An Investigation into Ambient Noise Levels at Rietenbosch Primary School

by

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Declaration

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Abstract

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Rietenbosch Primary has reported experiencing a noise challenge that negatively affects audible communication proficiency in the classroom environment. This difficulty in communication may be a contributing factor in the school's poor academic performance. Previous attempts to rectify the problem have been unsuccessful. The primary focus of this study was to identify the cause(s) of the noise problem and the extent to which the school's noise levels exceed those prescribed as acceptable by internationally recognised standards.

This study was predominantly based on a mixed methods approach, as the method allows the researcher to gather qualitative and quantitative data. A noise survey was conducted in multiple spaces, with varying parameters, to investigate the distinctive sound characteristics of the school building. In addition, a questionnaire regarding the acoustic characteristics of the classroom environment was distributed to teachers. This aided in consolidating and analysing perceptions about the noise challenge.

The results showed that the school's ambient noise levels, reverberation time, sound impact noise, and occupied classroom noise levels exceed national and international recommended values. These factors contribute to the poor auditory environment of the classrooms, causing a barrier to learning in the school. The investigation also found that the school's noise-related problems are due to the layout of the school. Acoustical treatment is recommended.

This investigation wishes to include South Africa in the international discussion on excessive noise levels in schools and the effects this has on learning.

Key terms: Ambient Noise Levels, Occupied Noise Levels, Reverberation Time, International Noise Standards, South African Standards, Barriers to Learning, Noise in Relation to Health.

Uittreksel

'n Ondersoek in Omgewingsgeraasvlakke in Rietenbosch Laerskool

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Rietenbosch Laerskool gaan gebuk onder algemene hoë geraasvlakke in die skoolgebou en klaskamers. Dit veroorsaak dat onderwysers en leerders sukkel om effektief te kommunikeer en word as moontlike rede uitgelig vir deurgaanse swak skolastiese prestasie. Tot op hede was pogings om die geraasprobleem aan te spreek ondoeltreffend. Die hooffokus van die studie is om die oorsaak van die geraas in die skoolgebou te bepaal en metings te neem, as aanduiding van hoe dit vergelyk met die voorgeskrewe (inter-) nasionaal aanvaarbare vlakke.

Die studie is oorwegend gebaseer op gemengde metodes-teorie. 'n Geraasstudie is in verskeie volumes en onder verskillende toestande onderneem, om die gebou se eiesoortige probleem te ondersoek. 'n Verdere manier van data-insameling was om voltooide vraelyste oor die skool se akoestiese katarsis te analiseer.

Die studie het gevind dat die skool se klaskamers, oor die algemeen, voorgeskrewe nasionale en internasionale toelaatbare vlakke oorskry vir weerkaatsingstyd, omgewings-, impak- en klaskamergeraasvlakke met insittende leerders. Die gemete geraasvlakke is van so 'n aard dat dit defnitief as leerhindernis geklassifiseer kan word. Verder is vasgestel dat die ongetwyfelste geraasprobleem veroorsaak word deur die onkonvensionele uitleg van die skoolsaal en -gange. Die studie het laastens ook ten doel om die breër gemeenskap uit te nooi om deel te word van internasionale geprekke oor die negatiewe gevolge van hoë geraasvlakke in enige leeromgewing – spesifiek as leerhindernis.

Sleutelwoorde: Omgewingsgeraasvlakke, Klaskamergeraasvlakke met Insittende Leerders, Weerkaatsingstyd, Internationale Geraasstandaarde, Suid-Afrikaanse Standaarde, Leerhindernisse, Geraas se Invloed op Gesondheid.

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Nomenclature

Acronyms and Abbreviations

AAAC	Association of Australian Acoustical Consultants
ADD	Attention Deficit Disorder
ADHD	Attention Deficit Hyperactivity Disorder
ANSI	American National Standards Institute
ASA	Acoustical Society of America
ASHA	American Speech-Language-Hearing Association
BB93	Building Bulletin 93
CAPS	Curriculum Assessment Policy Statements
dB	Decibel
dBA	Decibel A-Weighted scale
DIN	Deutsches Institut für Normung
EU	European Union
FAS	Fetal Alcohol Syndrome
Hz	Hertz
IEC	Electoral Commission of South Africa
ISO	International Organization for Standardization
JIS	Japanese Industrial Standards

JSA	The Japanese Standards Association
kHz	kilohertz
LED	Light Emitting Diode
MLS	Maximum Length Sequence
NBC	National Building Code
NBR	Norma Brasileira Regulamentadora
NC	Noise Criterion
NCRs	National Noise Control Regulations
NISOH	National Institute for Occupational Safety and Health
NR	Noise Rating
NZAS	The New Zealand Audiological Society
OCU	Spanish Organization of Consumers and Users
RASTI	Room Acoustics Speech Transmission Index
REL	Recommended Exposure Limit
RT	Reverberation Time
RT60	Reverberation Time decay of 60dB
RT40	Reverberation Time decay of 40dB
RT30	Reverberation Time decay of 30dB
RT20	Reverberation Time decay of 20dB
SABS	South African Bureau of Standards
SANS	South African National Standard
SAPPMA	Southern African Plastic Pipe Manufacturers Association

SATAS	South African Technical Auditing Service
SFS	Suomen Standardisoimisliitto
SLM	Sound Level Meter
SPL	Sound Pressure Level
SN	Standard Norge
SNR	Signal-to-Noise Ratio
SRL SA	Sound Research Laboratories South Africa
STC	Sound Transmission Class
UNI	Italian National Unification
WHO	World Health Organization

Units of Measurement

${L_{Req,T}}^a$ A-weighted equivalent continuous level over a period of time, plus adjustments for tonal character and time of day

$L_{Aeq,T}$ A-weighted equivalent continuous level over a period of time

L_A A-weighted sound level measurement

L_Aeq A-weighted equivalent continuous level

L_{eq} Equivalent continuous level

$L_{eq,30}$ Equivalent continuous level over 30 minutes

$L_{'nT(Tmf,max)}$, The maximum impact sound pressure level admissible for primary school classrooms

$L_{Amax,T}$ The maximum level with A-weighted frequency response over a period of time

$\mathrm{SNR} = \frac{Signal}{Noise}$ Ratio of signal power to the noise power

Chapter 1

Introduction

1.1 Background

Rietenbosch Primary School is located on the outskirts of Cloetesville[1] in Stellenbosch, South Africa. The school was founded in 1990 and a very pertinent noise problem immediately become evident. It is believed that the noise problem detracts significantly from teaching efficiency and has a direct, negative effect on academic results. Teachers complain that they are unable to communicate effectively, and that learners struggle to concentrate during classes. Currently, teachers argued that this work environment is negatively affecting their teaching abilities and their health. Learners, on the other hand, frequently complain that they struggle to hear teachers and find it hard to concentrate during class exercises. Teachers believe that their work achievement is negatively affected by this. It is disconcerting to think that a building that is supposed to facilitate learning is having a negative effect on academic outcomes.

