinnitus were then asked if this was perceived in one or both ears or if this varied. The valid responses (n = 56) are summarised in Figure 14.31.

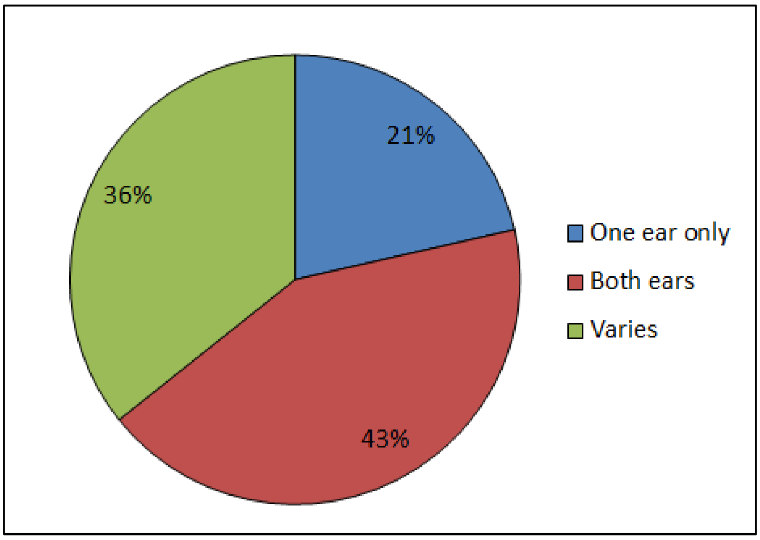


Figure 14.31: Tinnitus description

The final question in the tinnitus section asked respondents if their tinnitus was made worse by teaching. The valid responses (n = 55) are summarised in Figure 14.32.

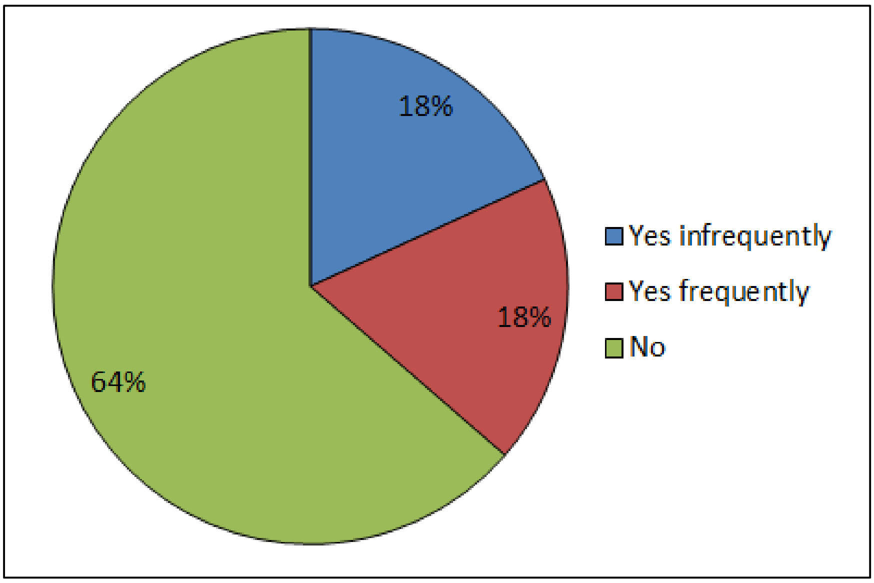


Figure 14.32: Tinnitus made worse by teaching

Tinnitus may be exacerbated by exposure to loud noise [169]. 36% of the respondents considered that their tinnitus symptoms were either infrequently or frequently made worse by teaching. This does not imply that the tinnitus itself was a result of teaching but does indicate that classroom acoustics may have a variety of effects on teachers.

14.9.3 General health (Q49-57)

Respondents were asked a number of questions about their general health (summarised in Figures 14.33 to 14.40) to gain an insight into their physical, mental and emotional wellbeing, which may affect, or be affected by, factors including voice problems and acoustics.

When asked about their general health in question 49, the majority of respondents considered their health to be fair or better.

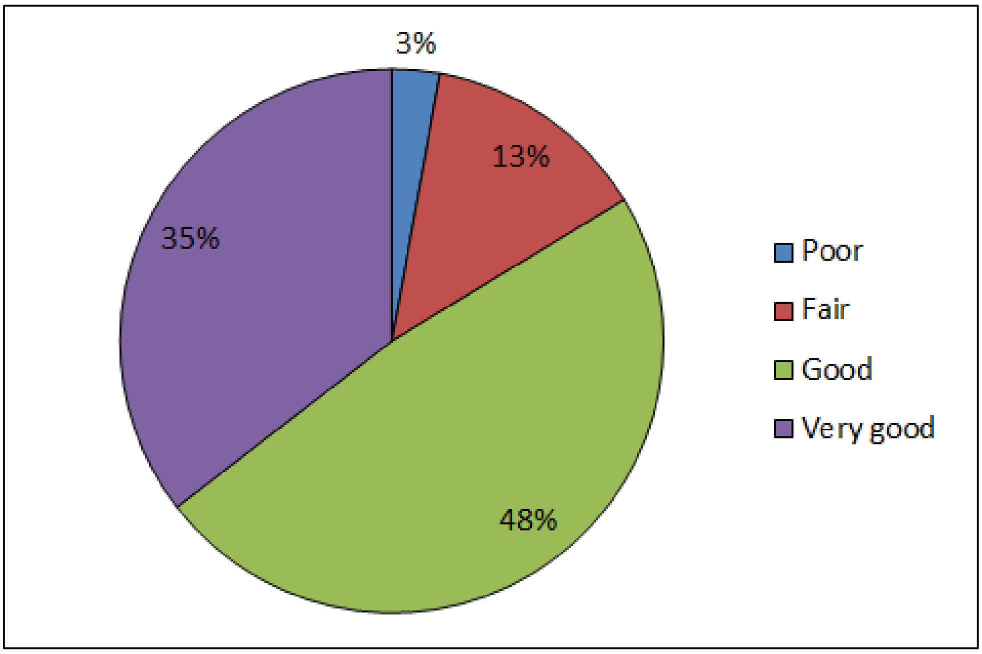


Figure 14.33: How would you describe your health? (*n* = 141)

In question 50, respondents were asked about pain limiting their activities, as summarised in Figure 14.34. 60% reported that their day-to-day activities were not limited by their physical health while 6% reported that such limitations were for more than half of the time.

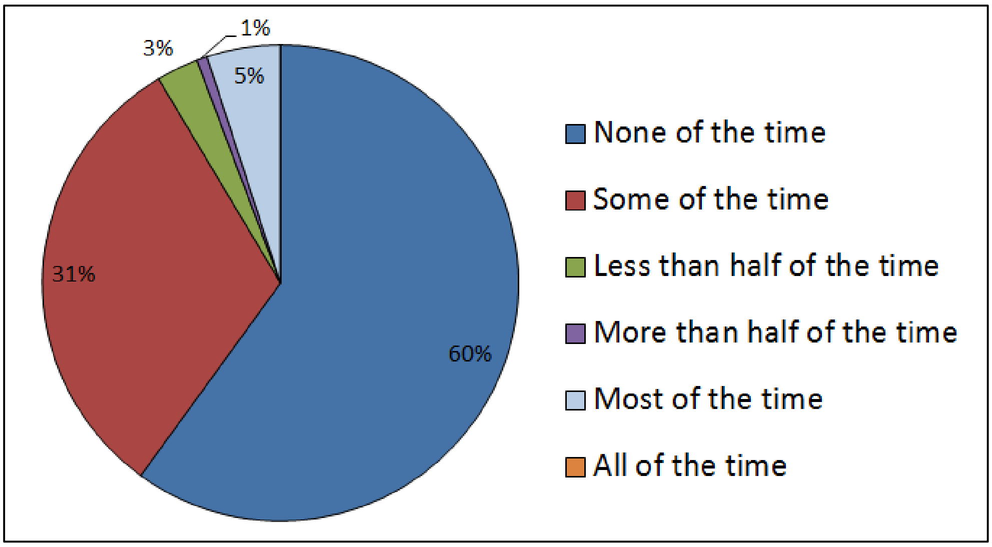


Figure 14.34: Does physical health limit day-to-day activities? (*n* = 140)

4% of respondents reported that pain specifically limited their day-to-day activities for more than half of the time as shown in Figure 14.35.

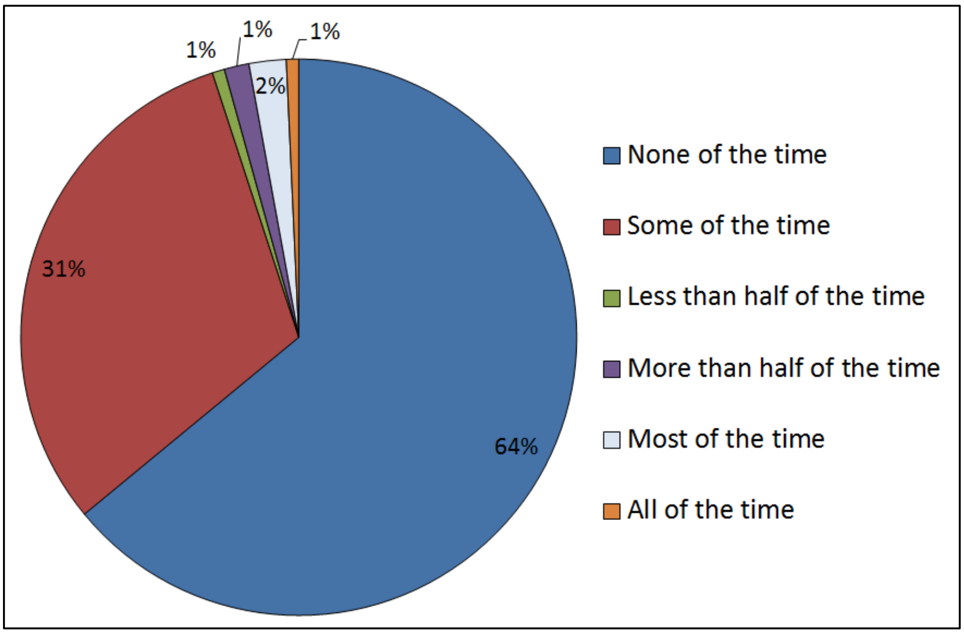


Figure 14.35: Does pain limit you in your day-to-day activities? (*n* = 139)

Questions 52 to 56 were designed to gain further information on stress. Figure 14.36 shows the responses to question 52; 11% of respondents did not feel cheerful or in a good mood for less than half, or none of the time, indicating negative emotions.

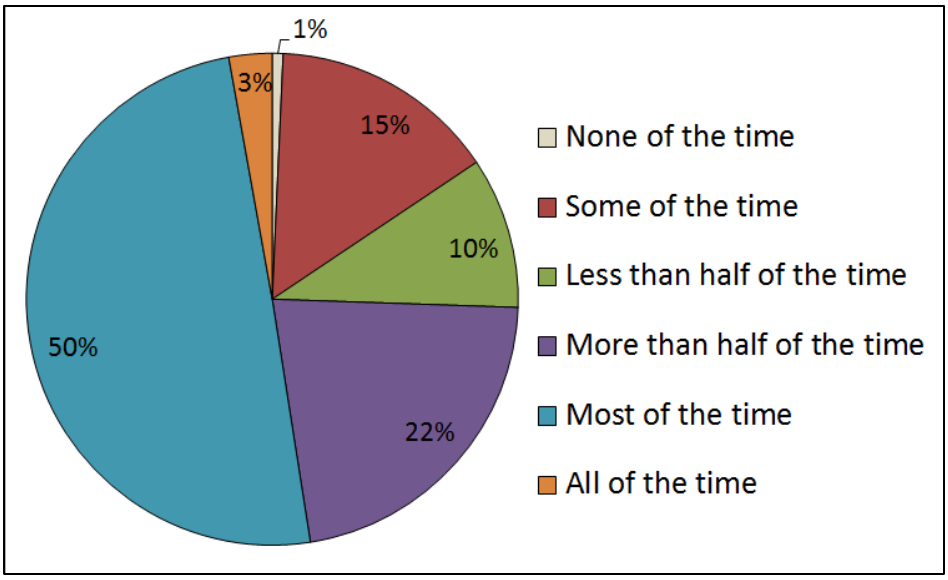


Figure 14.36: Over the last four weeks have you felt cheerful and in a good mood? (*n* = 141)

In terms of stress and anxiety, Figure 14.37 shows the responses to question 53 with 20% feeling calm and relaxed less than half, or none, of the time.

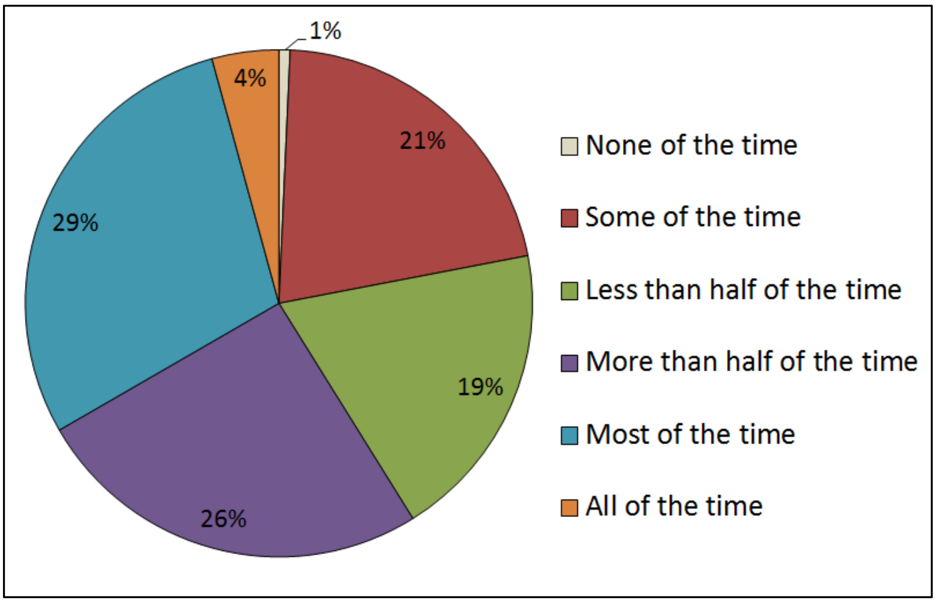


Figure 14.37: Over the last four weeks have you felt calm and relaxed? (*n* = 141)

Figure 14.38 gives details of the responses about energy levels and enthusiasm (question 54), with 25% not feeling active or energetic either less than half of the time or at all.

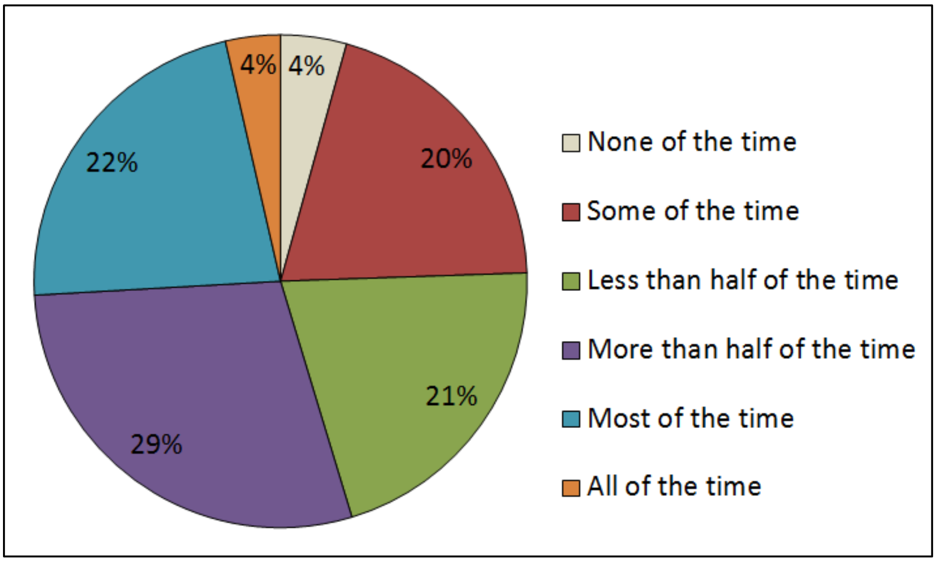


Figure 14.38: Over the last four weeks have you felt active and energetic? (*n* = 139)

Figure 14.39 gives details of responses to question 55, which related to how respondents felt when waking up and perhaps indicated the pressures of the profession, with 15% not feeling fresh or rested when waking up over the previous four weeks.

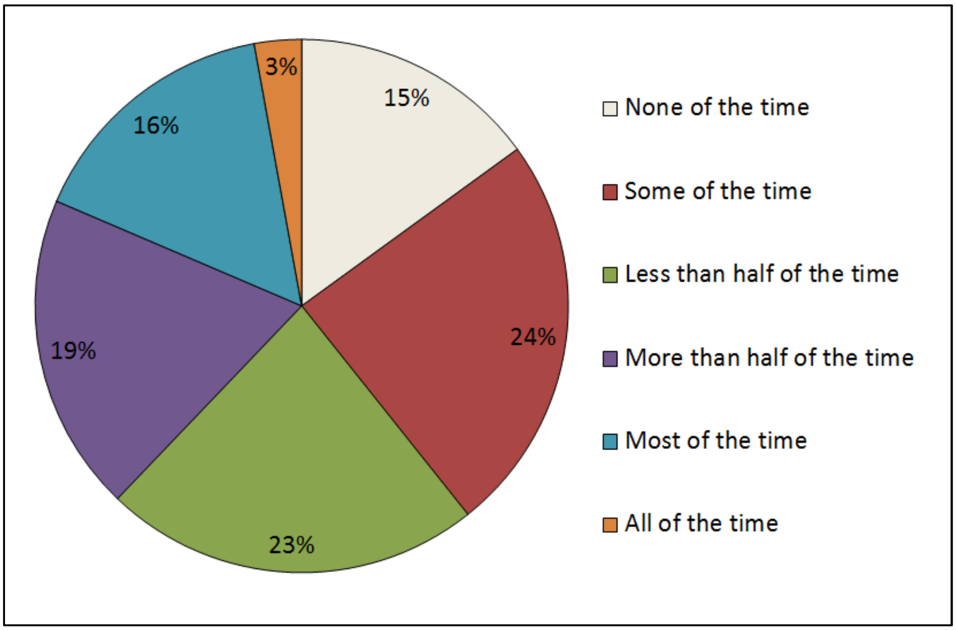


Figure 14.39: Over the last four weeks have you woken up feeling fresh and rested? (*n* = 140)

Figure 14.40 gives details of question 56 which was intended to gather information on how respondents viewed their day-to-day lives. 32% stated that their daily lives were filled with things that interested them either none of the time (2%), some of the time (20%) or less than half of the time (10%).