Since noise appears to be present throughout the school, this study investigates the noise problem at Rietenbosch Primary utilising various methods, including a noise survey and questionnaire. Previous, unsuccessful, attempts to improve the situation at the school have included:

1. planting trees outside the building (to help with noise absorption)
2. adding doors to some of the open doorways of the school hall (inhibiting noise propagation)
3. building extra walls on the lower floor of the school (reducing noise propagation)

One of South Africa's most prevalent problems is the quality of education, as illustrated by the high level of illiteracy and school drop-outs (De Wet and

[1]This location can be classified as a previously disadvantaged area in the current political landscape.

Mkwananzi, 2014, 5930-5931). This is unfortunate as there is legislation that should protect learners against this.

> The Constitution, the South African Schools Act and various education policy documents [state] that all South African learners should have access to the same quality of learning and teaching, similar facilities and equal educational opportunities (Gardiner, 2008, 7).

It is important that when children exercise their right to be educated, they receive an education of adequate quality. A noisy environment is not conducive to this outcome and is also a risk factor for negative health outcomes. When excessive noise is present in the learning environment, it is important to acknowledge and rectify the situation for both current and future learners and teachers. Because South Africa has a shortage of experienced teachers, ensuring they have a suitable and supportive working environment is vital in order to limit resignations due to poor working conditions (South African Council for Educators, 2010, 7-8; 21).

1.2 Research Aims

The main aim of this study was to investigate the cause of the noise problem at Rietenbosch Primary, and how it is transferred throughout the school. This was achieved by analysing data from a noise survey of the premises and questionnaire completed by the teachers. The goals of this thesis were therefore to:

1. prove that the noise levels present in Rietenbosch Primary during school hours infringe on productive teaching and learning, and
2. substantiate the cause of noise related health problems claimed by both teachers and learners.

By first proving and then investigating the noise challenge, the classroom experience of both teachers and learners will be enhanced, and academic performance of the Rietenbosch learners may be improved. Therefore, a holistic investigation was launched into the cause of high ambient noise by investigating:

1. the architectural design of the school building,
2. the types of activities taking place inside the classrooms.

The issue of classroom environments being negatively affected by ambient noise has seldom been addressed in developing countries, although the need to do so is well recognised. According to Berglund *et al.* (1995, 79), there is a direct correlation between the level of development in a country and the degree of noise pollution impacting its people.

As there are no previous South African studies documenting noise level measurements in schools, South African literature lacks an appropriate statistical baseline for school-based noise surveys. This study is therefore novel as it begins to address this issue in the South African context.

Thus, in addition to the main goals of this study, which focus on Rietenbosch Primary specifically, this research will contribute to the improvement of school noise standards in South Africa more generally by providing relevant data to the scientific community. It is hoped that this data will assist in expanding applicable noise laws for educational environments within South Africa so as to respond to the following caution: "[i]f governments implement only weak noise policies and regulations, they will not be able to prevent a continuous increase in noise pollution and associated adverse health effects" (Berglund *et al.*, 1995, 79).

1.3 Relevance of Research

Research into the effects of noise on people began as early as the 1900's. However, there is still a need for further research as these effects have not been sufficiently linked to childhood development. The current study contributes to this gap in the global literature by providing empirical data on the topic.

Globally, researchers have been trying to find a solution to poor classroom acoustics, especially after studying the detrimental effects of this issue on both teachers and learners[2]. It has been suggested that if noise-borne acoustic barriers can be removed, better learning for children can be facilitated, even if an inherent learning barrier exists. Research has also shown that when classrooms with high background noise levels and reverberation times are acoustically treated, learners' performance improves markedly.

On a micro-level this study serves the teachers and learners of Rietenbosch Primary by analysing their noise problem and suggesting possible solutions. On a macro-level, it hopes to encourage discussion and possible recognition of noise issues in other South African schools. Van Tonder *et al.* (2015, 1) posit that public schools in South Africa face numerous challenges that negatively influence the learning environment and, as a result the performance of learners. One such challenge is that school buildings and classrooms are often too small

[2]These effects have been well documented by Berglund *et al.* (1999, 31); Knecht *et al.* (2002, 70); Nelson *et al.* (2002, 2); Shield and Dockrell (2003, 1); Summers (2003, 1); Dockrell and Shield (2004, 24); Schneider *et al.* (2005, 14, 76-7); Dreossi and Momensohn-Santos (2005, 254); Dockrell and Shield (2006, 2); Estrada-Rodriguez (2009, 437); Neuman *et al.* (2010, 337); Association of Australian Acoustical Consultants (2010, 3-4); Laurinolli (2012, 1); Zannin *et al.* (2012, 201, 216); Clark *et al.* (2012, 2); Rantala *et al.* (2012, 1); Klatte *et al.* (2013, 2); Evidence-Space (2015, 1); Escobar and Morillas (2015, 1); Chan *et al.* (2015, 10), and Mealings *et al.* (2016, 1-2).

to adequately accommodate the number of learners, a factor that is especially evident in schools located in less affluent areas.

A second challenge for South African children is that they come from different linguistic backgrounds and are often not taught in their home language. This report, however, does not explore this fact as a possible reason for poor academic performance at Rietenbosch Primary.

This study also addresses the issue of ambiguous South African noise laws as these laws are not enforced. South Africa's ambiguous noise laws, and the inconsistent implementation of these laws, has meant that approved school building designs often do not adhere to the required specifications. The lack of consistent implementation of these laws is especially apparent when compared to the strict noise laws and measurement techniques enforced by developed nations.

A secondary aim of this study is therefore to contribute to expanding and promoting transparency in present South African noise law standards.

This thesis will base its findings on scientific measurements and provide possible solutions to the Rietenbosch Primary school case. Although improvements are suggested to alleviate the noise issues the school is facing, it is unlikely to eradicate the problem entirely. However, it has been shown (by tests conducted on acoustically treated classrooms) that an acoustically 'sound' learning environment has a positive effect on learners and their academic performance (Nelson, 2000, 354). Furthermore, studies have shown that children born with learning disabilities such as Attention Deficit-Hyperactivity Disorder (ADHD), Attention Deficit Disorder (ADD), Asperger syndrome, Fetal Alcohol Syndrome (FAS), or Autism, are severely affected by noisy classrooms. Many parents cannot afford medication or a private school for learners with special needs.

Finally, a report will be compiled with which Rietenbosch Primary can apply for acoustic renovations funding from the Department of Education and other non-governmental channels.

Chapter 2

Literature Review

Performing a noise survey is a meticulous process, and many factors should be considered. In order to understand a noise problem in a building, it is necessary to define the basic principles and physics of acoustics, as well as how and why noise propagates.

2.1 Fundamental Concepts of Acoustics

Noise

The term 'noise' can be simply defined as any unwanted sound that irks, frustrates, annoys, disturbs, or disrupts. What is sound? According to the Oxford online dictionary[1], sounds are composed of vibrations that travel through the air, or another medium, and can be heard when they reach a person's or animal's ear. Ballou (2015, 26) further explains that a sound wave is produced when a medium (e.g., air, concrete, steel, or water) is interrupted. This interruption causes a vibration in the ambient condition of the medium, the vibration (sound) that is produced propagates in the form of a wave. Waves propagate at different speeds depending on the medium (Ballou, 2015, 27) A wave has two fundamental properties: Amplitude (influencing the 'loudness' of a sound), and frequency (influencing the 'pitch' of a sound).

The human ear can perceive frequencies from about 20 Hz to 20 kHz (Ballou, 2015, 26).

Noise Sources

A noise source is responsible for generating sound. Depending on the acoustic properties of the room or building, this noise can then either attenuate

1. quite rapidly,

2. be amplified within the space

[1]https://en.oxforddictionaries.com/definition/sound

3. or exist between these extremes.

The context of the current study, the noise source in a school environment, would be people performing activities (e.g., speech, moving around, dropping things), or mechanical devices (e.g., a fan or air-conditioning unit) inside the premises, while the propagation is a wanted or unwanted property of the room or building within which this occurs.

How Sound is Perceived

The effects of noise on health will be discussed in an upcoming chapter (Chapter 2.3), but in short, humans detect sound in the inner ear by means of a set of sensory cells.

> These cells have tiny projections [...] on their surface. Extremely loud sounds (above 130 dB) e.g., [...] at a high setting can rip out the sensory microvillie, causing aberrant nerve signals that the brain interprets as a high-pitched whine or whistle. Many people experience ringing ears after exposure to very loud noises (Hassan, 2009, 36).

Acoustic Measuring Units

The brain interprets sound waves that reach the ear as sound or noise. One parameter that is generally used to assess humans' sound exposure is the sound pressure level (SPL) and is expressed in μPa or Pa (Scientific Committee on Emerging and Newly Identified Health Risks, 2008, 16). Because using this scale was not always practical, a logarithmic scale (which measures in decibels (dB)) was introduced. Ballou (2015, 23) explains that "the decibel is a way to express 'how much' in a way that is relevant to the human perception of loudness". The human ear is not equally sensitive to sound at different frequencies. The decibel (dB) is a unit of measurement used to quantify the 'loudness' of sound. The term dB(A) refers to the type of filters used to measure decibels. This term is employed for mid-frequencies as it is the bandwidth used to measure hearing damage.

> Sound energy is measured in decibels. The decibel is a convenient unit because it is approximately the smallest change in energy that the ear can detect. A decibel represents the ratio of two quantities, one being the sound level that is measured and the other being a reference sound level corresponding approximately to the faintest sounds detectable by the human ear (Hassan, 2009, 13).

The threshold of hearing for a human is 0 dB, and the threshold of pain lies between 120 dB and 140 dB. Generally, a change of 2 dB in sound is barely perceptible, where a 5 dB difference is clearly audible, and 10 dB appears to be twice as loud (Hassan, 2009, 13).

There are different weighting scales used to measure sounds, depending on the frequency bandwidth of interest and the context. This study will make use of the A-weighting scale as legislation regarding noise exposure limits are normally expressed in dB(A) (Hassan, 2009, 51). Peterson and Gross (1974, 18) explain that sound in the mid-frequency noise range (which is expressed in dB(A)) tends to be more damaging than low-frequency noise.

Berglund *et al.* (1995, 37) explains that the simplest way to measure indoor noise levels is to use an integrated A-weighted sound pressure level, denoted by $L_{Aeq,T}$. $L_{Aeq,T}$ is the average level in dB(A) over a time period (T), and $L_{Amax,T}$ is the maximum level in dB(A) during a specified time period (Dockrell and Shield, 2006, 5). The 'eq' in the formula indicates that tests will utilise a continuous A-weighted sound pressure level over a referenced time interval (Jongens, 2002, 3). According to Hassan (2009, 51)

> A-weighting serves two important purposes: (1) it gives a single number measure of noise level by integrating sound levels at all frequencies; (2) it gives a scale for noise level as experienced or perceived by the human ear.

When deciding how to analyse the schools' noise problem, it must be noted that there is a difference between measuring long-term exposure, such as would be present during school hours, as opposed to measuring short periods of noise. Noise levels are rarely steady and can vary considerably over the period of measurement. To rule out the uncertainty caused by irregular periods, the continuous equivalent level (L_{eq}) is measured. The continuous equivalent level can be measured as the constant sound pressure level, which produces the same total energy as the actual level over the given time (Kudesia and Tiwari, 1994, 6).