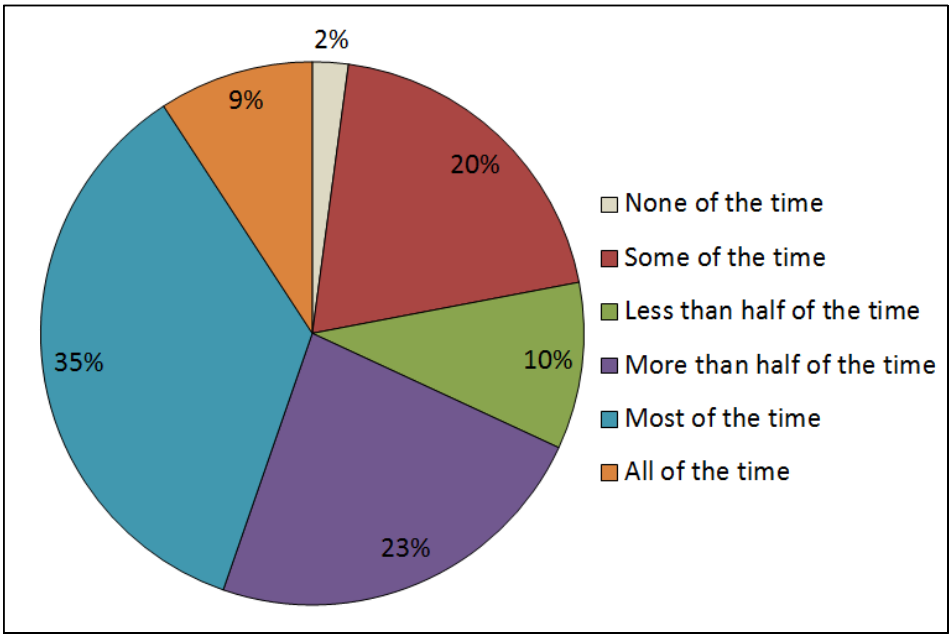


Figure 14.40: Over the last four weeks has your daily life been filled with things that interest you? (*n* = 141)

14.10 Conclusions

In the personal information section the demographics of the respondents were considered. This showed a similar gender balance to the general teaching population. The age distribution was skewed towards the older age groups compared to the wider teaching population.

The majority of respondents were currently working as teachers which meant that the opinions and experiences reflected the contemporary workplace and current teaching conditions.

The respondents predominantly taught in England, in the state sector, and in either primary or secondary schools. This means that the respondents were similar to the participants in the voice measurements element of this project.

The classrooms in which the respondents taught were built in a range of eras, again similar to those in the voice measurements, with around 22% likely to have been built when mandatory acoustic requirements were in force.

From the reported room finishes, it is likely that 40% of the classrooms have high reverberation times due to low amounts of sound absorption.

The questions covering voice problems showed that 66% reported having experienced voice problems, with 64% reporting that their voice felt tired at the end of the day. The prevalence rate was higher than the findings of other questionnaire surveys in the literature but this may be linked to bias in the self-selection of respondents in this study.

Of those with voice problems, 23% did not seek help and 71% remained at work with voice problems, compared with only 8% for other health reasons. This may indicate a lack of seriousness with which voice problems are treated both by sufferers and school management.

59% had received no voice training at all and 53% of those with voice problems were advised to change their voice technique. 93% supported mandatory voice instruction in teacher training.

The free comments section highlighted that some respondents felt that voice problems were not treated seriously and that there was a lack of understanding, empathy and training within the profession. There was a sense that there is a cultural issue with how the profession and society views voice problems.

In terms of classroom acoustics, 54% reported having rooms in which it was difficult to be heard, largely due to these rooms being too reverberant or in some cases too sound absorbent. Poor internal sound insulation was indicated by issues with activity noise from adjacent areas affecting the classroom. Underlying ambient noise was not perceived as problematic, though the findings of the voice measurements element of this study indicate that these effects may be subconscious.

72% of respondents reported raising their voice and 17% shouting frequently, which indicates potentially unhealthy voice behaviour.

In terms of the implications of voice problems, 78% considered that voice problems were significant for teachers, with three respondents reporting that voice problems had contributed to their leaving teaching. 13% had used voice reinforcement systems and found that these were helpful in assisting with voice problems. However, these systems require good acoustic conditions to work effectively, and responses relating to classroom acoustic conditions indicate that, in a large number of the classrooms, acoustic conditions would need improvement to enable voice reinforcement systems to work properly.

In regards to hearing and other health issues, a small number of respondents experienced hearing loss and in some instances reported that teaching made the symptoms worse. A larger proportion (41%) experienced tinnitus and in some cases reported that the symptoms were exacerbated by teaching.

A majority of respondents (83%) reported good health or better, though there were indications of stress and chronic tiredness within the responses which may indicate that occupational stress is a factor among the respondents.

The next chapter will give details of the analyses carried out on the survey results.

Chapter 15 Further analysis of online survey results

This chapter details further statistical analyses to explore relationships between different variables for the whole data set and for various subgroups.

The sample size was small relative to the overall teaching population (see section 3.2) meaning that non-parametric tests were the most appropriate method of analysing the data. As the variables were categorical rather than scalar, Chi-square tests for independence were used to explore the relationships between different combinations of categorical variables. This differs from the statistical tests in Chapters 11 and 12 which included at least one scalar variable meaning independent-samples t-tests were used.

The Chi-square test is based on cross-tabulation and examines the differences in frequencies between variables compared with what would be expected if there was no association between the parameters.

For 2 by 2 tables (where each variable has only two categories) Yates' Continuity Correction is reported; for tables larger than 2 by 2, Cramer's V is reported.

The Chi-square test for independence includes a number of assumptions including the expected lowest frequency in any cell in the cross tabulation tables. For some categories in the data the number of respondents within certain subgroups was small and violated the underlying statistical assumptions, meaning that valid results could not be obtained.

The number of respondents meant that statistically valid analyses could be carried out, with a ±8% margin of error at the 95% confidence level.

15.1 Voice problems

The responses relating to voice problems were analysed with other factors and are summarised in the following sections.

15.1.1 Voice problems and gender

The cross-tabulated data is shown in Table 15.1.

Table 15.1: Voice problems and gender

Gender	Male	Female
n	38	101
% voice problems	58	70

It can be seen that the prevalence of voice problems is higher among the female teachers. However, analysis indicated no statistically significant associations between gender and voice problem prevalence: X^2 (1, n = 139) = 1.40, p = 0.24, *phi* = -0.12. The relatively small number of males may have contributed to this lack of statistical significance.

15.1.2 Voice problems and respondent age

The cross-tabulated data is shown in Table 15.2.

Table 15.2: Voice problems and age

Age	21-30	31-40	41-50	51-60	61-70
n	30	36	36	23	14
% voice problems	57	78	69	78	36

Analysis indicated no statistically significant association between voice problems and age: X^2 (1, n = 139) = 1.27, p = 0.26, *Cramer's V* = -0.11.

15.1.3 Voice problems, respondent age and gender

The data was further analysed by both age and gender. Analysis indicated no statistically significant association between voice problems and age: Males: X^2 (1, n = 38) = 0.15, p = 0.70, *Cramer's V* = -0.14. Females: X^2 (1, n = 101) = 1.10, p = 0.30, *Cramer's V* = -0.13. The cross-tabulated results are shown in Table 15.3.

Table 15.3: Voice problems, age and gender

Gender	Male					Female				
Age	21-30	31-40	41-50	51-60	61-70	21-30	31-40	41-50	51-60	61-70
n	5	9	10	9	5	25	27	26	14	9
% voice problems	40	56	60	78	40	60	85	73	79	33

Table 15.3 shows voice problems at a consistently higher rate in female respondents apart from in the over 60s. This age group is likely to no longer be teaching which may explain the reduced prevalence reported, for both genders, in this age bracket.

15.1.4 Voice problems and years teaching

The data was analysed in three categories for numbers of years teaching; no statistically significant relationship was indicated: X^2 (2, n = 138) = 1.08, = 0.62 p = 0.97, *Cramer's V* = 0.02 see Table 15.4 for cross-tabulated data and Table 15.5 by gender groups. Statistical analysis by gender was not possible due to the group sizes.

Table 15.4 shows a relatively consistent rate of voice problems with number of years teaching. When considered by gender in Table 15.5 there does not appear to be a consistent pattern in the distribution of the prevalence by years teaching.

Table 15.4: Voice problems and years teaching

Years teaching	≤5 years	6-15 years	> 15 years
n	35	23	53
% voice problems	66	61	68

Table 15.5: Voice problems and years teaching by gender

Gender	Male			Female		
Years teaching	≤5 years	6-15 years	> 15 years	≤5 years	6-15 years	> 15 years
n	7	7	19	28	16	34
% voice problems	43	71	63	50	56	68

15.1.5 Voice problems and school type

Due to small numbers in other groups, analyses were carried out on the primary, infant and junior school teachers as one group and secondary school teachers as a second group as show in Table 15.6.

Table 15.6: Voice problems and school type

School type	Primary, infant and junior	Secondary
n	45	64
% voice problems	80	59

Analysis indicated a statistically significant association between voice problems and teaching type: X^2 (1, n = 109) = 4.25, p = 0.04, *phi* = 0.22, with a higher voice problem rate in teachers of younger children. This reflects other studies in the literature [3.5.1] and may be related to the findings of the voice measurements (see section 11.7.2) which showed higher mean voice levels and phonation times in the primary school teachers compared with those in secondary schools.

The cross-tabulated data by gender is shown in Table 15.7, however small group sizes meant further analysis was not valid. Nevertheless it can be seen that the rate of voice problems was lower for both male and female respondents who taught in secondary schools compared with those in primary schools, with females having a marginally lower prevalence rate than males in primary schools but a higher rate in secondary schools. This does not agree with the findings in the literature nor indicators of vocal loading in the voice measurements, this may be a result of the relatively small number of male respondents.

Table 15.7: Voice problems, school type and teacher gender

School type	Primary		Secondary	
Gender	Male	Female	Male	Female
n	7	25	15	49
% voice problems	86	84	53	61

15.1.6 Voice problems and open plan classrooms

Statistical tests indicated a statistically significant association between teaching in open plan classrooms and voice problems, X^2 (1, n = 139) = 4.93, p = 0.04, phi = 0.21. This indicated that the rate of voice problems was higher in those who taught in open plan classrooms. The cross-tabulated data is shown in Table 15.8.

Table 15.8: Voice problems and open plan classrooms

Classroom type	Open	Enclosed	Overall
n	28	111	140
% voice problems	86	61	66

Table 15.9 shows the cross-tabulated responses by gender, for both males and females. The male respondents teaching in open plan classrooms reported a greater prevalence of voice problems than their female counterparts. This is opposite to the general trend in the literature which indicates female teachers having a higher prevalence of voice problems. This may result from the relatively small number of male respondents and therefore may not be important.

Table 15.9: Voice problems and open plan classrooms by teacher gender

Classroom type	Open		Enclosed	
Gender	Male	Female	Male	Female
n	12	16	26	84
% voice problems	92	81	42	68

The amount of time for which respondents taught in open plan classrooms varied considerably, with only a small number teaching mainly in open plan classrooms. This limited the implications that could be drawn from the analysis; however the indications suggest that further research with a larger data set would be worthwhile. The cross-tabulated data by hours teaching in open plan spaces is shown in Table 15.10.

Table 15.10: Voice problems and open plan classrooms by hours teaching

Open plan teaching hours per week	1-4	5-20	>20
n	8	8	4
% voice problems	100	88	75

The values in Table 15.10 suggest that those teaching in open plan rooms for more hours per week experience fewer voice problems. One possible explanation could be that these teachers have adapted their teaching techniques to cope with the different demands of open plan teaching.

The number of participants in the group teaching more than 20 hours per week was small and therefore this may not be a reliable indication.

15.1.7 Voice problems and difficulty being heard in classrooms

Analysis indicated that, although there was a greater percentage of those reporting difficulty being heard who had voice problems, there was not a statistically significant association between voice problems and those who reported trouble being heard in their classrooms: X^2 (1, n = 134) = 1.65, p = 0.20, *phi* = 0.13. The cross-tabulated data is shown in Table 15.11.

Table 15.11: Voice problems and difficulty being heard

Difficulty being heard	Yes	No
n	76	58
% voice problems	72	60

15.1.8 Voice problems and classrooms too reverberant

Analysis showed no significant relationship between voice problems and respondents who reported classrooms as being too reverberant: X^2 (1, n = 90) = 0.00, p = 1.00, *phi* = 0.08. The cross-tabulated responses are summarised in Table 15.12.

Table 15.12: Voice problems and classrooms too reverberant

Classroom too reverberant	Yes	No
n	51	39
% voice problems	73	72

15.1.9 Voice problems and classrooms too noisy

No significant relationship was indicated between voice problems and respondents who reported classrooms as being too noisy: X^2 (1, n = 90) = 0.00, p = 1.00, phi = 0.00. The cross-tabulated responses are summarised in Table 15.13.

Table 15.13: Voice problems and classrooms too noisy

Classroom too noisy	Yes	No
n	72	18
% voice problems	72	72

15.1.10 Voice problems and pre/post BB93:2003 construction

Respondents were divided by the period of classroom construction; pre and post 2000s, with the assumption that classrooms constructed post-2000s were designed in accordance with BB93:2003 [121] criteria. Where respondents gave multiple answers to the classroom construction period these responses were discounted.

Statistical tests did not indicate a statistically significant association between the factors; X^2 (1, n = 114) = 0.00, p = 1.00, phi = -0.01. The cross-tabulated data is summarised in Table 15.14.

Table 15.14: Voice problems with pre and post BB93 construction

Classroom construction	Pre-2000	Post-2000
n	85	29
% voice problems	68	69

15.1.11 Voice problems with ceiling and floor finishes

Assuming that ceiling tiles reported were sound absorbent, the responses were divided into classrooms by ceiling and floor finish to identify classrooms which were likely to be more and less reverberant. Tests did not indicate a statistically significant relationship association between having particular ceiling types and voice problems: X^2 (1, n = 120) = 2.34, p = 0.13, *phi* = -0.16. There was similarly no significant difference for floor finishes X^2 (1, n = 124) = 0.06, p = 0.80, *phi* = 0.04 or for both floor and ceiling finishes; X^2 (3, n = 124) = 2.66, p = 0.45, *Cramer's V* = 0.15. The cross-tabulated data is shown in Tables 15.15 to 15.17. In fact it can be seen that the percentage of reported voice problems decreased in rooms with assumed less absorption.

One possible reason for this may be that such rooms may provide greater reflections to the speaker and this may reduce vocal effort.

Table 15.15: Voice problems and ceiling tiles

Ceiling type	Ceiling tiles	No ceiling tiles
n	77	43
% voice problems	71	56

Table 15.16: Voice problems and carpet

Flooring type	Carpet	No carpet
n	88	36
% voice problems	68	64

Table 15.17: Voice problems with carpet and ceiling tiles

Finishes	Carpet/tiles	Carpet/no tiles	No carpet/tiles	No carpet/no tiles
n	59	30	21	14
% voice problems	71	63	71	50

15.1.12 Voice problems and health rating

The relationships between reported voice problems and health ratings were analysed. The self-assessed health rating may have depended on whether respondents viewed voice problems as a general health issue. It was not possible to identify if, for those who reported voice problems and poor general health, that perception arose partially from having voice problems, or if poor health was a contributing factor to voice problems. The cross-tabulated data is shown in Table 15.18.

Table 15.18: Voice problems with general health rating

General health rating	Poor/fair	Good	Very good
n	21	68	50
% voice problems	67	75	56

The relatively low number of respondents in the 'poor' general health category meant that the 'poor' and 'fair' categories were combined for analysis. Analysis did not indicate a statistically significant association between voice problems and health rating, X^2 (2, n = 139) = 4.70, p = 0.10, *Cramer's V* = 0.18, although it can be seen that those who rated their health as very good reported fewer problems.

15.1.13 Other parameters

There were insufficient numbers of respondents to undertake analyses of other subgroups, including teaching status, state or private schools, academies and Local Authority schools, classroom layouts or stress and anxiety ratings from the general health section. For information cross-tabulated data on the subjects taught is included in Table 15.19.

Table 15.19: Voice problems and subject taught

Subject taught	Maths	English	Science	Music and Drama
n	12	12	19	10
% voice problems	67	75	53	80

The results in Table 15.19 may indicate varying levels of voice problems due to different pedagogies for the different subjects, particularly with Science, which may involve more individual and group working by pupils during experiments and less oral instruction by the teacher, resulting in fewer voice problems.

15.2 Voice training

The analyses relating to voice training are detailed in this section.

15.2.1 Voice training by gender

Analysis indicated that there was a close to statistically significant association between voice training and gender within the dataset, X^2 (1, n = 140) = 3.14, p = 0.08, *phi* = 0.17, with male respondents reporting voice training at a higher rate. However, the scope of voice training varied considerably, and therefore this relationship may not be very informative with regard to the relative prevalence of voice training, and is, in fact, the opposite of what might be expected.

Some voice training may be a result of individuals having experienced voice problems. However, the higher prevalence of voice problems in the female respondents is not mirrored in the levels of voice training.

The cross-tabulated data is shown in Table 15.20.

Table 15.20: Voice training by gender

Gender	Male	Female
n	39	101
% voice training	54	36

15.2.2 Voice training by age

There was no statistically significant association between voice training and age within the dataset, X^2 (1, n = 140) = 0.14, p = 0.90, *Cramer's V* = 0.03. The categorised results are shown in Table 15.21. This would indicate that the provision of voice training has not changed significantly over time with teachers trained in different periods not having significantly differing levels of voice training, with the exception of the oldest age bracket which reported the lowest rate of voice training.

Table 15.21: Voice training by age

Age	21-30	31-40	41-50	51-60	61-70
n	30	37	35	23	15
% voice training	43	41	40	48	27

15.2.3 Voice training and years teaching

Similarly, analysis did not indicate a statistically significant association between voice training and number of years teaching, X^2 (6, n = 139) = 1.99, p = 0.91, *Cramer's V* = 0.12.

The cross-tabulated results are shown in Table 15.22. As with the results in 15.21 this would indicate that the provision of voice training has not changed significantly over time.

Table 15.22: Voice training and years teaching

Years teaching	≤5 years	6-15 years	> 15 years
n	35	50	54
% voice training	40	46	39

15.2.4 Voice training and voice problems

The cross-tabulated data for voice problems and training is shown in Table 15.23.

Table 15.23: Voice problems and voice training

Training	Voice training	No training
n	58	81
% voice problems	74	60

Analysis of the relationship between voice training and voice problems is complicated as some respondents may have had voice training as a result of voice problems. Analysis did not indicate a statistically significant association between voice problems and voice training, X^2 (1, n = 139) = 2.24, p = 0.13, phi = 0.14.

From examining the data further for those who had received voice training (n = 58) the indications were that 11 had done so as a result of voice problems. Analysis was repeated with these cases of post-problem voice training excluded. The results showed that the reported rate of voice problems was higher in those with voice training which was not undertaken in response to voice problems, than those without voice training. However this difference was not statistically significant, X^2 (1, n = 128) = 0.45, p = 0.50, phi = 0.08.

Table 15.24: Voice problems and pre-emptive voice training

Training	Voice training	No training
n	47	81
% voice problems	68	60

Analysis of a larger data set, controlling for both voice problems and voice training, would be necessary to assess the relationship further.

15.3 Classrooms reported as too reverberant

This section includes analysis of respondents who reported their classrooms being too reverberant in the context of other factors.

15.3.1 Classrooms too reverberant and ceiling finish

There was no statistically significant association between reported reverberance and ceiling finishes, X^2 (1, n = 65) = 0.22, p = 0.64, phi = 0.09, although it can be seen that a higher percentage of those in rooms without tiles reported their classroom as being too reverberant. The cross-tabulated results are summarised in Table 15.25.