South Africa's legislation is in line with an A-weighting measurement scale (City of Tshwane, 2004, 3; City of Cape Town, 2016). Research done by Jongens (2002, 3) on noise related to road use in the Western Cape, indicated that the Western Cape Government accepts the A-weighted sound pressure level of both L_{Aeq} as well as L_A. The A-weighted L_A rating considers the physiological response that noise has on the average human ear, and is an indication of how annoying a noise might be (Hassan, 2009, 44).

Sound Impact Noise

Impact sound is the sound arising from the impact of an object on a physical structure. For example, the noise of foot fall, objects falling, or furniture being moved. Impact sound travels easily through a structure, with little loss of energy, particularly if the structure is continuous and rigid (Hassan, 2009, 90).

Sound Propagation

Hansen and Sehrndt (2001, 23) define noise propagation as a sound (or noise) resulting from pressure variations, present in an elastic medium, generated by a vibrating surface(s). Sound is propagated in longitudinal waves by incorporating a succession of compressions of rarefactions in an elastic medium. When a sound wave propagates in air, oscillations in pressure can be either above or below the ambient atmospheric pressure. In other words, sound is energy that travels through the air in the form of pressure waves, which can be perceived (heard) by humans. For example, if a sound is initiated by a sound source, such as a horn blaring, the physical vibration of the horn interacts with the air molecules next to it and they in turn interact with adjacent molecules, which interact with yet more molecules, and so on. This propagation does not execute instantaneously, which explains why one sees the smoke from a 100m sprint starting gun before one hears the 'bang!'. Sound travels through air, at standard atmospheric pressure and temperature, at a rate of 0.3 km/s while light travels at 300 000 km/s.

Sound Transmission

Sound transmission generally refers to how effectively sound passes through a medium. The current study defines the term 'transmission' as the efficiency of sound propagating from one acoustic space to the next (e.g., how well sound passes through walls, doors, and windows).

There are three main ways, according to Hassan (2009, 96-7), in which sound can transmit adjoining rooms:

penetration: sound waves are transmitted unimpeded between adjacent rooms through openings (e.g., doors, and windows), or holes (e.g., electrical outlets, or fan units).

airborne sound transmission: sound waves are transmitted through the air from the surfaces in one room to the surfaces of an adjacent room, thereby transferring noise between rooms.

structure borne transmission: through the flanking transmission, sound waves are transmitted from one space to the next, either by means of impact noise coming from the ceiling, or by oscillating walls.

Ambient Occupied and Unoccupied Noise

"The term 'ambient' denotes the ever-present collection of sounds of both natural and manmade origin" (Hassan, 2009, 47). Shield *et al.* (2015, 178) adds that the ambient noise level refers to the background noise, both internally and externally generated, of an unoccupied classroom, and is specified in terms of the highest equalised mean sound level derived within a determined period. External ambient noise is classified as the noise entering a classroom from outside (through open windows, poorly insulated walls, etc.). The terms 'ambient noise level' and 'background noise level' can be used interchangeably.

Occupied Noise Levels refer to noise that is measured while the teacher(s) and learners are present in the classroom. Noise levels in an occupied class fluctuate depending on the type of activity and the number of learners who are participating. Literature shows that a further distinction must be made with regards to occupied noise levels based on activity type:

1. Occupied noise: For example, a teacher busy lecturing in front of the classroom.
2. Occupied ambient noise: For example, learners present in the class performing activities such as reading, writing and using scissors.

Common sense dictates that the noise levels measured for the latter condition will be lower than that of the former.

> Believe it or not, up until a study in 2005, all references and recommendations relating to background noise had to do with an unoccupied classroom, ignoring the reality of student generated noise. In 2005, a pioneering study was done to measure the classroom sound levels in a student occupied classroom (The Institute for Enhanced Classroom Hearing, 4).

The Institute for Enhanced Classroom Hearing (5), states that 'Silent Reading' activities are measured at around 45 decibels, only slightly louder than the unoccupied room.

Reverberation Time

Reverberation time (RT) is defined as the length of time (s) required for a sound to decay by 60dB from its initial level (Lamancusa, 2000). It is measured from the moment the sound source is stopped or switched off. When a room has a discernible reverberation time, the sound will continue to be audible even after the original sound source has been terminated. These 'after' sounds, often described as echos, are caused by sound waves being bounced off reflective surfaces. The less absorption that occurs at these surfaces (i.e., through carpets), the longer it takes for the sound to 'die'. Long reverberation times affect the clarity of direct sounds, such as the intelligibility of speech (Corey, 2016, 61-2). Reverberation time is a powerful characteristic of any acoustic space, and instils a sense of spaciousness and depth in a room if it is relatively long. Depending on the observer's position within the space, the sound waves can superimpose in interesting ways. When sound is reflected within certain parameters it can accumulate due to the addition of the reflected sound(s) to the original noise or sound (Bies and Hansen, 2009, 287). In smaller spaces, the repetitions are generally too quick for the ear to discern between individual reflections. Therefore, as these echoes overlap with each other, it can become challenging to understand speech.

Sound Insulation and Soundproofing

Soundproofing refers to any method used to absorb sound within a space. It can be achieved by adding absorptive materials to dampen sound (Zhu *et al.*, 2013, 1764). Soundproofing is especially important if walls and ceilings are shared in a building.

Sound insulation describes the reduction of sound between two spaces that are separated by a dividing element. Sound energy passes through the dividing element by either direct transmission or indirect transmission. Any doors, windows, or openings in a room can influence sound insulation.

Additionally, it must be noted that all small sound leaks may need attention as noise will travel through any open path with little to no sound loss.

> For example, a very small air hole in a brick wall can easily reduce insulation from 50 dB to as low as 20 dB. Cracks and gaps around pipe work through a partition, louvred doors, porous construction, etc. are, therefore, to be avoided. [...] The sound transmission loss of holes and slits (circular and slip-shaped apertures in wall) can be increased substantially by sealing them with either porous sound-absorbing material or an elastomeric material or designing them as silencer joints (Hassan, 2009, 466).