Table 15.25: Ceiling finish and classrooms too reverberant

Ceiling tiles	Yes	No
n	44	21
% classroom too reverberant	52	62

15.3.2 Classrooms too reverberant and high pupil noise

There was no statistically significant association between classrooms reported as too reverberant and high pupil noise, X^2 (1, n = 73) = 0.52, p = 0.47, phi = 0.11, although a larger proportion of those in classrooms described as too reverberant did also report pupil noise as being too high. The cross-tabulated results are summarised in Table 15.26.

Table 15.26: Classrooms too reverberant and pupil noise too high

Classroom too reverberant	Yes	No
n	47	26
% report pupil noise too high	62	50

15.4 Difficulty being heard

Analyses relating to difficulty being heard are detailed in this section.

15.4.1 Difficulty being heard and classroom construction era

There was no statistically significant association between the classroom construction era and difficulty being heard within the dataset, X^2 (1, n = 115) = 0.36, p = 0.55, phi = -0.08. The cross-tabulated results are shown in Table 15.27.

Table 15.27: Difficulty being heard and classroom construction era

Classroom era	Pre-BB93	Post-BB93
n	86	29
% difficulty being heard	61	69

This may indicate that, subjectively, the likely improvements in reverberation time and reductions in underlying ambient noise levels in the post-BB93 classrooms are not perceived by teachers. It is however possible that these principal room qualities may affect the occupied noise conditions and the ability for teachers to be heard even if the effect is not perceptible by the speaker.

15.4.2 Difficulty being heard and ceiling finish

There was no statistically significant association between difficulty being heard and ceiling finish within the dataset, X^2 (1, n = 116) = 0.47, p = 0.49, phi = -0.08. The cross-tabulated results are shown in Table 15.28.

Table 15.28: Difficulty being heard and ceiling finish

Ceiling tiles	Yes	No
n	74	42
% difficulty being heard	61	52

The higher rate of those reporting difficulty being heard in rooms with ceiling tiles in Table 15.28 may indicate that these rooms are overly absorbent and could be reducing room support in terms of the speaker's perception.

The lack of a significant association indicates that ceiling finishes and associated different reverberation times do not appear to be primary factors in terms of perceived difficulties in being heard. There would be a large number of other variables that could also be factors in creating difficulties in being heard, such as external noise intrusion and sound insulation within the building, as well as discipline and the voice characteristics of the teachers. It may be that these other factors mask the effects of different ceiling types. However a more detailed data set would be needed to control for these factors.

15.5 Conclusions

Statistical analyses have been carried out to determine if there were significant differences between sub groups within the online survey data.

There were no statistically significant differences in the rate of voice problems reported between the genders. This was different to other studies in the literature (see section 3.5.5) which indicated that the prevalence of voice problems was higher in female teachers. The voice measurements in section 11.3 found that female teachers had a higher mean voice level, which in turn may mean greater vocal loading and associated risks of voice problems, this was not reflected in the survey responses. There may be inherent bias in the respondents due to a potentially greater tendency to respond to the questionnaire due to having experienced voice problems.

There was a statistically significant difference in the reporting of voice problems by school type with a higher prevalence in primary schools. This agrees with other studies in the literature (see section 3.5.1) and may also be linked to the higher voice levels found in primary school participants in the voice measurements element of this thesis (see section 11.3).

Those who taught in open plan classrooms had a statistically significant higher rate of reported voice problems compared with those who did not. This may be due to the different acoustic conditions in terms of signal to noise ratios and different reverberation time qualities of the classrooms placing different requirements on the teacher's voice in these types of classroom.

Interestingly there was no significant difference in the rates of reported voice problems between those who taught in classrooms constructed pre and post the mandatory requirements of BB93:2003 [121] being introduced. This also was the case for differences in surface finishes (which would represent different reverberation time characteristics) which showed no difference for voice problem rates or difficulties in being heard.

There were indications, though not at statistically significant levels, of different rates of voice problems by subject taught, with music, drama and English having the highest rates. This may be linked to different vocal loading patterns between the subjects though other studies in the literature are inconclusive on the influence of the subjects taught, apart from physical education (see section 3.5.2).

There were no significant differences in voice problems between those with and without voice training, however the nature of the voice training varied widely between respondents and may have prevented any differences being indicated.

Due to the self-selecting recruitment method for the survey it was not possible to either remove bias in the responses or control for different factors which may have affected the results. However the responses are considered to have provided useful further information on voice problems and acoustics in schools.

Further work which could be undertaken to follow on from the survey, as well as from the voice measurements, has been identified and is discussed in the next section along with the overall conclusions for the project.

Chapter 16 Conclusions and further work

16.1 Introduction

This chapter summarises the main findings of this thesis and suggest areas for further work as well as identifying limitations in the research.

This research was born out of the need for guidance for those involved with acoustic design in schools concerning relationships between classroom acoustics and teachers' voice parameters.

The existing school design guidance (detailed in Chapter 5) includes references to voice problems, in that it identifies that voice strain can result from poor acoustics but does not provide further information on appropriate criteria or what factors should be considered by designers. In terms of workplace health and safety legislation (see Chapter 5), the wording of the relevant legislation and guidance would appear to include a responsibility for employers to ensure that teachers can safely use their voices in classrooms. However it seems that this interpretation is not widely applied.

From the voice ergonomic sphere, vocal dose parameters have been proposed, such as those by Titze *et al.* [24]. However there are no established limits by which the vocal loading of individuals can be assessed in terms of safety and risk.

16.2 Voice and acoustic measurements

The majority of the classrooms involved in this thesis complied with the current school acoustic standards. This should mean that they also meet the intended aims of the guidance in making classrooms safe spaces for teachers to use their voices in.

However, the data showed that the mean voice levels of the teachers (67 dBZ at 1 m) were in the 'loud' category of guidance documents [30, 31, 32] and that the mean phonation percentage was also high at 21%. This showed that the participants had a high vocal load even in classrooms compliant with current acoustic requirements and guidance.

The mean values were higher in the female participants compared with males and higher in the primary school teachers compared with those in secondary schools. This means that those subgroups are likely to have higher vocal loading with the associated higher risks to the voice.

The key questions at the core of this strand of the project were the relationships between voice parameters and those factors in the remit of acoustic design, namely the room parameters such as reverberation time, unoccupied noise levels and the like.

The primary finding was a significant, moderate, positive correlation between voice levels in female participants and the 250 Hz unoccupied noise levels (UANL) for both L_{eq} and L_{90} parameters. This indicated a rate of increase of 0.9 dB in voice level per 1 dB increase in UANL in this octave frequency band. This 250 Hz band includes the mean female SF_0 value and therefore it may be the case that a Lombard effect [28] (see section 6.1) in the spectral domain is occurring.

Comparison of the unoccupied and occupied noise level spectra showed that in a number of cases the UANL values were less than 10 dB below those in occupied conditions which means there is scope for the UANL sources to influence occupied noise levels in these low frequency bands, and hence potentially to also give rise to voice problems.

There were also indications, though not at a statistically significant level, of a similar positive correlation between voice levels in the male participants and 125 Hz UANL values, an octave band which includes the mean male SF_0 value. For the male participants a lower increase of 0.3 dB in voice level per dB in UANL 125 Hz was indicated.

This is pertinent to schools guidance as the current UANL criteria are overall dBA values without specific requirements for lower frequencies. Similarly reverberation time criteria are given at mid-frequencies leaving scope for high values at low frequencies even in currently compliant classrooms.

Other room acoustic parameters have not been found to have significant correlations with voice parameters which indicated that their influence, based on this data set, was not substantial.

16.3 Online survey

The online survey respondents had a similar demographic profile to the teaching profession as a whole and taught in classrooms constructed both before and since mandatory acoustic requirements applied.

Of the respondents, 66% reported having experienced voice problems, the rate was statistically significantly higher in those teaching in primary schools, but there was no difference by gender. Similarly, for those teaching in open plan classrooms, the rate of reported voice problems was higher. There were also indications of a variation by subject taught across the data set, though not at significant levels.

There were no significant differences in the rate of voice problems by classroom construction era, or for classroom finishes, although the actual acoustic parameters of classrooms were not known.

Many respondents remained at work with voice problems and at a higher rate than applied for other health reasons. This may indicate a lack of seriousness with which voice problems are treated both by sufferers and school management.

The majority of respondents (59%) had received no voice training which underlined the importance of providing a suitable acoustic environment for voice use. If, as indicated in the voice measurement strand of this project, room acoustics are related to vocal loading, the fact that most teachers are not trained to use their voice efficiently or safely means that suitable acoustics are even more important than they might otherwise be in reducing the risks of voice problems.

There were indications of substantial vocal loading with a high proportion of respondents raising their voices or shouting frequently, which may result from inadequate or absent voice training as well as high classroom noise levels.

In terms of linking the subjective impressions with inferred room acoustics factors, poor internal sound insulation and excessive reverberation times were indicated as the main issues affecting voice ergonomics. Sources of unoccupied noise were not considered significant, although the Lombard effect [28], discussed in section 16.2, may be present without the speaker being aware.

In terms of the implications for voice problems, 78% considered that voice problems were significant for teachers, which validates the motivation for this research and a need for practical measures to improve voice ergonomics for teachers.

The comments from participants showed that those experiencing voice problems felt isolated and unsupported with their problems and that they felt the profession and society did not treat the subject with the gravity it deserved. These were perhaps the most important aspects of the survey and gave a sombre view of the personal impact of voice problems behind the data.

16.4 Limitations of the research

The voice and acoustic measurements study included a number of limitations which should be considered alongside the results. These do not render the results invalid but mean that the findings should be seen as indicative rather than definitive.

The primary limitation is that voice parameters are influenced by a myriad of factors and this study has looked at a small number of these. It has not been possible, within the scope of this research, to control for the variables involved such as pedagogy, teacher experience, voice training, an individual's physical characteristics and the like. Where relationships have been identified between parameters, causality has not been established.

Similarly the relationship between voice behaviour and parameters and voice problems is not definitive. However the risks of voice problems are considered to increase with vocal loading based on studies in the literature [16] and therefore high voice levels have been considered to place individuals at higher risk of vocal loading and voice problems.

The measurements of voice parameters were undertaken with the APM device which has a mean accuracy in terms of voice level of around 3 dB (see section 7.6). This limits the absolute accuracy of the data, however as the study primarily considered relative differences between participants this was considered suitable. This consideration also applies to other voice parameters measured using the APM device.

The online survey had limitations which should be taken account of. The number of respondents meant that statistically valid analyses could be carried out, however a larger respondent group with greater numbers in various subgroups would allow more detailed analyses.

The structure of some questions meant that a relatively shallow depth of data was collected, for instance on voice training, which could vary significantly in nature. This was a consequence of balancing the overall length of the survey and the desired depth on the basis that a longer survey would elicit fewer responses.

The accuracy of the survey data is reliant on accurate self-reporting of problems, however as the survey was intended to gather information on subjective impressions these remain important in voice problems and acoustics more widely, where the perceived impacts will vary from individual to individual.

The self-selecting recruitment method meant that bias may have been present in the responses, with those having experienced voice problems being potentially more interested in the subject and the survey. There is no ready solution to this other than selecting the respondents directly to enable these factors to be controlled for; however the responses are considered to have provided useful further information on voice problems and acoustics in schools.

16.5 Further work

Further work has been identified which could be carried out to both the voice measurement and online survey elements of this thesis.

For the voice and acoustic measurements, the sample size in the study was relatively small and a larger data set would provide greater certainty in the indicative findings.

This would ideally also include a control group and controls for variables such as pedagogy, teacher experience and baseline voice parameters.

The data was gathered using a cross-sectional rather than longitudinal method due to practical constraints of time, resources and willing participants. As such it represents parameters at a single point in time, these may not be representative of individual's long term voice parameters, and the same applies to other factors such as UANL. This is particularly pertinent to voice parameters which may vary at different points in the teaching term cycle and also to sources of unoccupied noise which may, for instance, be affected by windows being open during warmer periods.

The UANL values were measured at different times to those of the occupied noise levels and teachers' voice parameters. One area of further work would be to develop a methodology for undertaking simultaneous external and internal measurements. Coupled with the external to internal sound insulation, which could be measured separately and would not change in use, this would give a more representative estimation of the contribution of UANL sources to the occupied noise levels.

To further investigate the indicated relationships between low frequency UANLs and voice levels one option to reduce the influence of other factors would be to undertake laboratory measurements. These could include participants speaking in virtual rooms via auralisation and acoustic modelling. This would enable incremental variations in the UANL at different low frequency bands and voice parameters to be measured simultaneously. This approach would also reduce the influence of other non-acoustic factors such as classroom stress and discipline.

Following further research and development, if the indications of this research were confirmed with a larger study, it may be possible to determine suitable octave band UANL criteria values for classrooms particularly at low frequencies. This could assist in reducing voice levels and vocal loading in teachers, with the associated likely reductions in the risk of voice problems.

Further work has also been identified which could enhance and develop the survey.

Further work should aim to increase the number of respondents to the questionnaire survey with consideration of possible methods of distribution of the questionnaire, and greater publicity, to increase awareness and encourage responses.

The primary technical development would be to add objective data to the subjective impressions. The use of smart phone based applications to provide photographs tied to the survey data showing room finishes, and potentially measuring indicative acoustic parameters, could be considered.

In terms of the selection process, a survey cohort with controls for pre-existing voice problems would assist in removing some of the risks of bias, though careful consideration would be needed to the methodology to ensure respondents felt able to give frank responses.

Linking the survey data with medical examinations to determine any physical manifestations of reported voice problems would be a useful additional facet to the data and APM-type measurement data would also enable voice parameters to be integrated with the subjective data.

A full list of journal and conference papers and presentations published in relation to this research to date are included in Appendix I.

16.6 Overall conclusions and implications for acoustic design of schools

The research has shown that subjectively, via the online survey, teachers are concerned about voice problems and feel that there is insufficient training in how to use their voices safely and a lack of support for those who do develop problems. The findings of the voice and acoustic measurements element of the study indicated that those measured experienced heavy vocal loads due to occupational voice use, speaking at high sound levels and for prolonged periods.

The analysis of the voice and acoustic data has indicated that noise intrusion into the classrooms from sources such as traffic and building services which are under the remit of school design guidance has a significant effect on teachers' voice levels when classrooms are in use. This study has also identified that in particular the teachers' voice levels were influenced by noise at low frequencies, the control of which is not specified in current guidance.

It has therefore been indicated that the acoustic design of classrooms does have the scope to affect the voice parameters of teachers and to therefore increase voice loading and the risks of voice problems. It is hoped that this study will assist in contributing to practical guidance for school design in how best to consider the voice ergonomics of teachers.

The recommendations from the project are:

- Voice problems are a significant cause for concern for teachers and should be taken more seriously by policy makers, schools and both the teaching and acoustics professions.
- Voice problems should be classified as an occupational disease.
- There is a need for more voice training for teachers.
- Teachers in primary schools, open plan classrooms and female teachers in particular appear to be at a higher risk of voice problems due to vocal loading and the risks for these groups should be considered accordingly.
- Any future revision of the current acoustic standards in England should specify unoccupied ambient noise level criteria at low frequencies, specifically in the 125 and 250 Hz octave bands.

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APPENDIX A - Template health and safety checklists and risk assessments

Figure A1: HSE Health and safety checklist for teachers [116]

HSE

Health and Safety Executive

Health and safety checklist for classrooms

How this checklist can help you

School premises are a valuable resource for local communities and are increasingly being used for extended services.

Health and safety in a school is about taking a sensible and proportionate approach to ensure the premises provide a healthy and safe place for all who use them, including the school workforce, visitors and pupils.

Because written risk assessments are not required for every classroom activity, this checklist is being made available for use as required. It is not mandatory, but is intended as a helpful tool. Schools may choose other ways to comply with health and safety legislation and ensure staff and children are safe.

School-wide measures should be in place to deal with the real risks, so that teachers and support staff do not need to produce written assessments for an ordinary classroom – unless new activities lead to additional risks.

Members of staff can use this checklist to help ensure ordinary classrooms meet minimum health and safety standards. However, the results and findings from completed checklists will provide a useful resource to the school management team when reviewing their whole-school risk assessments.

The checklist is a tool for school staff to raise awareness of areas of concern in a classroom. Employers in the education sector, whether they are a local authority, governing body, trust or proprietor, have wider responsibilities under health and safety law (see www.hse.gov.uk/services/education for further advice).

Using the checklist

This checklist covers the most common areas of concern/risk in ordinary classrooms, but is not exhaustive. It does not cover drama and sports facilities or specialist classrooms, including laboratories, art, IT, design and technology facilities or pupil referral rooms.

It can be used by class teachers, teaching assistants, premises staff or department heads – those running the school can decide how best to use the checklist in their school. It can be used as required, for example at the start of a term to provide reassurance to teaching staff that the most common areas of risk in the classroom are being adequately controlled.

It is designed to be helpful and quick and easy to use but there is no obligation on staff to use it. If an issue is not relevant to a classroom, simply mark it as 'N/A' (not applicable) and move to the next question. There is space at the end to list any additional issues.

Further information

HSE's homepage (www.hse.gov.uk/) has information on general topics to help employers and teaching staff comply with health and safety law. We have specific web pages for education, which provide guidance on the common types of risks within the sector (www.hse.gov.uk/services/education).

The Department for Education, Welsh Assembly Government and Scottish Government have guidance for schools on health and safety:

- **England:** www.education.gov.uk/schools/adminandfinance/healthandsafety
- **Wales:** www.wales.gov.uk/topics/educationandskills/allsectorpolicies/healthandsafety
- **Scotland:** www.scotland.gov.uk/topics/education/schools

The Health and Safety Executive has developed this checklist, through a public consultation, to help schools comply with health and safety law. It has been produced in consultation with:

- Department for Education (DfE), England;
- Department for Children, Education, Lifelong Learning and Skills (DCELLS), Welsh Government;
- Learning Directorate, People and Places (LDSG), Scottish Government;
- Department for Communities and Local Government (DCLG), England;
- trade unions.

HSE

Health and Safety Executive

Questions you should ask:		Yes	Further action needed	N/A
Movement around the classroom (slips and trips)	Is the internal flooring in a good condition?			
	Are there any changes in floor level or type of flooring that need to be highlighted?			
	Are gangways between desks kept clear?			
	Are trailing electrical leads/cables prevented wherever possible?			
	Is lighting bright enough to allow safe access and exit?			
	Are procedures in place to deal with spillages, eg water, blood from cuts?			
	For stand-alone classrooms: ■ Are access steps or ramps properly maintained? ■ Are access stairs or ramps provided with handrails?			
Work at height (falls)	Do you have an 'elephant-foot' stepstool or stepladder available for use where necessary?			
	Is a window-opener provided for opening high-level windows?			
Furniture and fixtures	Are permanent fixtures in good condition and securely fastened, eg cupboards, display boards, shelving?			
	Is furniture in good repair and suitable for the size of the user, whether adult or child?			
	Is portable equipment stable, eg a TV set on a suitable trolley?			
	Where window restrictors are fitted to upper-floor windows, are they in good working order?			
	Are hot surfaces of radiators etc protected where necessary to prevent the risk of burns to vulnerable young people?			
Manual handling	Have trolleys been provided for moving heavy objects, eg computers?			
Computers and similar equipment	If you use computers as part of your job, has a workstation assessment been completed?			
	Have pupils been advised about good practice when using computers?			
Electrical equipment and services	Are fixed electrical switches and plug sockets in good repair?			
	Are all plugs and cables in good repair?			
	Has portable electrical equipment, eg laminators, been visually checked and, where necessary, tested at suitable intervals to ensure that it's safe to use? (There may be a sticker to show it has been tested.)			
	Has any damaged electrical equipment been taken out of service or replaced?			
Asbestos	If the school contains asbestos, have details of the location and its condition in the classroom been provided and explained to you?			
	Have you been provided with guidance on securing pieces of work to walls/ceilings that may contain asbestos?			
Fire	If there are fire exit doors in the classroom, are they: ■ unobstructed; ■ kept unlocked; and ■ easy to open from the inside?			
	Is fire-fighting equipment in place in the classroom?			
	Are fire evacuation procedures clearly displayed?			
	Are you aware of the evacuation drill, including arrangements for any vulnerable adults or children?			
Workplace (ventilation and heating)	Does the room have natural ventilation?			
	Can a reasonable room temperature be maintained during use of the classroom?			
	Are measures in place, for example blinds, to protect from glare and heat from the sun?			