Noise Sources, Propagation, Insulation, and Transmission in Practice

Sound propagates from its source in all directions, but the energy is not always equally distributed. This is easily demonstrated by considering a loudspeaker: The sound is projected in the direction of the cone (i.e., the direction the loudspeaker faces), which has the desirable effect that sound is observed to be the loudest in front of the speaker, relative to the same distance away, but adjacent or behind the speaker. As sound propagates, it loses energy/intensity as a function of the distance travelled. When the noise source and observer are confined in a room with flat, reflected surfaces (walls/floor), sound waves are reflected off these surfaces, causing a 'lingering' effect after the sound source has been terminated. This characteristic is described as 'reverberation time'. CertainTeed (2011, 7) explains that normally

> sound pressure level decreases 6 dB for each doubling of distance. If, however, the sound source is indoors, reflected or reverberant sound will add to the overall sound level within the room to make up for the decreasing direct sound energy.

Reverberation efficiency is influenced by the material used in the room as sound is a combination of (a) direct sound from the source, and (b) sound that is reflected from the walls, ceiling, floor, and objects in the room (Hassan, 2009, 90). It is therefore important to consider the construction and materials used inside the building.

Any opening in a building that provides air (windows, doors, air-conditioning ductwork, etc.) will allow noise to leak into a room. CertainTeed (2011, 11), a company specialising in acoustic solutions for buildings, states that noise insulation is therefore difficult because noise can go through the smallest hole in a wall or door, and even through wiring and piping. In line with this statement, Hassan (2009, 95) and the Australian Building Codes Board (2016, 22) stress the importance of sealing or caulking these penetration areas. The Australian Building Codes Board (2016, 16) emphasises that acoustic seals at penetration points must be functional as long as the building is to be occupied, as repairs are expensive.

CertainTeed (2011, 11) also states that hollow core doors are 'poor sound blockers'. If privacy is a key consideration, as it is in a school, doors should be made of solid wood (or have insulated cores) and should preferably be gasketed, which will prevent sound from passing between the door and the jamb or sills. Hassan (2009) agrees with this statement, and also explains that insulation in walls and windows should be a priority if one wants to impede noise propagation. Bies and Hansen (2009, 271) suggests another solution: By adding rubber seals to the doorframe, a door can be made significantly more airtight, which improves sound attenuation.

The layout of a building or school is another very important aspect to consider, since teaching is a noise-sensitive activity. The Australian Building Codes Board (2016, 18) explains that it is therefore good practice to situate noise-sensitive classrooms away from noisy areas.

Wagner (2016, 5) states that "never before in history have people needed to build a physical barrier to shield themselves from noise". This is an indication that problematic noise levels is a modern crisis that is set to become worse in future years. All over world people are being exposed to high noise levels throughout the whole day, leading to hearing damage, fatigue, and other health-related problems. This is a health risk that not everyone is conscious of.

The detrimental physical and psychological effects that noise can have on individuals have been established by researchers such as Rantala *et al.* (2012, 1), Sound Reduction Systems (2013, 5), Zannin *et al.* (2012, 216), Chan *et al.* (2015, 10), Knecht *et al.* (2002, 70), Schneider *et al.* (2005, 76-7), Dreossi and Momensohn-Santos (2005, 254), Laurinolli (2012, 1), Mealings *et al.* (2016, 2), Nelson *et al.* (2002, 2), and the Association of Australian Acoustical Consultants (2010, 4).

NC Curve, NR Curve and SNR

The noise criteria curve (NC), noise rating curve (NR) and signal-to-noise ratio (SNR) are all methods to measure certain acoustic properties of indoor spaces.

The NCs are curves of approximately equal loudness (Tocci, 2000, 108) and different frequencies. The curves can indicate whether the octave band noise levels are suitable for satisfactory speech communication (Tocci, 2000, 108).

Another international noise standard similar to the NC curves, is the NR curves. It is most commonly used for regulatory purposes by deriving a rating for an internal space. These curves were developed as an International Organization for Standardization (ISO) standard to determine the acceptable indoor environment for hearing preservation, speech communication, and annoyance (NTi-audio, 2012, 2).

Crandell et al. (in Knecht *et al.* (2002, 66)) define SNR as the "relationship between the intensity of the signal and the intensity of the ambient noise at [a persons] ear". SNR is important considering that children require a higher SNR than adults to understand spoken language (Nelson *et al.*, 2002, 3). SNR is calculated as follows: $\text{SNR} = \frac{Signal}{Noise}$.

Absorption

Hassan (2009, 10) defines absorption as:

> the loss or dissipation of sound energy in passing through a material or on striking a surface, usually through conversion to heat energy. The term may also refer to the property of a medium, material or object to damp sound energy.

The sound waves that strike a surface can be either partly absorbed, reflected, or transmitted depending on the surface materials in question. The decrease in amplitude that occurs by this absorption is called 'decay' (Hassan, 2009, 10). The fraction of sound energy that is absorbed by the material is called the absorption coefficient.

Noise Survey

A noise survey is conducted in an area where noise exposure is suspected to be dangerous to people's health, and involves measuring the ambient noise level and/or noise levels. The measurements are then analysed to gauge the severity of the problem. One normally conducts a noise survey with a sound level meter (SLM) to measure daily exposure, average noise intensity, and peak intensity. The National Noise Control Regulations (NCRs) defines a disturbing noise as any sound that is 7 dB(A) above the ambient noise level (Sound Research Laboratories South Africa, 2011, 1).

Performing a noise survey is a meticulous test during which many factors have to be considered. To understand a noise problem in a building, it is necessary to understand the basic principles and physics of acoustics, as well as how noise propagates. First the noise that is present in the room needs to be investigated and identified. This in turn allows one to determine how to approach the noise problem.

2.2 Noise Standards

Unless otherwise specified, the sound level measurement unit, dB(A), implies that measurements have been taken in the scale of L_{Aeq}, with an equivalent continuous sound level meter. This refers to the sound level meter's ability to determine, within a specified period of time, an average value for continuously fluctuating sound levels in an occupied room. The meter measures the levels as they fluctuate, and calculates an average intensity utilising the A-weighted scale.