This is not an exhaustive list and you should identify any other hazards associated with the daily use of the classroom in the space overleaf, including any further actions needed. If necessary, discuss this with your head teacher or employer.

Figure A2: Voice: *The union for educational professionals* voice care risk assessment form [117]

Risk Assessment - Voice Care

Date of Assessment.......................................

....School recognises that the voice is of paramount importance in the teaching and learning process and acknowledges that voice care is a legitimate aspect of health and safety management because school staff can be at risk of developing voice problems.

The purpose of this risk assessment is to assess the risk of our staff developing voice problems at work, and how, so that we can decide what precautions and preventive measures should be introduced.

STEP 1 What are the Hazards?	**STEP 2** Who might be harmed & how?
› Walk around. › Ask colleagues what they think. › Look at reasons for absence. › Contact the LA/your advisors.	Say who is at risk and how the hazard could cause harm.
Factors for consideration: **a. The working environment** Constantly speaking above background noise	
Limited breaks	
Large class sizes	
Demanding pupils - vocal input from staff	
b. Physical factors Noise - technology, music	
Dust	
Fumes - glues, whiteboard markers	
Acoustics - PE, swimming pools, playground	
Heat / ventilation	
c. Personal factors Stress	
Smoking	
'Over-talking' - speaking more loudly than necessary	
d. The school and the voice Pressure to continue working when voice not 100%	
Inadequate understanding of the voice	

STEP 3 What are you already doing?	What further action is necessary?	STEP 4 How will you put the assessment into action & review it?			
List what is already in place to reduce the likelihood of voice damage or make any voice problems less serious.	Make sure that you have reduced the risks "so far as is reasonably practicable". Compare what you are doing with good practice. If there is a difference, list what needs to be done.	Remember to prioritise. Deal with those hazards that have serious consequences first.			
Factors for consideration:		Action	By whom	Done	Date
a. The working environment Policy on class sizes					
Classroom discipline policies					
Classroom support					
Teacher / pupil ratios					
Non-contact time					
b. Physical factors Classroom design					
Acoustics					
Availability of drinking water					
Staffroom facilities					
c. Personal factors Information available					
Occupational Health support					
d. The school and the voice A school voice policy					
Information on how the voice functions					
Access to professional voice advice					
Voice training					
Voice & professional development					

STEP 5 Review date	By whom

Voice
The union for education professionals

APPENDIX B - Ethical approval documentation

London South Bank
University

Ref: UREC 1283

Thursday, April 15, 2013

Dear Nicholas,

Re: An investigation into the effect of acoustics on vocal strain in teachers.

Thank you for submitting this proposal and for your response to the reviewers' comments.

I am pleased to inform you that Full Chair's Approval has been given by Chair on behalf of the University Research Ethics Committee.

I wish you every success with your research.

Yours sincerely,

Noopur Upadhyay

Assistant, LSBU Research Ethics Committee

cc:

Prof Joan Curzio, Chair, LSBU Research Ethics Committee

APPENDIX C - Invitation letter, participant information sheet and consent forms

Invitation Email

Dear Head Teacher,

Recent studies indicate that around 60% of British teachers experience voice problems and that this rate is far higher than for the general population.

The Acoustics Group at London South Bank University are undertaking research into speech levels in schools and the influence of classroom acoustics. The research is being supervised by Professor Bridget Shield, President of the Institute of Acoustics, and Dr Stephen Dance, Reader in Acoustics,

We are currently looking for schools to participate in the study and would like to invite you to take part.

The study will involve us undertaking measurements in empty classrooms to measure the acoustic conditions. In addition we will be measuring teachers' voice levels with compact equipment that the teacher wears for a teaching day along with a small discreet piece of equipment installed in the classroom to measure the classroom noise in general.

The measurements would be carried out over a working day, and repeated for a number of different staff members and classrooms on different days.

The tests will require around 15 minutes at the start of the day to calibrate the equipment with the teacher and also around 15 minutes prior to the teaching starting to install the equipment in the classroom. Testing of the unoccupied classroom acoustics can be performed outside school hours or term time as required and will take around 30 minutes per classroom.

To provide further details of the study I have enclosed a copy of the teacher information sheet which would be given to all participants in the study.

If you would like further information, or would like to take part in the study please contact myself Nick Durup, (durupn@lsbu.ac.uk) or Professor Bridget Shield (shield@lsbu.ac.uk).

We will then contact you to provide further information and/or to arrange a convenient time for you to participate.

Further information on the Acoustics Group can be found at: http://www.lsbu.ac.uk/esbe/research/acoustics.shtml and on Bridget, Stephen and myself at:

http://profbridgetshield.blogspot.co.uk/
http://drstephendance.blogspot.co.uk/
http://mrnickdurup.blogspot.co.uk/

Best Regards,

Nick Durup,

PhD Student, Acoustics Group, London South Bank University.

Research Participant Information and Consent Form

1. Research description.

You are being asked to participate in a research study into school acoustics and the teaching voice.

You must be at least 18 years old to participate in this research.

You will be asked to wear a small measuring device for a working day. The device measures vibration from your voice via a pad temporarily fixed to your neck. This pad is attached with a medical adhesive which is easily removed with an alcohol wipe following the measurements.

Please note - the wipe will also remove nail polish.

If you are allergic to adhesives, such as those used in plasters, or to silicone you will be unable to participate in the study.

The neck pad is shown in the image below to give you an idea of what is involved. This can be then covered over with clothing or scarf etc. if you wish with no effect on the measurement.

It may help to wear a jacket, cardigan or similar on the day to cover the cable which normally will run down your back.

The pad is linked via a cable to a small box which is worn in a small bag around your waist, this is shown in the following picture:

The equipment must be set up at the start of the working day, which takes around 15 minutes somewhere quiet during which you will be asked to speak into a microphone at different speech levels, quiet, normal and loud.

In order to understand your teaching patterns and voice history the researcher will ask you a few questions, these will be confidential and your answers will be treated anonymously in any analysis.

You will be asked to sign a consent form and given a copy of the participant information sheet as well as a copy of your signed consent form.

You will then be asked to carry on with your day as normal, returning at the end of the day to have the equipment removed by the researcher.

In addition during the voice measurements a small sound level meter will be installed and running in your classroom. This will measure a number of different sound parameters through the day, it will be installed discreetly and it will not be noticeable. It does not make an audio recording.

The data gathered will be stored in a password protected electronic format accessible only by the investigator and supervisors. Any use of the data in public documents will be anonymised to comply with the relevant data protection requirements.

The data will be stored for no more than 10 years after completion of the research study.

2. Participants rights.

Participation in this research project is completely voluntary. You have the right to say no. You may change your mind at any time and withdraw. You may choose not to take part in a specific element, choose not to answer any questions in the question section or to stop participating at any time with no consequences. You also can ask for someone of your choosing to be present, or no-one present, during the equipment fitting. If you wish to do it yourself with no-one present a mirror and instructions can be provided.

3. Contact information for questions or concerns

If you have concerns or questions about this study please contact the researcher Nick Durup (durupn@lsbu.ac.uk). Further information on the Acoustics Group can be found at: www.lsbu.ac.uk/esbe/research/acoustics

This study has been reviewed and approved by London South Bank University's University Research Ethics Committee.

If you experience any issues that you are unable to resolve with the research team you can contact the Chair of the University Research Ethics Committee at ethics@lsbu.ac.uk.

If you have general concerns or questions relating to your voice or hearing you should contact your GP in the first instance. Further information for the professional voice user can be accessed via:

The British Voice Association (www.britishvoiceassociation.org.uk)

The Voice Care Network (www.voicecare.org.uk)

London South Bank University

Participant Consent Form

Title of study: School acoustics and the Teaching Voice

Name of Participant:

- I have read the attached information sheet on the research in which I have been asked to participate and have been given a copy to keep. I have had the opportunity to discuss the details and ask questions about this information.
- The Researcher has explained the nature and purpose of the research and I believe that I understand what is being proposed.
- I have been informed that the proposed study involves monitoring which has been explained to me, together with possible risks involved.
- I understand that the study will include a small pad being temporarily fixed to my neck using a medical adhesive and consent to this.
- I confirm that I am not allergic to adhesives such as those used on sticking plasters or to silicone.
- I understand that my personal involvement and my particular data from this study will remain strictly confidential. Only researchers involved in the study will have access.
- I have been informed about what the data collected will be used for, to whom it may be disclosed, and how long it will be retained.
- I have received satisfactory answers to all of my questions
- I hereby fully and freely consent to participate in the study which has been fully explained to me.

- I understand that I am free to withdraw from the study at any time, without giving a reason for withdrawing.

Participant's Name: (Block Capitals) ....

Participant's Name: Signature ....

Participant's Witness' Name: ....

Witness' Signature: ....

As the Researcher responsible for this study I confirm that I have explained to the participant named above the nature and purpose of the research to be undertaken.

Researcher's Name: ....

Researcher's Signature: ....

If you are at all concerned about this research study please contact:

Mr Nick Durup (durupn@lsbu.ac.uk)

If you experience any issues that you are unable to resolve with the research team you can contact the Chair of the University Research Ethics Committee at ethics@lsbu.ac.uk.

All copies of the completed consent forms are retained securely on file by the researcher.

APPENDIX D - Classroom floorplans and photographs

School 1 (pilot study)

Figure D.1: Ground floor plan

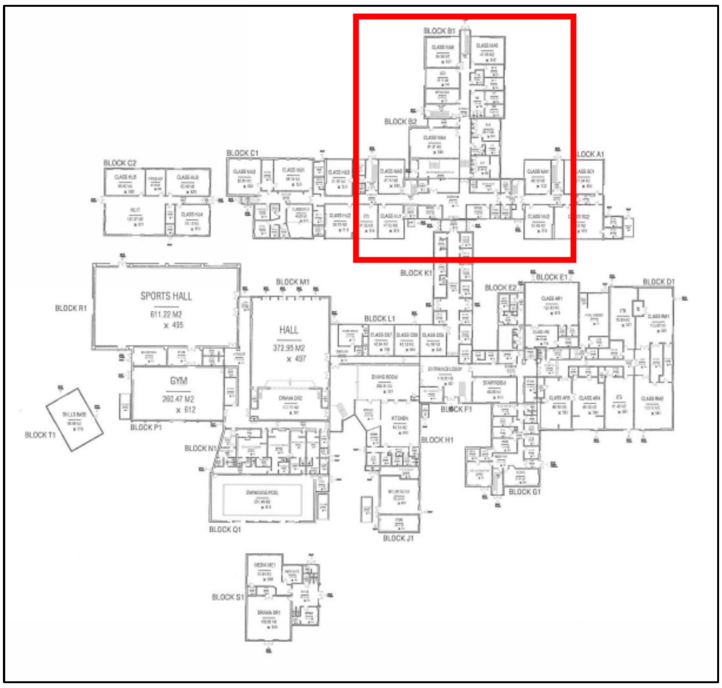
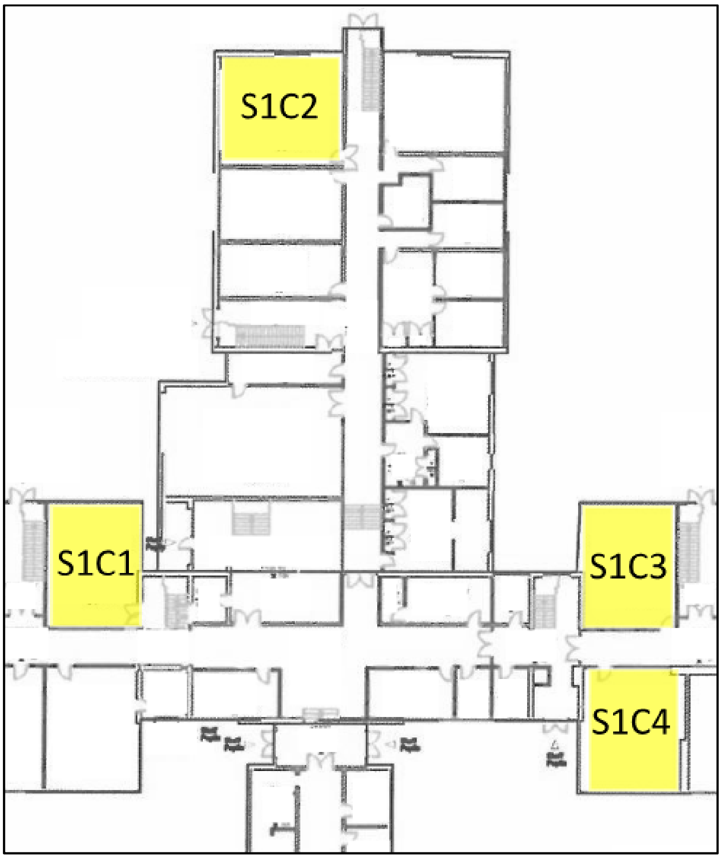


Figure D.2: School 1 Classrooms (pilot study)



School 1 Classroom photos (pilot study)