2.2.1 International Noise Standards

Over the years, as the influence of noise on learners' learning abilities was noted, noise laws changed and became more distinct all over the world. This subsection discusses international literature focused on noise standards for different countries, and will particularly compare countries' recommended unoccupied background (ambient) noise levels, and suggested ambient levels in an occupied classroom (facilitating optimal learning). Furthermore, the effect of SNR and reverberation time on speech intelligibility are discussed in this section.

The necessity of noise laws for schools derives from the duty of a country to give its children an adequate education. Driving this aim is a function of values and ideals of the reigning political party that should be part of their agenda, as money should be made available to implement and enforce these regulations. The Association of Australian Acoustical Consultants (2010, 4) founds that dramatic changes in teaching style have meant that the traditional style of lecturing has been deemed inadequate and has been adapted so that, dependent on the class level, about 40 % of time in class is spent in group activities for senior students, and about 30 % is spent on mat work for junior learners. As new teaching styles, curricula, and methodologies are regularly implemented in schools around the world, one can deduce that learning spaces built at an earlier stage might not being sufficient for newer styles of teaching. Therefore, all schools need to regularly evaluate their classrooms in order to make sure that the learning environment is adequate.

It should be noted that the noise laws of a country cannot simply be applied without insight. The recommendations need to be compared and evaluated against one another, as well as against international criteria so as to prove useful for the present study. The noise levels and reverberation times recommended by countries vary as a result of various researchers emphasising different aspects within the acoustic field. For the purpose of this study, the information provided in this section is compiled from English publications and translations.

2.2.1.1 Unoccupied Ambient Noise Levels in Schools

The following subsections discuss applicable noise recommendations (noise laws) pertaining to enclosed classrooms. In the absence of a national standard, studies usually follow an international standard.

United States of America

According to Pekkarinen and Viljanen (in Knecht *et al.* (2002, 65)), the United States (US) has historically lacked national noise standards, which has resulted in highly variable acoustic conditions in US classrooms. Research conducted in the early 1950s already indicated that unoccupied noise levels should not exceed between 35 dB(A) and 40 dB(A) (Lubman and Sutherland, 2004, 12). This research was widely disregarded by people in power, who believed that it was not an important issue, and was therefore not enforced. A study by Knecht *et al.* (2002, 66), in Ohio in the US, showed that only four out of 32 diverse, unoccupied classrooms had background noise levels below the preferred level of 35 dB(A).

However, the US' noise laws have improved over the last two decades as new research was conducted and made available. These tests mainly focused on factors concerning speech and hearing, as new measuring methods became available for such tests. One of the first institutions to make a noise standard available for schools was The American Speech-Language-Hearing Association (ASHA). This standard was implemented in 1995. Knecht *et al.* (2002, 65) explain that ASHA initially recommended that unoccupied classroom noise levels not exceed 30 dB(A). In the early 2000s this was amended to a recommended maximum background noise level of 35 dB(A) as 30 dB(A) is an unrealistic value.

Surprisingly the US has more than one noise standard that is internationally acclaimed, proving that they are at the forefront of noise law research. The American National Standard Institute standard for acceptable noise levels in schools was adopted in 2002, and is known as ANSI S12.60 (2002). This standard largely confirmed ASHA's specifications. The ANSI Working Group specialising in classroom acoustics has recommended a maximum background level of 35 dB(A) (Knecht *et al.*, 2002, 65). However, ANSI standards are not currently mandatory and can be adopted voluntarily by schools.

As already mentioned ASHA and ANSI are internationally accepted standards, so in the case where a country does not have its own noise laws these can be used as reference standards.

US-based studies, such as those by Shield and Dockrell (2003, 11), Neuman *et al.* (2010), Hassan (2009, 689), Nelson *et al.* (2002, 3), Knecht *et al.* (2002, 66), and Lubman and Sutherland (2004, 12), reference the value of 35 dB(A) for unoccupied classrooms, as prescribed by ANSI and ASHA. A slight addition in the data is found in Lubman and Sutherland (2004, 13) as they provide an unoccupied level of 40 dB(A) for furnished learning spaces larger than 20,000

ft^3 (approximately 566 m^3).

United Kingdom

According to England's Building Bulletin 93 (BB93), an ambient noise level limit of 35 dB(A) $L_{Aeq30min}$ is recommended for unoccupied primary and secondary school classrooms (Dockrell and Shield, 2006, 6). Just as ASHA's limits were revised, the Building Bulletin's recommendations have also undergone updates. BB 93 is the recent update of Building Bulletin 87 (BB87), where the unoccupied classroom background noise level was changed from 40 dB(A) in BB87 to 35 dB(A) in BB93.

Shield *et al.*'s (2015, 117) research into unoccupied classroom levels in England and Wales showed that, following the introduction of legislation relating to school acoustics, the number of school spaces complying with current standards has approximately doubled since 2003. This is because schools in these regions are now required to comply with the Building Regulations in terms of their acoustic design (Shield *et al.*, 2015, 178). This statistic proves that enforced legislation goes a long way to improving the acoustics of learning environments.

The UK has a good track record when it comes to noise surveys being conducted in their schools, showing that they take the issue of classroom acoustics seriously. Dockrell and Shield (2004, 8) conducted their tests in 43 classrooms in schools in London, and Shield *et al.* (2015, 177) conducted a survey in 185 unoccupied spaces in 13 schools. These extensive surveys provide information on the typical acoustic environment of secondary schools by recording background noise levels and room acoustic parameters.

Australia and New Zealand

Australia and New Zealand share a standard called the Australian and New Zealand Standard AS/NZ2107 (2000), which specifies that an ambient noise level for unoccupied classrooms of 35 dB(A) is satisfactory, and specifies a maximum limit of 45 dB(A) (Wilson *et al.*, 2002, 7; Mealings *et al.*, 2016, 2).

The Association of Australian Acoustical Consultants (AAAC) has been concerned for some time that there are no country-wide regulations or standards that encompass all aspects of the acoustical qualities of educational and training facilities. These values are applicable to primary and secondary schools (Association of Australian Acoustical Consultants, 2010, 3). They concluded their study by finding that there is a need for an appropriate set of consistent country-wide acoustical criteria (Association of Australian Acoustical Consultants, 2010, 4). Association of Australian Acoustical Consultants (2010, 4; 9) references 35 dB (as measured with L_{Aeq}) for teaching spaces in primary schools, but explains that, if possible, background levels of 30–40 dB(A) should be attained. This low background noise value should be attained to ensure good understanding (Association of Australian Acoustical Consultants, 2010, 7).

The New Zealand Audiological Society (NZAS) endorses the improvement of acoustic properties of classrooms throughout New Zealand, so that all learners can better understand their teachers via direct instruction and their peers via indirect instruction (New Zealand Audiological Society, 2015, 1).

New Zealand also experiences the same problems as other countries, as most older-style classrooms have poor acoustics, long reverberation times, and ambient noise intrusions (New Zealand Audiological Society, 2015, 1). Mealings' (2016, 2) research concurred that New Zealand guidelines for ambient noise level should be 35 dB(A) or less. The New Zealand Audiological Society (2015, 3) suggests that in order to achieve the ambient noise level of 35 dB (as measured with L_{Aeq} over a period of 10 minutes), there needs to be protection from outside noise.

In certain cases, the different values refer to the volume of a classroom; 35 dB(A) is preferred for smaller classes (smaller than 283,17 m^3) and 40 dB(A) for larger classes (bigger than 283,17 m^3). New Zealand literature also compares their data against ANSI's standard.

India

India's classrooms have high levels of ambient noise. Tests conducted by John *et al.* (2014, 35) compared their measured sound levels to the parameters of the National Building Code of India to ensure comfort and acceptability. The National Building Code states that the maximum comfort range for a classroom is 40–45dB$_{(L_{Aeq})}$. This is higher than most other countries and could indicate that noise pollution is a big issue in India. The results of their study measured levels of 55 dB(A). The research was also compared to a NC curve, which, when translated, identifies the classroom ambient noise to be between 35–40 dB(A).

NTi-audio (2012, 7) and CertainTeed (2011, 8) list the acceptable NC level of a classroom as 25–30 — translating to 35–40 dB(A).

India also adopts international noise standards as shown by Sundaravadhanan *et al.* (2017, 39) and Armstrong Ceiling Solutions' (7) use of ANSI.

Nigeria

A study was conducted by Ana *et al.* (2009, 1) in Nigeria, regarding the effects of high noise levels and traffic noise on health and learning abilities of learners and teachers.

In the absence of a national standard, they cited the World Health Organization's (WHO) international noise law identifying the permissible noise level in a school environment to not exceed 35 dB(A).

Sweden

Hygge (2014, 2) showed that unoccupied noise levels for classrooms should be between 30 and 40 dB(A). According to Knecht *et al.* (2002, 65), 35 dB(A) is acceptable for unoccupied classrooms.

Kihlman *et al.* (2014, 5) believe that, Swedish, requirements for classroom acoustics have been weaker from a legislative point of view. Studies done by Hygge (2014, 14) found that unoccupied ambient noise levels in Swedish classrooms do not, on average, meet criteria set out in noise specifications. A study done by Shield *et al.* (2015, 178) confirms this notion as Swedish schools tend to exceed the recommended unoccupied noise level, measuring in the range of 58–69 dB L_{Aeq}.

Denmark

Mealings' (2016, 3) research for Denmark's noise laws gives a guideline of 35 dB(A). Knauf Room Acoustics (2006, 3) states that the maximum unoccupied ambient value should be below 45 dB(A). Many scholars[2] would disagree with this value, as such a loud noise level over a long period of time has detrimental effects on teachers' voices.

Finland

Finland has a national standard called Standard SFS 5907 (Mikulski and Radosz, 2011, 782). In Finland, Mealings' (2016, 2) research showed that the guideline for ambient noise should be less than 35 dB(A). Hygge (2014, 3) preferred background noise levels be even lower – 28 dB(A), which could indicate that the classroom was used for 'sensitive groups'.

Germany and Switzerland

The German national standard, Deutsches Institut für Normung (DIN) 18041 was revised and published in 2004 (Eggenschwiler, 2005, 1). It is common practice to use this standard in Switzerland as well. Eggenschwiler (2005, 2) cites the German standard DIN 18041 preferred values of between 30 dB(A) and 35 dB(A), as the permissible noise limit for a lecture hall. It is to be noted that DIN requirements are also dependant on room volume.

Spain

A study carried out by the Spanish Organization of Consumers and Users, (OCU), measured the noise levels in 10 elementary schools in Madrid and Barcelona, Spain. The Organisation of Consumers and Users (2017, 1) research showed that seven out of ten classrooms exceeded the standard permissible noise level of 40 dB inside classrooms, as established by Spanish regulation. The stricter recommended limit by the WHO (35 dB), showed that nine out of ten schools in Spain do not meet the recommended level (Organisation of Consumers and Users, 2017, 1).

[2] Among them Laurinolli (2012, 1), Dreossi and Momensohn-Santos (2005, 254), Wilson *et al.* (2002, 6) andT & R Interior Systems (2014, 6)

Italy

The Italian standard is named the Italian National Unification (UNI) 11367 (De Giuli *et al.*, 2014, 33). Studies done by De Giuli *et al.* (2014, 34) in primary schools in Italy reference ANSI's value of 35 dB(A).

China

Chan *et al.* (2015, 1) conducted a large study in Hong Kong, China, where noise levels were measured in 146 classrooms in 37 schools. Chan *et al.* (2015, 3) references the WHO and ANSI's ambient noise value of 35 dB(A) for unoccupied classrooms. The maximum background level, as stated by Roy (2016, 7), is 45 dB(A) for unoccupied classrooms.

Chile

Roy (2016, 3) conducted a noise measurement in 52 schools in Santiago, Chile, and found evidence of voice related afflictions amongst teachers. The tests results showed that unoccupied ambient noise levels varied from 38 to 66 dB(A).

Another test conducted in Chile, by members from Santiago University, showed that in 50 % of the measured schools the average noise level was 70 dB (Organisation of Consumers and Users, 2017, 1).

Brazil

Da Graça *et al.* (2007, 987) reference ASHA's level of 35 dB(A) as the ideal limit for classroom background noise in Brazil. Mealings (2016, 3) references guidelines for less than 40–50 dB(A) in an unoccupied class, but does not state the volume of the classroom.