Figure D.3: S1C1

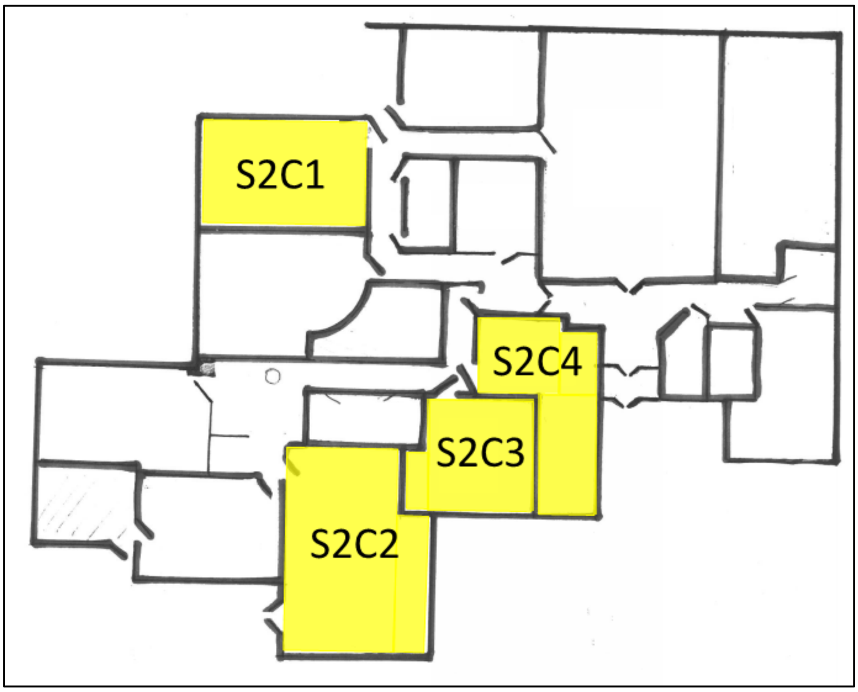
Figure D.4: S1C2

Figure D.5: S1C3

Figure D.6: S1C4

School 2 plans

Figure D.7: Ground floor



School 2 classroom photos

Figure D.8: S2C1

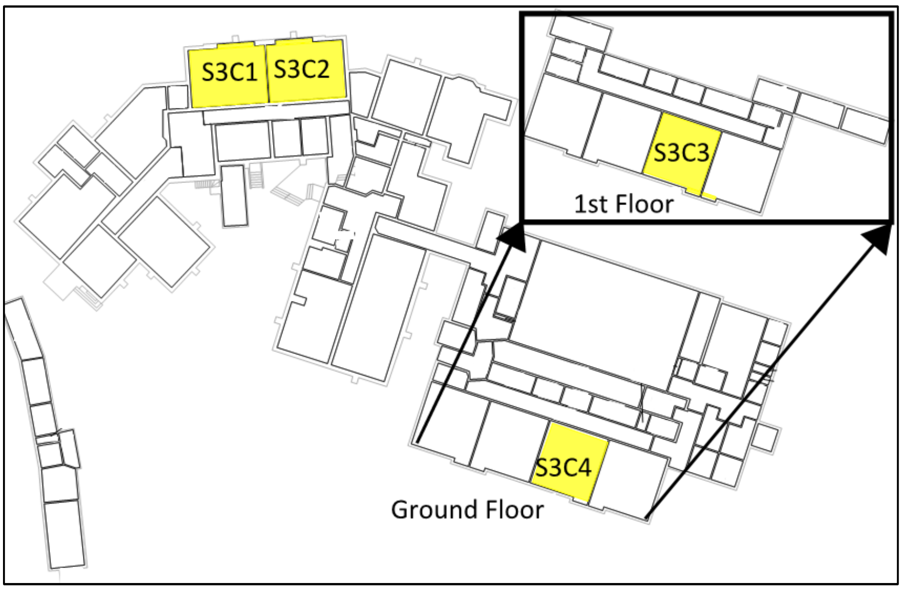
Figure D.9: S2C2

Figure D.10: S2C3

Figure D.11: S2C4

School 3 plans

Figure D.12: School 3 plans



School 3 classroom photos

Figure D.13: S3C1

Figure D.14: S3C2

Figure D.15: S3C3

Figure D.16: S3C4

School 4 plans

Figure D.17: Ground floor

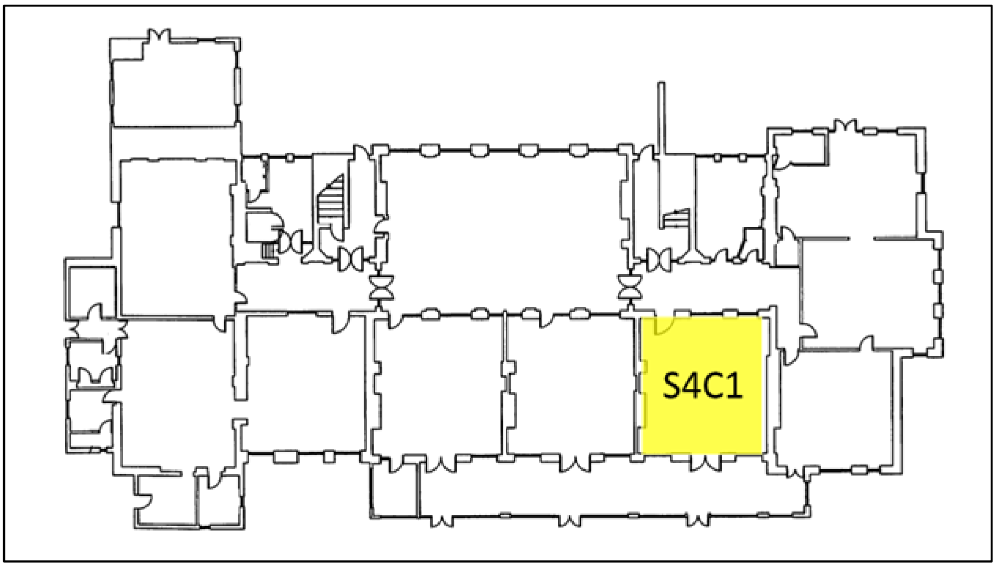


Figure D.18: First floor

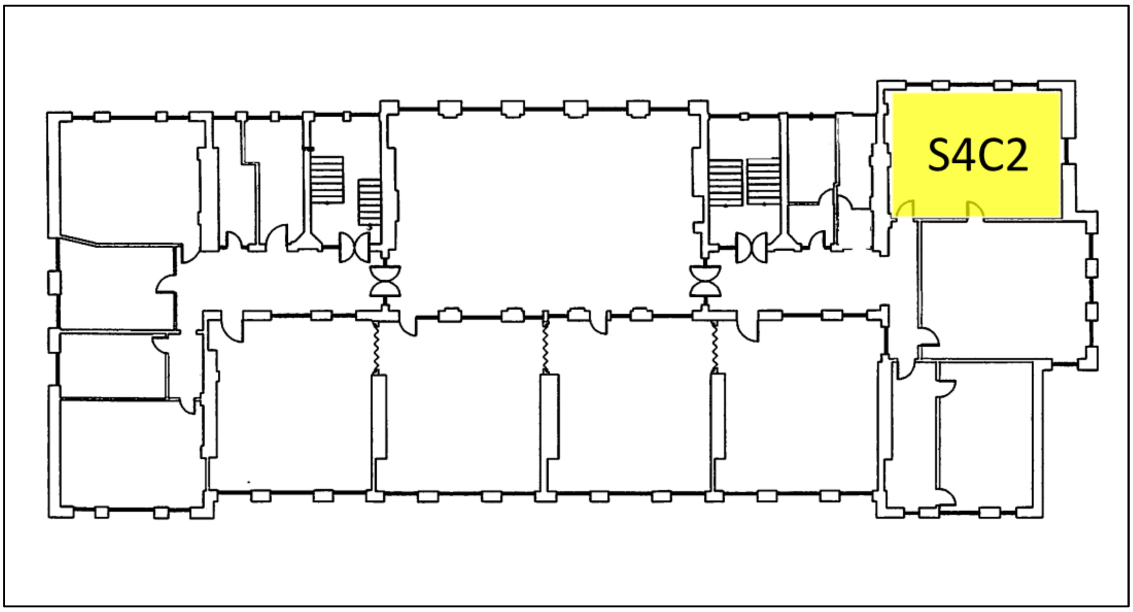
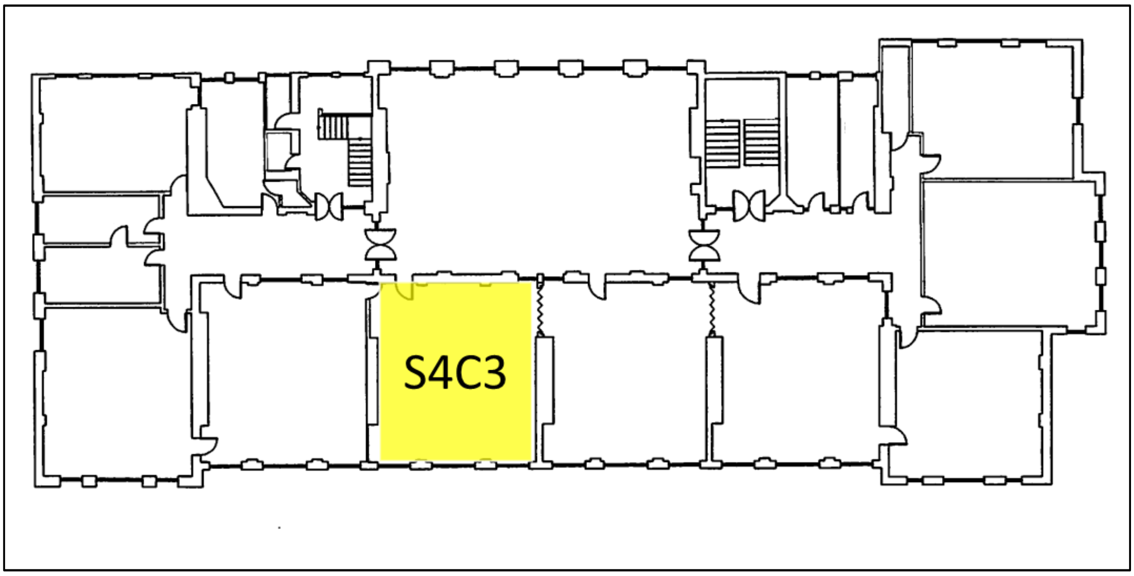


Figure D.19: Second floor

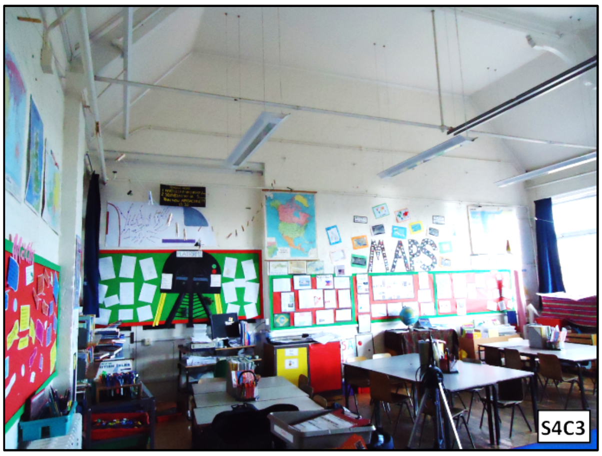


School 4 classroom photos

Figure D.20: S4C1

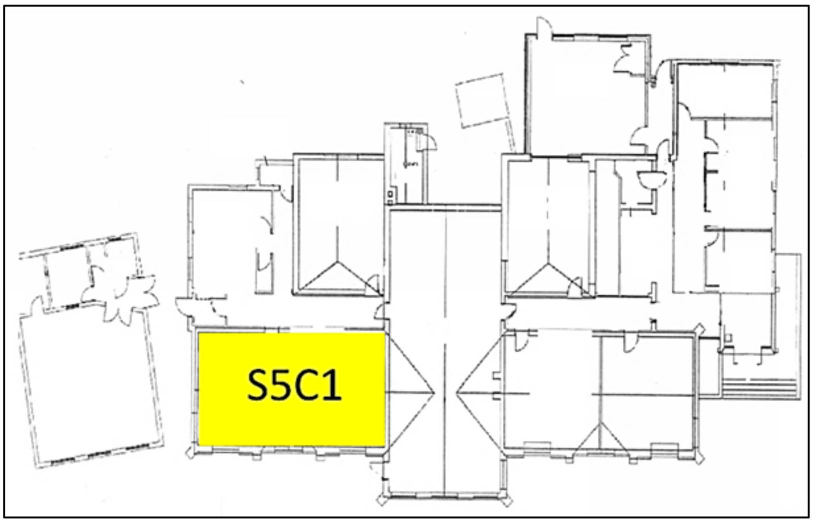
Figure D.21: S4C2

Figure D.22: S4C3



School 5 plans

Figure D.23: Ground floor

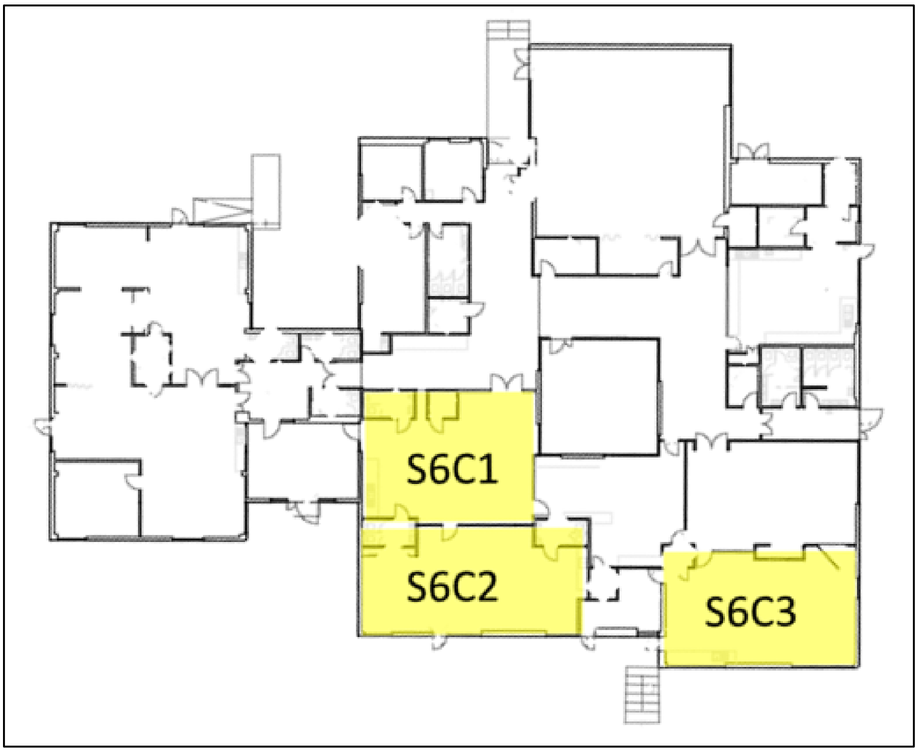


School 5 classroom photos

Figure D.24: S5C1

School 6

Figure D.25: Ground floor



School 6 classroom photos

Figure D.26: S6C1

Figure D.27: S6C2

Figure D.28: S6C3

APPENDIX E - Participant questionnaire for voice measurements

London South Bank University

Participant Questionnaire

Title of study: School acoustics and the Teaching Voice

Participant number..............................

Participant date of birth......./....../.......

Date...../...../......

Section 1		Yes	No
1	Do you take any medication regularly? (eg blood pressure pills, HRT, anti-depressants)		
2	Do you have any allergies?		
3	Do you have any joint or muscle problems?		
4	Have you any mobility problems?		
5	Do you have any chest problems affecting your breathing?		
6	Do you have asthma?		
7	Do you regularly use inhalers?		
8	Are you ever short of breath?		
9	Do you have any recurring viral illness? (eg post-viral fatigue syndrome, ME)		
10	Have you had open-heart surgery?		

Section 2		Yes	No
1	Have you ever noticed any change in the way your voice sounds?		
2	Were you ever hoarse as a child?		
3	Have you ever completely lost your voice?		
4	Do you often have throat infections?		
5	Have you ever had any surgery to your throat?		
6	Have you ever had a traumatic injury to your throat?		
7	Have you any recurring ear, nose or throat problems?		
8	Has a problem with your voice ever limited your activities?		
9	Have you ever sought advice from anyone regarding your voice?		
10	Have you ever had speech and language therapy due to a problem with your voice?		

Section 3	Yes	No
1 Do you have a hoarse voice?		
2 Does your throat or mouth often feel dry?		
3 Do you often want to clear your throat?		
4 Do you regularly have a lot of catarrh?		
5 Do you regularly have acid reflux? (eg heartburn or indigestion)		
6 Do you ever feel as if you have a lump in your throat?		
7 Do you ever feel tension or constriction in your throat?		
8 Does your voice ever feel tired?		
9 Do you feel any pain or discomfort when you use your voice?		
10 Does it take a lot of effort to talk?		

Section 4	Yes	No
1 Do you smoke?		
2 Do you drink a lot of tea, coffee or other drinks containing caffeine?		
3 Do you drink less than two litres of water a day?		
4 Do you frequently eat dairy produce and/or carbohydrates?		
5 Do you frequently eat hot and spicy food?		
6 Do you often shout?		
7 Do you often use your voice when you have a sore throat?		
8 Are you ever hoarse after a night out?		
9 Do you ever worry about your voice?		
10 Do you feel you neglect to care for your voice?		

Section 5	Yes	No
1 Do you use your voice a lot at home or at work?		
2 Do you have to speak for long periods without rest?		
3 Do you feel that you use your voice too much?		
4 Do you put too many demands on your voice?		
5 Do you have to talk over background noise? (eg children, television, music, equipment)		
6 Would you have to leave your current occupation if you lost your voice?		
7 Have you ever had to change your job because of a problem with your voice?		
8 Do you regularly meet anyone who is hard of hearing?		
9 Do you feel that your voice deteriorates the more you use it?		
10 Does your voice recover with voice rest?		

Section 6	Yes	No
1 Do you feel that your voice has altered over the past year?		
2 Do you feel that your voice has altered in loudness?		
3 Do you feel that your voice has altered in pitch?		
4 Does your voice quality vary during the day?		
5 Do you feel that your voice is less flexible that it used to be?		
6 Does your voice ever break?		
7 When you speak or sing, are you ever uncertain about how your voice will sound?		
8 Do you frequently find it difficult to make yourself heard?		
9 Are you unhappy with how your voice sounds?		
10 Do people ever comment adversely on your voice?		

Section 7	Yes	No
1 Are you in a dry atmosphere for any length of time during the day?		
2 Do you often work in conditions with poor air quality?		
3 Do you find the temperature level uncomfortable, either at home or at work?		
4 Are there times during your week when you are in a difficult acoustic environment?		
5 Would your voice benefit from adaptations in your workplace?		
6 Do you talk to people at some distance from you?		
7 Do you sit in one position for long periods of time?		
8 Does your work cause you physical discomfort? (eg back pain, stiff neck/shoulders)		
9 Do you have many changes of environment during your day? (eg indoors/outdoors)		
10 Do you feel that you have insufficient breaks during your day?		

The questions used were taken from The Voice Impact Profile authored by Martin and Lockhart [161].

Table E.1: Participant questionnaire responses data

Questionnaire results (1 = yes, 0 = no). * Estimated age.

No.	Question	Participant number																				%	
		Pilot				Main study																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
1	Gender	F	M	M	F	F	F	F	F	F	M	F	F	F	M	F	F	M	F	F	M		
2	Age	24	27	38	34	38	39	60*	49	59	38	30	22	33	28	46	45	28	27	23	27	Yes	No
5	Do you take any medication regularly (e.g. blood pressure pills, HRT, anti-depressants)?	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	15	85
6	Do you have any allergies?	0	1	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	30	70
7	Do you have any joint or muscle problems?	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	15	85
8	Have any mobility problems?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
9	Do you have any chest problems affecting your breathing?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
10	Do you have asthma?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
11	Do you regularly use inhalers?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
12	Are you ever short of breath?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
13	Do you have any recurring viral illness (e.g. post viral fatigue syndrome, ME)?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
14	Have you ever had open-heart surgery?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
15	Have you ever noticed any change in the way your voice sounds?	0	1	0	0	1	1	0	0	1	0	0	0	1	1	0	1	0	0	0	0	35	65
16	Were you ever hoarse as a child?	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	95
17	Have you ever completely lost your voice?	1	1	0	1	1	1	0	0	1	0	1	1	1	0	1	0	1	0	0	1	60	40
18	Do you often have throat infections?	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	10	90
19	Have you ever had any surgery to your throat?	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	95
20	Have you ever had a traumatic injury to your throat?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
21	Have you any recurring ear, nose or throat problems?	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	95
22	Has a problem with your voice ever limited your activities?	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	0	1	0	25	75
23	Have you ever sought advice from anyone regarding your voice?	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	90
24	Have you ever had speech and language therapy due to a problem with your voice?	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	95
25	Do you have a hoarse voice?	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	95
26	Does your throat or mouth often feel dry?	0	0	0	1	1	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	25	75
27	Do you often want to clear your throat?	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	20	80
28	Do you regularly have a lot of catarrh?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
29	Do you regularly have acid reflux? (e.g. heartburn or indigestion)?	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	90
30	Do you ever feel as if you have a lump in your throat?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5	95

No.	Question	Participant number																				%	
		Pilot				Main study																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Yes	No
31	Do you ever feel tension or constriction in your throat?	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	15	85
32	Does your voice ever feel tired?	0	1	0	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	50	50
33	Do you feel any pain or discomfort when you use your voice?	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	15	85
34	Does it take a lot of effort to talk?	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	95
35	Do you smoke?	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	90
36	Do you drink a lot of tea, coffee or other drinks containing caffeine?	0	1	0	0	1	0	1	1	1	0	1	0	0	0	0	0	1	0	1	1	45	55
37	Do you drink less than two litres of water a day?	1	1	0	1	1	1	0	0	-	0	-	1	1	1	0	0	1	1	1	0	61	39
38	Do you frequently eat dairy produce and/or carbohydrates?	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	90	10
39	Do you frequently eat hot and spicy food?	1	1	1	1	0	1	0	0	1	0	0	1	1	1	0	0	0	0	0	1	50	50
40	Do you often shout?	0	1	0	1	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	25	75
41	Do you often use your voice when you have a sore throat?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	90	10
42	Are you ever hoarse after a night out?	0	0	0	1	0	1	0	0	0	1	1	0	1	1	0	1	0	0	0	1	40	60
43	Do you ever worry about your voice?	0	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	25	75
44	Do you feel you neglect to care for your voice?	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	15	85
45	Do you use your voice a lot at home or at work?	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	90	10
46	Do you have to speak for long periods without rest?	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	90	10
47	Do you feel that you use your voice too much?	0	1	0	1	1	1	0	0	1	0	1	1	0	1	1	0	1	0	1	1	60	40
48	Do you put too many demands on your voice?	0	1	0	1	1	1	0	0	1	0	1	1	1	1	1	0	1	0	1	1	65	35
49	Do you have to talk over background noise? (e.g. children, television, music, equipment	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	90	10
50	Would you have to leave your current occupation if you lost your voice?	1	1	1	1	1	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	85	15
51	Have you ever had to change your job because of a problem with your voice?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
52	Do you regularly meet anyone who is hard of hearing?	1	1	1	1	0	0	0	1	-	0	0	0	0	0	0	0	0	0	0	1	32	68
53	Do you feel that your voice deteriorates the more you use it?	0	0	0	0	1	1	0	0	0	0	0	1	0	1	1	0	1	0	0	1	35	65
54	Does your voice recover with voice rest?	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	90	10
55	Do you feel that your voice has altered over the past year?	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	20	80
56	Do you feel that your voice has altered in loudness?	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	20	80
57	Do you feel that your voice has altered in pitch?	0	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	20	80
58	Does your voice quality vary during the day?	0	1	0	0	1	1	0	1	0	0	1	0	1	0	1	0	0	1	1	1	50	50
59	Do you feel that your voice is less flexible that it used to be?	0	0	0	0	1	1	0	0	1	0	1	0	0	0	1	0	0	1	0	0	30	70
60	Does your voice ever break?	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	10	90

No.	Question	Participant number																				%	
		Pilot				Main study																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Yes	No
61	When you speak or sing, are you ever uncertain of how your voice will sound?	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	20	80
62	Do you frequently find it difficult to make yourself heard?	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5	95
63	Are you unhappy with how your voice sounds?	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	15	85
64	Do people ever comment adversely on your voice?	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10	90
65	Are you in a dry atmosphere for any length of time during the day?	0	n/a	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	89
66	Do you often work in conditions with poor air quality?	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	10	90
67	Do you find the temperature level uncomfortable, either at home or at work?	0	0	0	1	1	1	0	0	0	0	0	1	0	1	0	0	1	0	0	1	35	65
68	Are there times during the week when you are in a difficult acoustic environment?	0	0	0	0	0	1	1	0	1	1	1	0	0	0	0	1	0	0	0	1	35	65
69	Would your voice benefit from adaptations in your workplace?	0	1	0	0	1	0	0	0	-	1	1	1	0	1	0	1	1	0	0	1	47	53
70	Do you talk to people at some distance from you?	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	85	15
71	Do you sit in one position for long periods of time?	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	5	95
72	Does your work cause you physical discomfort? (e.g. back pain, stiff neck/shoulders)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5	95
73	Do you have many changes of environment during your day? (e.g. indoors/outdoors)	0	0	0	0	1	0	1	1	0	0	0	0	1	0	1	1	1	0	1	1	45	55
74	Do you feel that you have insufficient breaks during your day?	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	1	0	1	1	30	70
77	Have you had any voice training? (oral question)	1	0	0	1	0	0	1	0	1	0	1	0	0	1	1	1	1	0	0	1	50	50

APPENDIX F - Unoccupied classroom acoustic data

Spectral data from 8 Hz to 16 kHz was measured and is retained on file. Values from 63 Hz to 4 kHz only are reported in this section as this is the core range of interest.

All decibel values are corrected to the nearest whole decibel.

The dBA values are calculated from the full spectrum range and therefore may not be equal to the logarithmic sum of the spectral values included here.

Table F.1: Mean EDT

School	Classroom	EDT Octave band centre frequency Hz							EDT_{mf}
		63	125	250	500	1000	2000	4000	
S1* Pilot study	S1C1	0.8	0.6	0.6	0.4	0.4	0.4	0.4	0.4
	S1C2	1.2	1.3	1.3	1.3	1.2	1.0	0.7	1.2
	S1C3	0.5	0.4	0.4	0.3	0.3	0.4	0.4	0.3
	S1C4	0.9	0.9	0.9	1.0	0.9	0.8	0.5	0.9
S2	S2C1	0.6	0.6	0.7	0.7	0.6	0.6	0.5	0.6
	S2C2	0.6	0.7	0.5	0.5	0.5	0.5	0.4	0.5
	S2C3	0.6	0.6	0.9	0.8	0.5	0.4	0.5	0.5
	S2C4	0.8	0.9	0.9	0.5	0.5	0.4	0.3	0.5
S3	S3C1	0.8	0.6	0.7	0.8	0.9	0.8	0.7	0.8
	S3C2	0.9	0.8	0.8	0.9	0.9	0.8	0.7	0.9
	S3C3	0.8	0.8	0.7	0.8	0.7	0.6	0.5	0.7
	S3C4	0.8	0.7	0.4	0.3	0.3	0.3	0.3	0.3
S4	S4C1	0.9	0.8	1.0	1.1	1.1	1.0	0.8	1.0
	S4C2	2.1	1.6	1.1	0.9	0.8	0.7	0.6	0.8
	S4C3	1.0	1.0	0.9	1.0	1.0	0.9	0.8	1.0
S5	S5C1	0.7	0.6	0.8	0.8	0.9	0.8	0.7	0.8
S6	S6C1	0.5	0.4	0.5	0.4	0.4	0.3	0.3	0.4
	S6C2	0.3	0.4	0.5	0.4	0.3	0.3	0.3	0.3
	S6C3	0.6	0.6	0.5	0.4	0.3	0.3	0.3	0.3

*EDT values for school S1 courtesy of Jack Harvie-Clark and Nick Dobinson of Apex Acoustics.

Table F.2: Mean T_{20}

School	Classroom	T_{20} Octave band centre frequency Hz							T_{mf}
		63	125	250	500	1000	2000	4000	
S1 Pilot study	S1C1	0.8	0.5	0.6	0.5	0.4	0.4	0.3	0.4
	S1C2	1.4	1.4	1.3	1.2	1.0	0.9	0.6	1.0
	S1C3	0.7	0.4	0.4	0.4	0.3	0.3	0.3	0.3
	S1C4	1.3	0.8	0.9	1.0	0.9	0.8	0.5	0.9
S2	S2C1	0.6	0.7	0.7	0.7	0.7	0.6	0.5	0.7
	S2C2	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5
	S2C3	0.6	0.7	0.6	0.6	0.5	0.5	0.4	0.5
	S2C4	0.8	0.8	0.7	0.6	0.6	0.5	0.4	0.6
S3	S3C1	1.6	0.9	0.7	0.9	0.9	0.8	0.7	0.8
	S3C2	1.0	0.9	0.9	0.9	0.9	0.8	0.7	0.9
	S3C3	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.7
	S3C4	1.1	0.6	0.5	0.3	0.3	0.4	0.3	0.3
S4	S4C1	1.2	0.9	1.1	1.1	1.1	1.0	0.8	1.1
	S4C2	2.7	1.7	1.2	0.9	0.8	0.7	0.6	0.8
	S4C3	1.2	1.1	1.0	1.0	1.1	1.0	0.8	1.0
S5	S5C1	0.8	0.8	0.9	0.9	0.9	0.9	0.7	0.9
S6	S6C1	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4
	S6C2	0.6	0.6	0.6	0.4	0.3	0.3	0.3	0.4
	S6C3	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.4

Table F.3: Unoccupied classroom L_{eq} noise levels

S	C	L_{Aeq} dB unoccupied	L_{eq} Octave band centre frequency Hz						
			63	125	250	500	1k	2k	4k
S1 Pilot study	S1C1	23	32	29	18	16	17	15	13
	S1C2	28	38	27	27	26	22	18	14
	S1C3	24	42	26	26	18	16	13	13
	S1C4	27	39	30	26	21	21	21	16
S2	S2C1	35	42	38	37	31	31	26	21
	S2C2	35	39	45	37	33	29	24	21
	S2C3	29	38	41	30	23	20	19	18
	S2C4	37	38	38	37	34	30	30	26
S3	S3C1	37	52	42	40	33	32	28	18
	S3C2	38	55	51	39	33	30	26	17
	S3C3	28	44	34	33	23	19	14	12
	S3C4	28	42	35	28	24	24	15	14
S4	S4C1	29	44	31	27	26	26	18	16
	S4C2	32	40	32	31	28	28	22	15
	S4C3	30	41	33	27	23	26	23	22
S5	S5C1	32	36	32	30	28	22	24	27
S6	S6C1	29	38	35	31	26	21	19	17
	S6C2	26	38	35	30	22	17	13	15
	S6C3	30	40	39	30	25	26	19	15

Table F.4: Unoccupied classroom L_1 noise levels

S	C	L_{A1} dB unoccupied	L_1 Octave band centre frequency Hz						
			63	125	250	500	1k	2k	4k
S1 Pilot study	S1C1	32	43	38	27	25	29	25	18
	S1C2	33	44	36	34	29	29	26	21
	S1C3	27	44	30	28	22	22	19	16
	S1C4	33	48	37	32	30	29	28	22
S2	S2C1	38	47	42	39	32	34	30	28
	S2C2	41	44	47	41	38	35	31	30
	S2C3	34	41	43	32	26	26	26	25
	S2C4	40	51	45	41	37	33	33	30
S3	S3C1	44	62	51	48	39	37	33	26
	S3C2	49	65	65	50	42	38	35	25
	S3C3	33	50	38	35	30	28	24	16
	S3C4	36	49	47	40	34	28	18	15
S4	S4C1	32	52	35	29	28	27	22	23
	S4C2	33	45	35	34	30	29	24	16
	S4C3	33	46	40	31	25	28	27	26
S5	S5C1	34	45	37	33	30	25	27	29
S6	S6C1	34	43	37	35	31	27	29	25
	S6C2	30	43	39	37	25	22	20	22
	S6C3	39	44	45	36	33	38	27	24

Table F.5: Unoccupied classroom L_{90} noise levels

S	C	L_{A90} dB unoccupied	L_{90} Octave band centre frequency Hz						
			63	125	250	500	1k	2k	4k
S1 Pilot study	S1C1	20	27	23	13	10	10	10	11
	S1C2	25	34	24	21	25	15	12	11
	S1C3	23	41	23	25	17	10	10	12
	S1C4	23	36	27	23	17	13	13	12
S2	S2C1	34	39	36	36	30	29	24	17
	S2C2	34	37	43	36	32	28	22	19
	S2C3	27	36	40	29	22	16	12	11
	S2C4	37	33	36	36	33	28	30	25
S3	S3C1	33	41	33	31	27	29	24	15
	S3C2	28	39	32	30	25	23	17	14
	S3C3	26	41	33	31	21	14	10	11
	S3C4	26	39	29	22	20	23	14	14
S4	S4C1	29	40	29	26	25	25	17	11
	S4C2	32	38	30	30	28	28	22	14
	S4C3	29	38	30	25	22	24	22	20
S5	S5C1	31	28	30	28	26	20	22	25
S6	S6C1	27	36	34	29	22	19	17	16
	S6C2	25	36	34	28	21	16	11	12
	S6C3	26	37	36	28	21	14	11	11

APPENDIX G - Occupied classroom acoustic data

The values given are the arithmetic mean of the 1 hour measurements during the teaching day for each participant.

Table G.1: Occupied noise levels acoustic data Participant 1 (pilot study) classroom S1C2

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	63	60	53	60	61	60	55	48
L_{90}	37	45	37	36	36	29	24	19
L_{fmax}	89	93	82	92	86	86	83	78

Table G.2: Occupied noise levels acoustic data Participant 2 (pilot study) classroom S1C1

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	60	59	52	60	58	54	51	44
L_{90}	40	53	38	39	37	32	29	24
L_{fmax}	87	86	81	92	86	81	80	71

Table G.3: Occupied noise levels acoustic data Participant 3 (pilot study) classroom S1C3

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	60	55	49	54	57	56	51	45
L_{90}	41	46	39	37	36	36	32	25
L_{fmax}	86	85	78	84	84	83	80	76

Table G.4: Occupied noise levels acoustic data Participant 4 (pilot study) classroom S1C4

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	64	56	58	63	62	60	57	49
L_{90}	45	41	40	43	43	38	35	28
L_{fmax}	91	87	89	96	86	86	85	76

Table G.5: Occupied noise levels acoustic data Participant 5 classroom S2C3

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	69	63	60	64	67	66	58	52
L_{90}	45	47	50	45	42	37	30	26
L_{fmax}	93	100	90	86	89	92	84	80

Table G.6: Occupied noise levels acoustic data Participant 6 classroom S2C4

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	69	55	53	60	66	64	57	53
L_{90}	41	41	45	41	40	32	26	22
L_{fmax}	91	90	86	83	87	89	84	80

Table G.7: Occupied noise levels acoustic data Participant 7 classroom S3C2

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	67	62	55	59	63	63	59	54
L_{90}	50	50	44	48	47	44	39	33
L_{fmax}	88	85	80	80	83	85	82	78

Table G.8: Occupied noise levels acoustic data Participant 8 classroom S5C1

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	63	61	59	58	61	59	54	49
L_{90}	42	40	38	39	40	36	32	27
L_{fmax}	87	91	88	86	87	83	78	75

Table G.9: Occupied noise levels acoustic data Participant 9 classroom S4C2

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	67	58	57	62	65	63	58	53
L_{90}	50	43	40	45	47	45	41	35
L_{fmax}	89	92	89	86	88	87	81	79

Table G.10: Occupied noise levels acoustic data Participant 10 classroom S4C3

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	66	61	57	61	63	63	56	49
L_{90}	45	47	44	41	42	39	35	30
L_{fmax}	89	92	86	88	86	88	81	76

Table G.11: Occupied noise levels acoustic data Participant 11 classroom S6C1

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	65	57	57	63	63	61	54	46
L_{90}	45	41	43	45	42	38	32	24
L_{fmax}	91	90	94	95	91	88	82	74

Table G.12: Occupied noise levels acoustic data Participant 12 classroom S6C3

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	64	50	52	57	62	60	55	49
L_{90}	41	38	41	39	38	33	29	23
L_{fmax}	92	84	81	85	90	91	85	79

Table G.13: Occupied noise levels acoustic data Participant 13 classroom S2C1

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	67	59	59	63	64	63	58	52
L_{90}	42	43	40	40	39	35	31	27
L_{fmax}	92	92	88	90	88	89	86	81

Table G.14: Occupied noise levels acoustic data Participant 14 classroom S3C1

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	63	64	55	58	61	59	53	48
L_{90}	46	53	45	44	44	39	35	29
L_{fmax}	86	85	79	78	83	85	78	73

Table G.15: Occupied noise levels acoustic data Participant 15 classroom S2C2

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	68	59	59	59	64	65	62	55
L_{90}	50	49	53	43	46	45	41	36
L_{fmax}	92	90	87	83	86	89	89	82

Table G.16: Occupied noise levels acoustic data Participant 16 classroom S4C1

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	71	62	60	67	69	67	62	57
L_{90}	48	46	41	45	45	42	37	32
L_{fmax}	92	88	86	93	91	89	87	81

Table G.17: Occupied noise levels acoustic data Participant 17 classroom S6C3

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	66	52	53	60	65	63	58	51
L_{90}	40	41	42	40	38	31	26	22
L_{fmax}	90	82	80	84	86	87	85	78

Table G.18: Occupied noise levels acoustic data Participant 18 classroom S6C2

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	68	51	54	65	67	65	58	50
L_{90}	41	36	38	42	39	33	26	21
L_{fmax}	94	85	86	91	93	92	85	78

Table G.19: Occupied noise levels acoustic data Participant 19 classroom S3C4

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	65	59	57	58	62	61	57	53
L_{90}	42	49	42	38	38	35	31	26
L_{fmax}	93	87	84	87	89	90	84	82

Table G.20: Occupied noise levels acoustic data Participant 20 classroom S3C3

Parameter	dBA	Octave band centre frequency Hz						
		63	125	250	500	1k	2k	4k
L_{eq}	67	60	61	63	65	63	59	52
L_{90}	49	51	49	46	45	44	39	33
L_{fmax}	91	90	89	89	92	89	85	78

Table G.21: Summary table of differences between UANL and occupied octave bands for L_{90}

Differences of <10 dB are highlighted in yellow

Participant number	Difference L_{90} UANL and occupied dB						
	Octave band centre frequency Hz						
	63	125	250	500	1k	2k	4k
1	21	16	12	21	17	13	6
2	30	25	29	27	22	18	11
3	23	14	21	26	26	20	11
4	14	17	26	30	25	23	15
5	7	21	23	26	25	19	13
6	5	9	8	12	2	1	1
7	18	14	23	25	28	25	19
8	11	10	13	20	14	7	6
9	13	10	17	19	24	27	21
10	17	19	19	18	17	15	14
11	7	15	23	23	21	16	9
12	2	13	18	24	22	18	10
13	7	4	10	10	11	14	12
14	20	14	17	15	15	20	16
15	6	17	11	18	23	22	19
16	17	15	20	20	26	26	19
17	5	14	19	24	20	15	9
18	3	10	21	23	22	14	7
19	20	20	18	15	21	17	12
20	19	19	26	31	34	28	19

Table G.22: Summary table of differences between UANL and occupied octave bands for L_{eq}

Differences of <10 dB are highlighted in yellow

Participant number	Difference L_{eq} UANL and occupied dB						
	Octave band centre frequency Hz						
	63	125	250	500	1k	2k	4k
1	22	26	33	36	38	37	34
2	27	23	42	42	38	36	31
3	13	24	28	39	40	38	32
4	17	28	37	41	39	36	33
5	25	19	34	44	46	40	34
6	17	15	23	32	34	27	27
7	7	4	20	31	33	33	37
8	25	27	29	33	37	30	23
9	18	25	31	37	35	36	38
10	20	24	34	40	38	33	27
11	19	22	32	37	40	35	29
12	10	13	27	37	34	36	34
13	17	21	26	33	33	33	31
14	12	13	18	28	27	26	30
15	20	14	22	31	36	38	34
16	18	29	40	43	42	44	42
17	12	14	30	40	37	39	36
18	13	19	36	45	48	45	35
19	17	23	30	38	38	42	39
20	16	27	30	42	44	45	40

APPENDIX H - Online survey for teachers

Figure H.1: Survey publicity in *Your Voice* magazine, no. 24, January 2014 [170]

Give voice to your opinions

By Nick Durup, LSBU Acoustics Group

Did you know that around 60% of UK teachers experience voice problems during their career or that these voice problems are estimated to cost £15 million annually in teacher absence?

Despite this, little research has been carried out into the issue. Possible ways to reduce the problem, such as voice training, remains largely absent from teacher training courses.

The Acoustics Group at London South Bank University (LSBU) is undertaking research in this area and would like your help in understanding more about the experiences of teachers.

The research group is running an online questionnaire for teachers, and would like to ask you about voice problems, sound, noise and acoustics in your school.

You are invited to fill out the survey, which will take about 15 minutes to complete. If necessary you can return and complete the survey at a later time once you have started.

The questionnaire is anonymous and all questions are optional – further details are given in the online introduction page.

Please access the questionnaire via **www.survey.bris.ac.uk/lsbu/voicesurvey** or the QR code.

Voice levels

In addition to the online questionnaire, the research team are hoping to measure teachers' voice levels in different acoustic environments in their schools.

If your school would be interested in participating in this, or if you would like further information on the project, please contact me (**durupn@lsbu.ac.uk**).

LSBU Acoustics Research Group

The project is supervised by Professor Bridget Shield and Dr Stephen Dance of the LSBU Acoustics Group and forms part of ongoing research into many aspects of the acoustic design of schools.

The Acoustics Group has long-standing involvement in research into school acoustics, including open plan classroom design, as well as direct involvement in developing the Building Regulations for acoustics in schools.

Further information on the Acoustics Research Group can be found at: **www.lsbu.ac.uk/research/centres-themes/sites/acoustics-group**

Resources

Voice has produced an information sheet, Voice Care, and Risk Assessment: Voice Care for members. Advice includes:

- Warm up your voice by humming gently or doing some vocal exercises.
- Drink water/juice at regular intervals.
- Ensure that the environment is well humidified (with plants or a bowl of water).
- Reduce background noise.
- Relax shoulders and neck.
- Breathe from the diaphragm.
- Wait until the class is quiet before speaking.
- Use a lower pitch of voice to gain children's attention, or signals such as sound (clap) or visual (raised hand). Use silence to emphasise or to get attention.
- Be sensitive to the first sign of vocal fatigue.

Avoid:

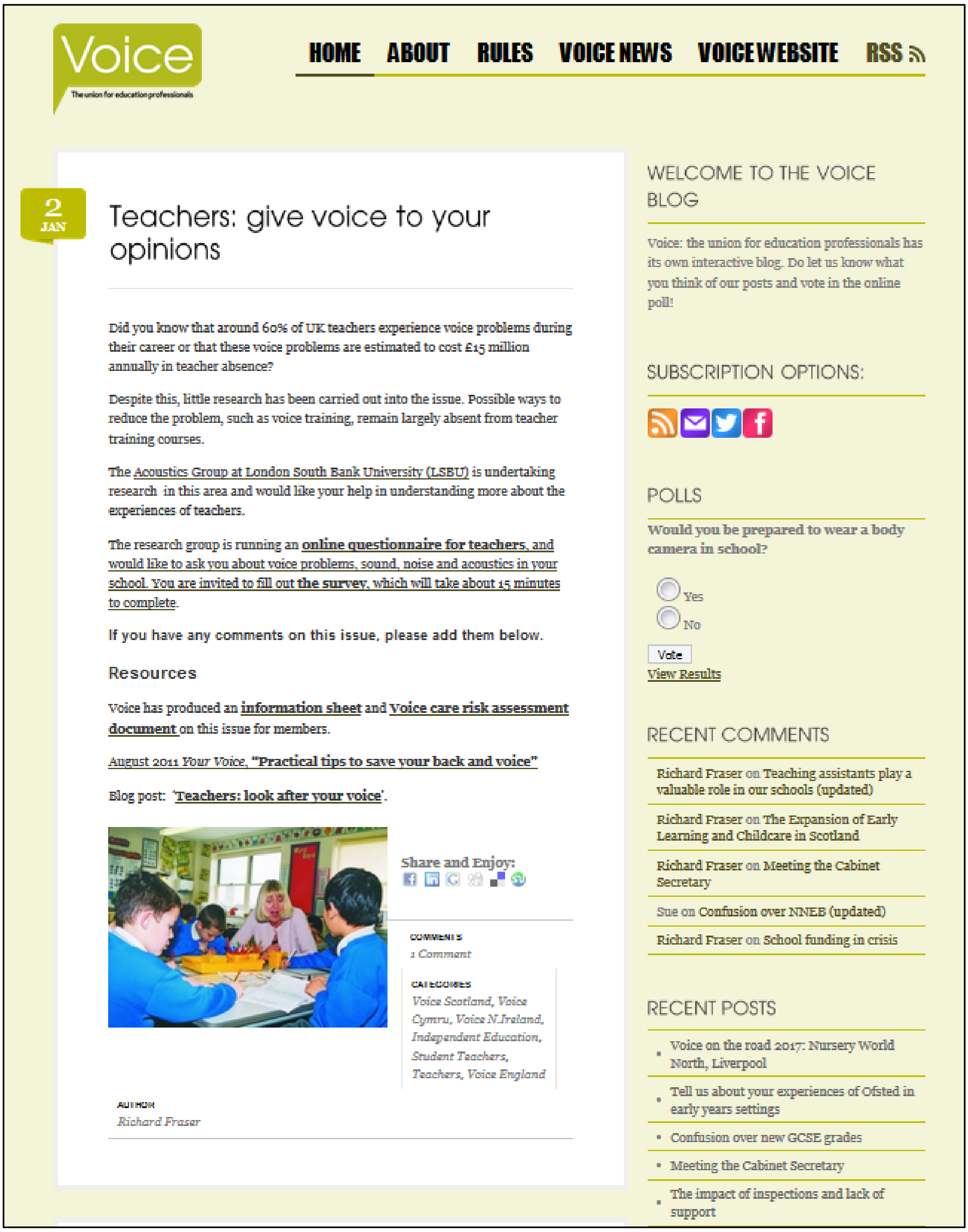
- smoking
- very hot foods and drinks
- speaking over noise /shouting
- raising your vocal volume or pitch over prolonged periods
- chalk/dust/fumes
- stress
- singing if your throat is sore, and
- excessive use of the telephone.

An article in the August 2011 issue of *Your Voice*, **'Practical tips to save your back and voice'**, also gives some **useful advice**.

All these resources can be accessed via the Blog post **'Teachers: look after your voice'** (**www.blog.voicetheunion.org.uk/?p=5735**).

8

Figure H.2: Survey publicity *Voice* blog [171]



Voice
The union for education professionals

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2 JAN

Teachers: give voice to your opinions

Did you know that around 60% of UK teachers experience voice problems during their career or that these voice problems are estimated to cost £15 million annually in teacher absence?

Despite this, little research has been carried out into the issue. Possible ways to reduce the problem, such as voice training, remain largely absent from teacher training courses.

The Acoustics Group at London South Bank University (LSBU) is undertaking research in this area and would like your help in understanding more about the experiences of teachers.

The research group is running an **online questionnaire for teachers**, and would like to ask you about voice problems, sound, noise and acoustics in your school. You are invited to fill out **the survey**, which will take about 15 minutes to complete.

If you have any comments on this issue, please add them below.

Resources

Voice has produced an **information sheet** and **Voice care risk assessment document** on this issue for members.

August 2011 *Your Voice*, **"Practical tips to save your back and voice"**

Blog post: '**Teachers: look after your voice**'.

Share and Enjoy:

COMMENTS
1 Comment

CATEGORIES
Voice Scotland, Voice Cymru, Voice N.Ireland, Independent Education, Student Teachers, Teachers, Voice England

AUTHOR
Richard Fraser

WELCOME TO THE VOICE BLOG

Voice: the union for education professionals has its own interactive blog. Do let us know what you think of our posts and vote in the online poll!

SUBSCRIPTION OPTIONS:

POLLS

Would you be prepared to wear a body camera in school?

Yes
No

Vote
View Results

RECENT COMMENTS

- Richard Fraser on Teaching assistants play a valuable role in our schools (updated)
- Richard Fraser on The Expansion of Early Learning and Childcare in Scotland
- Richard Fraser on Meeting the Cabinet Secretary
- Sue on Confusion over NNEB (updated)
- Richard Fraser on School funding in crisis

RECENT POSTS

- Voice on the road 2017: Nursery World North, Liverpool
- Tell us about your experiences of Ofsted in early years settings
- Confusion over new GCSE grades
- Meeting the Cabinet Secretary
- The impact of inspections and lack of support

Figure H.3: Survey publicity in *The Teacher* magazine January 2014 [172]

Lend us your ears

The Acoustics Group at London South Bank University researches noise and acoustics in schools. It is running an online survey to gather information about possible links with health or voice problems and asks you to take part (whether or not you experience problems). This involves completing a short survey via the link or QR code below.

The researchers are also measuring teachers' voice levels in different acoustic environments. If your school would like to take part, email durupn@lsbu.ac.uk.

www.survey.bris.ac.uk/lsbu/voicesurvey

Figure H.4: NUT Twitter feed [173]

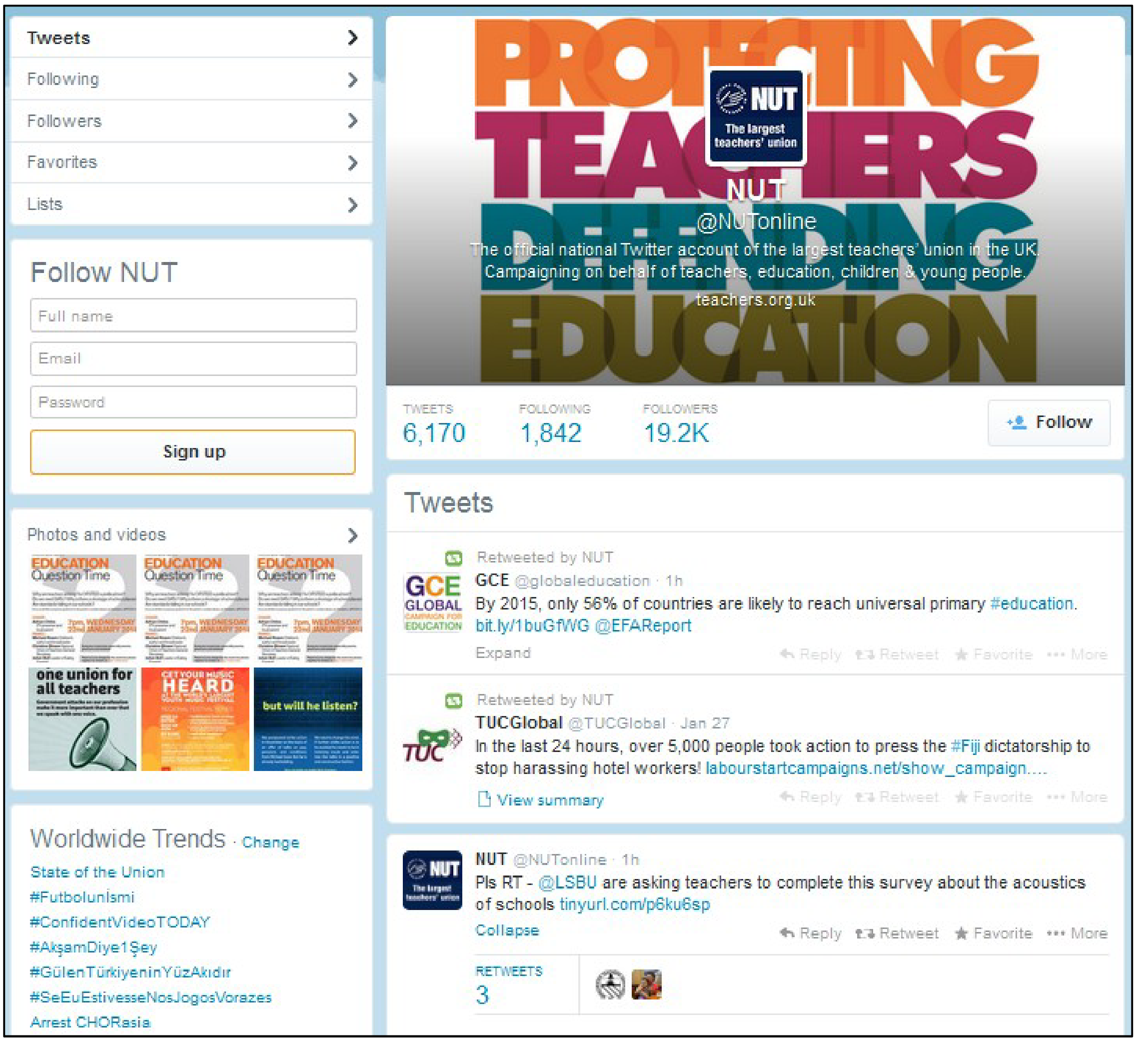

Figure H.5: LSBU Acoustics Group blog post [174]

friday, 17 january 2014

NUT Acoustics Survey goes live

On the 17th January 2014 PhD student Nick Durup's NUT Acoustics Survey went live. The survey targets UK teachers and requests their opinions of their classroom environment. You can find the survey here and more information here

posted by dr stephen dance at 03:06 no comments:

Figure H.6: Institute of Acoustics LinkedIn group [175]

Institute Of Acoustics

Discussions Members Search

Hello all, Do you know any teachers? Please could you pass on details of this London South Bank University online survey on acoustics to them: Any help is greatly appreciated. Nick

Nick Durup

Acoustic Consultant at Sharps Redmore Partnership Ltd.

Teachers' opinions wanted in an online survey:

The Acoustics Group at London South Bank University are currently running an online survey of teachers, to gather more information about the acoustics of schools and possible links with general health or voice problems.

We are keen for as many teachers as possible to take part (whether or not you experience voice or health problems, if you are a school teacher, a former or retired teacher, or have contacts who are that you could pass this on to, we would like to invite you to participate.

Please help by completing the survey, which is anonymous and takes about 15 minutes, via the link:

www.survey.bris.ac.uk/lsbu/voicesurvey

The research team are also measuring teachers' voice levels in different acoustic environments in their schools. If your school would be interested in participating please contact researcher Nick Durup (durupn@lsbu.ac.uk).

Online survey questions

Teaching Voice Survey

Page 1: Participant Information Sheet

1. Research description.

You are being asked to participate in a research study of school acoustics and the teacher's voice. This survey includes questions about you, your workplace and your teaching experiences and takes around 15 minutes to complete.

Please note that, to participate, you must be at least 18 years old and currently teach, be a former teacher or a retired teacher in the UK.

2. Participant rights and data protection.

Participation in this research project is completely voluntary. You may choose not to answer the survey after all, not to answer some of the questions or to stop participating at any time during the survey with no consequences.

Your responses will be anonymous and no personal information will be requested or held during the survey. The data gathered will be stored in a password protected electronic format accessible only to the research team. This data will be stored for no more than 10 years after completion of the survey.

Please note that once you have completed and submitted the survey it will not be possible to withdraw your data from the study. This is because, as the responses are anonymous, your particular submission would not be identifiable or traceable to enable it to be retracted.

3. Contact information for questions or concerns

If you have concerns or questions about this study please contact the researcher Nick Durup at durupn@lsbu.ac.uk.

This study has been reviewed and approved by London South Bank University's Research Ethics Committee. If you experience any issues that you are unable to resolve with the research team you may contact the Chair of the University Research Ethics Committee at ethics@lsbu.ac.uk.

If you have general concerns or questions relating to your voice or hearing you should contact your GP.

Further information for the professional voice user can be obtained from the following organisations:

The British Voice Association (www.britishvoiceassociation.org.uk)

The Voice Care Network (www.voicecare.org.uk)

4. Documentation of implied consent.

In completing and submitting the survey responses you are giving implied consent that you voluntarily agree to participate in this research study. Following submission of the survey you will not be able to modify or retract your responses due to the anonymous nature of the study.

Page 2: Questions

About you:

1. Are you:

- Male
- Female

2. What age are you:

3. Is English your first language?

- Yes
- No

4. Are you a:

- Current teacher
- Former teacher
- Retired teacher

If you are a retired teacher please answer subsequent questions based on your teaching experiences during your career.

Your teaching and your workplace

5. How many years have you been teaching?

- Less than 1
- 1-5
- 6-10
- 11-15
- 16-20
- 21-25
- 25+

6. Where do you teach?

- England
- Northern Ireland
- Scotland
- Wales

7. What type of teaching do you do?

7.a. If you selected Other, please specify:

7.b. [missing question text]

- [blank option]

8. What is your main subject area? If you teach in HE/FE please go to Q11 after answering this question.

8.a. If you selected Other, please specify:

9. Do you teach in the-

- State sector
- Private sector

10. If you teach in the state sector is the school -

- Local Authority School
- Academy

- Free School
- Not applicable - teach in the private sector
- Other

10.a. If you selected Other, please specify:

____

11. How is your classroom or teaching space normally laid out?

- ☐ Tables in clusters
- ☐ Tables in rows
- ☐ Tables in horse shoe (C-shaped)
- ☐ Sitting on carpet
- ☐ Laboratory benches
- ☐ Workshop
- ☐ Sports hall
- ☐ Drama studio
- ☐ Other

11.a. If you selected Other, please specify:

12. When were the rooms that you mainly teach in constructed (approximately)?

- ☐ Victorian
- ☐ 1960's
- ☐ 1970's
- ☐ 1980's
- ☐ 1990's
- ☐ 2000's
- ☐ New build
- ☐ Converted from another type of building
- ☐ Don't know
- ☐ Other

12.a. If you selected Other, please specify:

13. Do you teach in any open-plan spaces?

- Yes
- No

13.a. If you teach in open plan spaces how many hours a week do you spend teaching in these rooms?

14. How many pupils are there normally in the classes you teach?

15. Thinking about your main teaching room what are the room finishes?

	Tick all those that apply												
	Carpet	Vinyl	Wood	Plaster	Brick/ block	Concrete	Glass	Sound Absorbent wall panels	Ceiling tiles	Pin boards	Skylights	Other	Don't know
Floor	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Walls	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ceiling	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Your experiences

16. Have you experienced problems with your voice during your teaching career?If you answered no please go to Q23

- Yes
- No

17. If you experienced significant voice problems how would you describe them:

- ☐ Partial voice loss occasionally
- ☐ Partial voice loss frequently
- ☐ Total voice loss occasionally
- ☐ Total voice loss frequently
- ☐ Changes in voice quality or characteristics
- ☐ Pain and discomfort

- ☐ Not applicable - haven't experienced significant voice problems
- ☐ Other

17.a. If you selected Other, please specify:

18. If you have experienced voice problems did you seek help or advice from the following?

- ☐ Didn't seek help despite significant voice problems
- ☐ Colleagues
- ☐ ENT Specialist
- ☐ Friends and Family
- ☐ GP
- ☐ Head Teacher
- ☐ Speech and Language Therapist
- ☐ Teaching Union
- ☐ Not applicable - haven't experienced significant voice problems
- ☐ Other

18.a. If you selected Other, please specify:

If you didn't seek help or advice please go to Q21.

19. If you sought help what measures, if any, were advised?

- ☐ Voice rest
- ☐ Changes to vocal technique e.g. warming up, fluid intake etc.
- ☐ Posture changes
- ☐ Changes to your working environment
- ☐ Speech amplification system
- ☐ Further medical investigations
- ☐ Surgery

- Stress management techniques
- Not applicable - haven't experienced significant voice problems
- Other

19.a. If you selected Other, please specify:

20. If you followed this advice did this help your voice problems?

- Yes
- No
- Not applicable - didn't seek advice

21. If you have voice problems when are these most pronounced?

- Start of term
- Mid term
- End of term
- No variation - have problems consistently
- Problems vary but with no pattern
- Don't have voice problems

22. How much time off work have you had due to voice problems in the last two years?

- No voice problems
- No time off - problems were during holidays
- No time off - remained at work with voice problems
- Less than 1 week
- 1-2 weeks
- 2-3 weeks
- 3-4 weeks
- More than 4 weeks
- Other

22.a. If you selected Other, please specify:

23. How much time off work have you had due to ill health (other than voice problems) in the last two years?

- No ill health
- No time off - ill health was during holidays
- No time off - remained at work with ill health
- Less than 1 week
- 1-2 weeks
- 2-3 weeks
- 3-4 weeks
- More than 4 weeks
- Other

23.a. If you selected Other, please specify:

24. If you have had time off from work due to ill health, other than voice problems, please give brief details if possible:

25. Does your voice often feel tired at the end of the day?

- Yes
- No

26. Have you ever received training on using your voice?

- Yes
- No

26.a. If yes how frequent were the sessions?

27. Do you feel that voice training should be included in all teacher training courses?

- Yes
- No

28. If you have any further experiences or comments on voice problems or voice training please give them below:

29. Are there some teaching rooms in your current workplace in which it is difficult to make yourself heard?

- Yes
- No

30. Were there teaching rooms at your previous workplace(s) (if applicable) in which it was difficult to make yourself heard?

- Yes
- No
- Not applicable - no previous workplace

31. If you answered yes to Q29 and/or Q30, why do you think you have trouble being heard in these rooms?

- The room is too large
- The room is too reverberant ("echoey")
- The sound from my voice is absorbed by the room
- Students do not pay attention
- Noise from students in the room

- ☐ Noise from students in the corridor
- ☐ Noise from students in another classroom
- ☐ Another teacher talking in another room
- ☐ Other noises in the room e.g. computers, projectors etc.
- ☐ Too much noise from outside the room e.g. traffic, playground
- ☐ Not applicable - no trouble being heard
- ☐ Other

31.a. If you selected Other, please specify:

32. Please rate the acceptability of different noise sources in your main teaching room:

	Too high constantly	Too high at times	Acceptable	Don't notice
External noise from traffic, aircraft or trains	○	○	○	○
External noise from the school itself e.g. playground, sports field	○	○	○	○
Mechanical/equipment noise from outside the building	○	○	○	○
Mechanical/equipment noise from other classrooms	○	○	○	○
Mechanical/equipment noise in your classroom	○	○	○	○
Pupil noise from the corridor	○	○	○	○
Pupil noise from other classrooms	○	○	○	○
Pupil noise in your classroom	○	○	○	○
Teachers speaking in other classrooms	○	○	○	○
Other noise sources	○	○	○	○

33. How does your main teaching room make your own voice sound?

- ☐ My voice sounds muffled by the room
- ☐ The room supports my voice
- ☐ I can hear myself clearly
- ☐ My voice sounds echoey or reverberant
- ☐ None of the above

34. If you have difficulty speaking or being heard what strategies do you use?

- ☐ Talk louder
- ☐ Talk slower

- Try to speak more clearly
- Repeat yourself
- Use techniques to reduce the noise from pupils
- I don't have a strategy
- Other

34.a. If you selected Other, please specify:

35. Do you have to do any of the following frequently when you are teaching?

- Raise your voice
- Shout
- Talk over loud noise e.g. others talking or equipment
- Ask pupils to be quieter
- Stop speaking
- None of the above

36. Do you feel that voice problems are a significant issue for teachers, either for yourself or colleagues?

- Yes
- No

37. If you are a former or retired teacher did voice problems contribute to you stopping teaching?

- Yes
- No
- Not applicable

38. If you answered yes please give further details if possible

39. Have you used voice reinforcement systems in the classroom e.g. a loudspeaker and microphone?If you answered no please go to Q42

- Yes
- No

40. If yes did you find this helped to reduce your voice problems?

- Yes
- No
- Not applicable- used these systems but not due to voice problems
- Not applicable - haven't used these systems

41. If you have used speech reinforcement systems did you receive any training in their use?

- No training - just given equipment
- Was given the equipment manual
- Quick run through
- Full training
- Not applicable - haven't used these systems
- Other

41.a. If you selected Other, please specify:

42. Do you have any hearing loss?If you answered no please go to Q46

- Yes
- No

43. If yes do you use:

- One hearing aid
- Two hearing aids

- No aids
- Not applicable - don't have hearing loss

44. If you have hearing loss are there some teaching rooms you find it more difficult to hear in than others?

- Yes
- No
- Not applicable - don't have hearing loss

45. If you have hearing loss, do you believe it is made worse by your teaching?

- Yes
- No
- Don't know
- Don't have hearing loss

46. Do you experience Tinnitus (ringing in your ears)?If you answered never please go to Q49

- Never
- Occasionally
- Frequently
- Constantly

47. Do you experience Tinnitus in:

- One ear only
- Both ears
- Varies
- Not applicable - don't experience Tinnitus

48. If you experience Tinnitus is it made worse by teaching?

- Yes infrequently
- Yes frequently
- No
- Not applicable - don't experience Tinnitus

General Health

Thank you for completing most of questionnaire. We would be grateful if you could now answer the remaining questions about your general health.

49. How would you describe your health?

- Very good
- Good
- Fair
- Poor

50. Does your physical health limit you in your day-to-day activities?

- All of the time
- Most of the time
- More than half of the time
- Less than half of the time
- Some of the time
- None of the time

51. Does pain limit you in your day-to-day activities?

- All of the time
- Most of the time
- More than half of the time
- Less than half of the time
- Some of the time
- None of the time

52. Over the last four weeks have you felt cheerful and in a good mood

- All of the time
- Most of the time
- More than half of the time
- Less than half of the time
- Some of the time
- None of the time

53. Over the last four weeks have you felt calm and relaxed

- All of the time
- Most of the time
- More than half of the time
- Less than half of the time
- Some of the time
- None of the time

54. Over the last four weeks have you felt active and energetic

- All of the time
- Most of the time
- More than half of the time
- Less than half of the time
- Some of the time
- None of the time

55. Over the last four weeks have you woken up feeling fresh and rested

- All of the time
- Most of the time
- More than half of the time
- Less than half of the time
- Some of the time
- None of the time

56. Over the past four weeks has your daily life been filled with things that interest you

- All of the time
- Most of the time
- More than half of the time
- Less than half of the time
- Some of the time
- None of the time

57. If you have any other health-related information which you feel may be relevent please give further details below:

Page 3: Thank you.

Thank you for taking part in this survey which forms part of a research project being carried out at London South Bank University.

The research is supervised by Professor Bridget Shield and Dr Stephen Dance of the Acoustics Group at the University and forms part of ongoing research into many aspects of the acoustic design of schools.

Further information on the Acoustics Research Group at London South Bank University can be found at:www.lsbu.ac.uk/esbe/research/acoustics

If you would be willing for us to contact you again in relation to this project, or if you would like further information on the progress of the project, please contact Nick Durup at durupn@lsbu.ac.uk.

APPENDIX I - Journal and conference papers

Peer reviewed journal paper

N. Durup, B. Shield, S. Dance and R. Sullivan, 'An investigation into relationships between classroom acoustic measurements and voice parameters of teachers', *Building Acoustics*, 22(3-4), pp. 225-241, 2015.

Conference papers

Institute of Acoustics Spring Conference, Nottingham, UK, May 2013.
N. Durup, B. Shield, S. Dance and R. Sullivan, 'Vocal stress and acoustics in schools – a pilot study', *Proc. Institute of Acoustics*, 35 (1), pp. 496-502, 2013.

International Congress on Acoustics, Montreal, Canada, June 2013.
N. Durup, B. Shield, S. Dance and R. Sullivan, 'Vocal strain in UK teachers: An investigation into the acoustic causes and cures', *Proc. Meetings on Acoustics ICA2013*, 19 (1), p 040131, 2013.

Internoise, Innsbruck, Austria, September 2013.
N. Durup, B. Shield, S. Dance and R. Sullivan, 'Vocal stress and acoustics in schools - A pilot study', *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*, 247 (3), pp. 5038-5041, 2013.

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Institute of Acoustics 40th anniversary conference, Birmingham, UK, October 2014.
N. Durup, B. Shield, S. Dance and R. Sullivan, 'Voice problems and acoustics in schools – online survey for teachers', *Proc. Institute of Acoustics*, 36 (3), pp. 430-434, 2014.

International Building Physics Conference, Turin, Italy, June 2015.
N. Durup, B. Shield, S. Dance, R. Sullivan and L. Gomez-Agustina, 'How classroom acoustics affect the vocal load of teachers', *Energy Procedia*, *78*, pp. 3084-3089, 2015.

Conference presentations

Nordic Voice Ergonomic Group conference: The damaging effects of noise on hearing, voice and well-being in children's learning environment. National University Hospital of Iceland. 12-13th October 2012.

Invited presentation at 5th symposium of the Finnish Society of Voice Ergonomics. Biomedicum, Helsinki, Finland. 9th September 2016.

Invited presentation at 5th Meeting of the Nordic Voice Ergonomic Group. Scandic Hotel Simonkenttä, Helsinki, Finland. 10th September 2016.

Invited presentation at the joint meeting of the Acoustical Society of America and the European Acoustics Association - Acoustics '17 Boston, USA, 25-29 June 2017. Further details:

N. Durup, B. Shield, S. Dance and R. Sullivan, 'Teachers' voice parameters and classroom acoustics - A field study and online survey', *J. Acoustical Society of America*, 141 (5), pp. 3540-3540, 2017.

Appendix J – APM software images

Figure J.1: Enlarged Figure 7.9

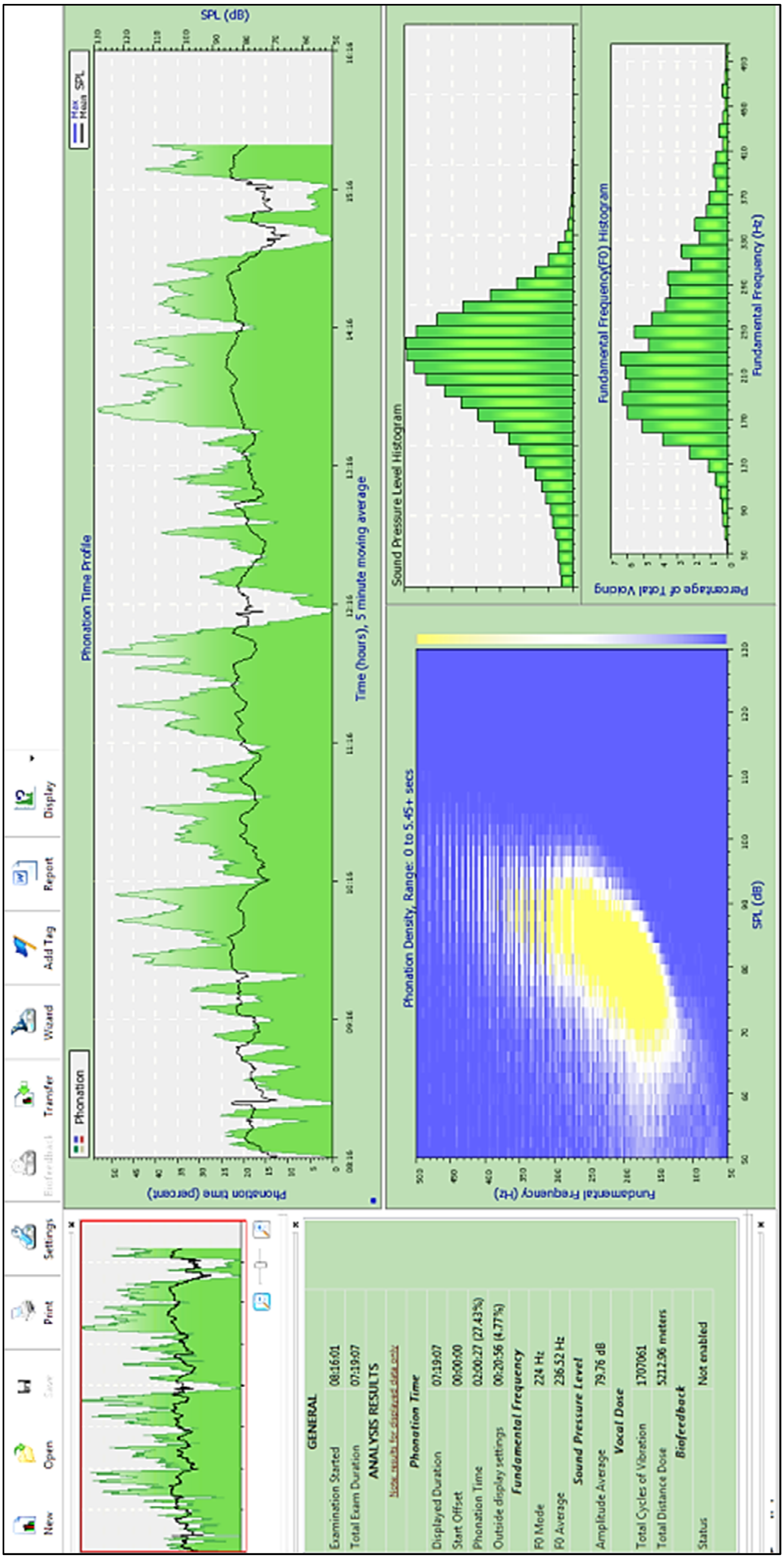
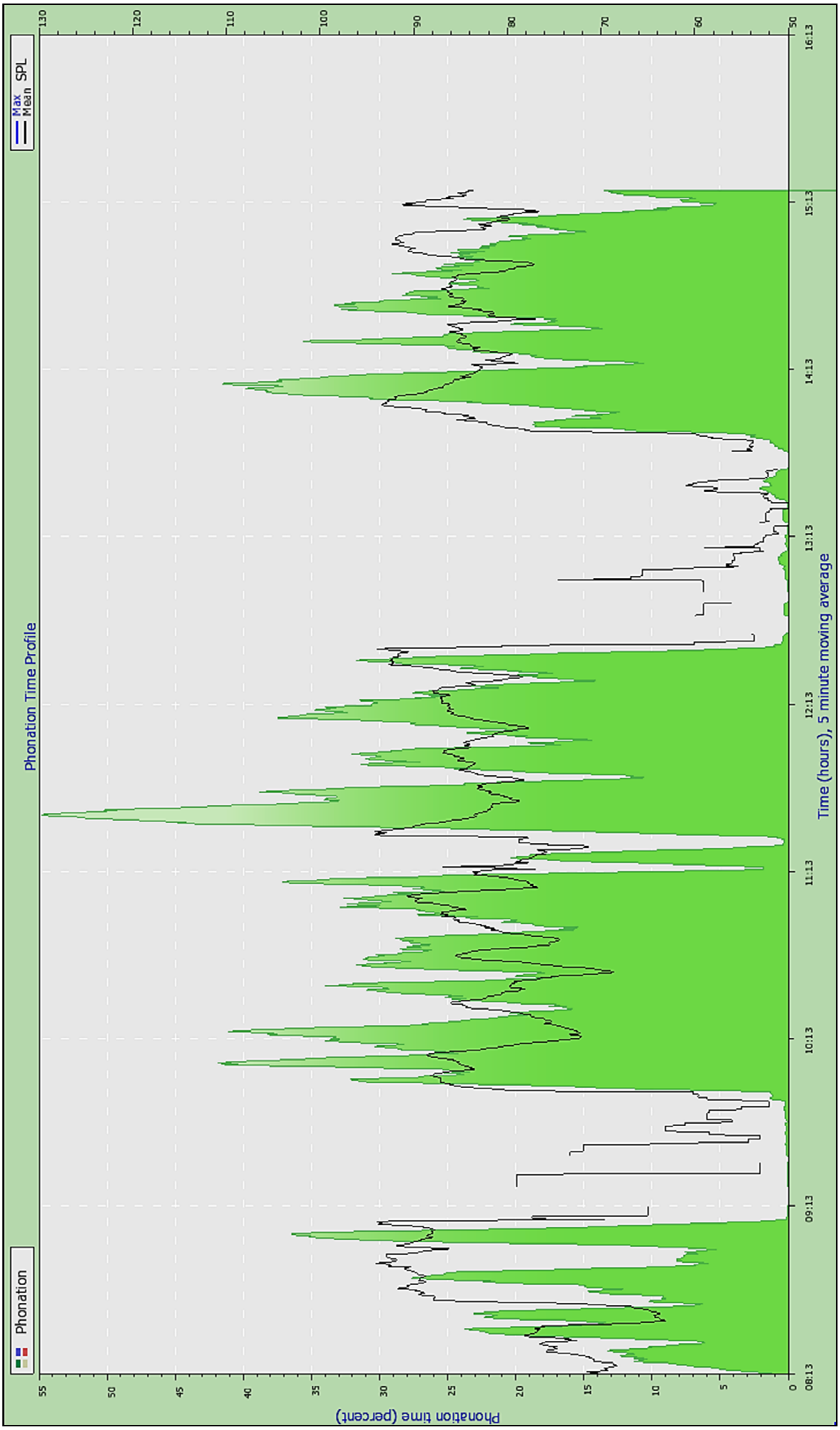


Figure J.2: Enlarged Figure 7.10



Appendix K – Viva voce presentation

Viva Voce Presentation

An Investigation into the Effects of Classroom Acoustics on Teachers' Voices

Nick Durup

London South Bank University

EST 1892

An investigation into the effects of classroom acoustics on teachers' voices – Nick Durup - Viva voce presentation 26.1.18

Introduction

This presentation will give an overview of the thesis:

- Motivation
- Literature review
- Selection of methodology
- Participant recruitment
- Challenges faced
- Results highlights
- Application of results

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Motivation

- Interest in school acoustics through my work as an Acoustic Consultant and hearing experiences of voice problems from friends and family who teach.
- Voice problems appeared to be an issue for teachers.
- Design guidance for school acoustics in England referred to poor acoustics increasing voice strain for teachers but gave no criteria.
- A need to determine if classroom acoustics in the field effected voice parameters in teachers.
- More information on teachers' experiences of voice problems and acoustics needed.

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Literature review

Voice measurements of teachers made previously (Astolfi, Rantala, Titze). Specific gaps in knowledge identified:

- Interactions between teachers' voice parameters and room acoustic parameters in the context of classroom acoustic design and acoustic criteria in England.
- Interactions between teachers' voice parameters and spectral room acoustic parameters e.g. UANL and occupied noise levels not only dBA values.

Surveys of teachers' voice problems have been carried out (Smith in US, Russel in Australia, Shield in UK) but not:

- Detailed survey on voice problems in England from acoustic perspective.
- Consideration alongside classroom acoustics and BB93 criteria.

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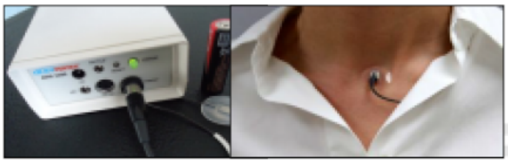
Selection of methodology

Voice measurements

- Voice parameters for the teacher's voice only. Choice of method.
- Microphone-based systems measure all noise sources.
- Ambulatory phonation monitor identified as suitable.
- Reliable measurements in the field, discreet, less impact on classroom behaviour.
- Range of voice parameters.



Online survey

- Online survey gave access to large group of potential participants.
- Anonymous – participants could give candid answers.
- Sections on classroom acoustics, voice problems, training and general health developed.
- Detailed information on teachers' subjective impressions.

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Participant recruitment

Voice measurements

- Access via school contacts.
- Pilot at one school to develop methodology.
- Overall 20 participants.
- 5 primary, 1 secondary school- more voice problems reported in primary teachers according to literature.

Online survey

- Pilot at 2 schools from voice measurements.
- Pilot survey link direct to school.
- Main study link publicised by *NUT* and *Voice* trade unions.
- Also direct to teachers involved in voice measurements, through contacts network and Institute of Acoustics.

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Challenges faced

Voice measurements

- Finding schools and teachers willing to participate.
- Arranging access for benchmarking.
- Concerns from schools about what results may show.
- Ethical approval for the research from UREC.
- CRB check for schools access.

Online survey

- Maximising number of responses.
- Publicity about survey through many channels and contacts.
- Approached several bodies for assistance.
- Extended time survey was open for by 12 months.

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Results highlights – voice measurements

- Majority of classroom complied with existing UANL and RT requirements. Risks of vocal loading still in compliant classrooms.

- Mean voice level 67 dBZ 'loud'. Females higher voice level (f= 69, m= 63 dBZ). High phonation percentage 21%.

- Primary teachers significantly higher voice level and phonation time, indications of higher SF_0 within genders = more vocal loading likely.

- UANL L_{eq}/L_{90} 250 Hz correlated with female voice level (SF_0 band). Indications similar for males at 125 Hz.
  UANL at low frequencies contributed to occupied levels.

- No correlation with other room acoustic parameters e.g. reverberation time.

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Results highlights – online survey

Highlighted concerns over voice problems, lack of voice training and voice problems not being taken seriously by others.

- 66% had experienced voice problems.
- 71% worked despite voice problems.
- 59% no voice training, 93% supported mandatory voice training.
- More voice problems in primary and open plan.
- No difference in voice problems pre/post BB93 classrooms, or by gender or voice training.
- UANL sources not judged significant, noise from other areas (indicating poor SI) and pupil noise in own classroom main issues.
- 58% had difficulty being heard as classroom too reverberant.

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Application of results

- Voice problems significant concern for teachers.
- Voice problems should be considered an occupational disease.
- More voice training needed for teachers.
- Those teaching in primary schools, open plan classrooms and female teachers appear at greater risk of vocal loading.
- Future revisions of acoustic standards in England should specify UANL criteria at low frequencies as indications of effects on teachers' voice levels.

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