Universally Accepted Standards

Countries with the most consistent ambient noise level values are either those that had existing noise laws of their own national standard, or those that adopted international standards such as ASHA, ANSI, the WHO and BB93. Adopting international standards compensates for the absence of a national standard.

The WHO is a specialised agency of the United Nations that is concerned with international public life. Berglund *et al.* (1999, 43) conducted their research for the WHO and recommend unoccupied classroom ambient noise levels not exceed 35 dB L_{Aeq}. Evidence-Space (2015, 1), Schneider *et al.* (2005, 9), as well as Shield and Dockrell (2003, 12) use this recommendation in their publications.

Hassan (2009, 767) and Sound Reduction Systems (2013, 3) cite the following international NR values:

1. 25 for a school lecture room ($\sim$ 30 dB $L_{Aeq,30min}$)
2. 30 for a school corridor ($\sim$ 35 dB $L_{Aeq,30min}$)

3. 30 for an assembly hall ($\sim 35\,\mathrm{dB}\ L_{Aeq,30min}$)

The prescribed values are not beyond reproach and can be reviewed and amended, as these laws are still evolving. In more recent literature, ANSI has been compared to ASHA and in doing so some of ANSI's inadequacies have been highlighted:

> Unlike ASHA, ANSI fails to address the Signal-to-noise ratio, the most critical component. While ASHA and ANSI both provide recommended acoustical standards, their intent is different. ANSI standards were adopted to provide school districts with guidelines for new construction and renovation that would improve the acoustical environment in the schools (The Institute for Enhanced Classroom Hearing, 1).

The countries mentioned in the table below (Table 2.1) refer to a national or international standard. It is, however, not always clear whether they have adopted international values or whether their values were derived from local measurement data.

Table 2.1: International Unoccupied Noise Level [Knecht *et al.* (2002, 65), Dockrell and Shield (2006, 6), Wilson *et al.* (2002, 7), Sundaravadhanan *et al.* (2017, 39), Mealings (2016, 3), (Concerned About Classroom Coalition, 1), Mikulski and Radosz (2011, 782), Eggenschwiler (2005, 2), Organisation of Consumers and Users (2017, 1), Estrada-Rodriguez (2009, 441-2), Dreossi and Momensohn-Santos (2005, 252), Berglund *et al.* (1999, 43), CertainTeed (2011, 8), and Hassan (2009, 767)]

Country	Standard	Unoccupied dB(A) Level
International	WHO	35
International	NC Curve	35–40
International	NR Curve	35
America	ASHA (2000)	35
America	ANSI (2002)	35
Canada	ANSI	35
England	Building Bulletin 93	35
Australia and New Zealand	AS/NZ 2107 (2000)	35
Brazil	NBR 10152	35–45
Germany and Switzerland	DIN 18041	30–35
Norway	NS 8175	35
Denmark		35
Finland	SFS 5907	35
India	NBC of India	35
Japan		< 40
Spain	OCU	40
Italy	UNI 11367	< 36
Mexico		35
Sweden		35
Portugal	NBR 12179 (1992)	35
France		< 38
Turkey		< 45
Belgium		30–45

2.2.1.2 Occupied Ambient Noise Levels

This subsection reviews relevant international occupied ambient noise levels. Chan *et al.* (2015, 3) references the WHO and ANSI background noise values for occupied classrooms of between 40–50 dB(A). For the US the Acoustical Society of America (ASA) states that the recommended goal level for speech sound levels is 65 dB(A) throughout a classroom (Acoustical Society of America, 1998, 1). However, according to ASHA, the occupied classroom ambient noise level should not exceed 40 to 50 dB(A) (Knecht *et al.*, 2002, 65), bringing it in line with WHO and ANSI. According to Berg, Blair, and Benson (1996) (in Mealings *et al.* (2016, 2)), literature suggests that noise in an occupied classroom should be less than 50 dB(A). Brazil's preferred occupied ambient noise level for a silent classroom is 40 dB(A), with the teacher talking at their normal voice of around 65 dB(A) (Fidêncio *et al.*, 2014, 156) Brazil tends to make use of ASHA's levels.

A document published by The Swedish National Board of Occupational Safety and Health recommends that if an environment has a permanently high demand on communication and concentration, the background noise level should not exceed 40 dB(A) to avoid negative effects[3] (Lundquist, 2000, 1). It acknowledges that some classrooms may require very low background noise levels (e.g., 25 dB) to reach an acceptable speech intelligibility, especially if the classroom is to be used for 'sensitive groups'[4] (Lundquist, 2000, 1).

Berglund *et al.* (1999, 38) identified an optimal occupied background indoor noise level of 45 dB(A) as the level at which speech can be understood fairly well. Australian legislation recommends that the overall sound level (comprised of teacher and student voice) in a classroom should not exceed 65–70 dB(A), allowing the appropriate spoken voice level to lift the overall sound level by at least 15 dB above the background noise level throughout the room (Association of Australian Acoustical Consultants, 2010, 4). This value is closer to what is preferred in the US and Brazil.

Eggenschwiler (2005, 3) found that in Switzerland, the background noise speech level of a classroom (at all seats) should be at least 65 − 75 dB(A). This level is higher than the previously discussed literature, and it must be noted that maintaining a level of 75 dB(A) a lecturer or teacher will result in voice-related problems (Eggenschwiler, 2005, 3). John *et al.* (2014, 38) suggest that the value of a speaking voice must be even lower - not exceeding 60 dB.

Laurinolli (2012, 1) researched the acoustics and voice ergonomics in 40 classrooms in Finland to see why so many teachers suffer from voice disorders. He suggests that an occupied ambient level of 40 decibel should be the threshold level for speaking in a classroom, as higher levels start to cause vocal strain for teachers in their effort to make themselves audible. This study's main aim was to discern why so many teachers have voice disorders. The 40 decibels ambient occupied noise level will be very difficult to recreate within realistic conditions, as Fidêncio *et al.* (2014, 156) and others have stated that 65 dB(A) is a 'normal' voice loudness and levels closer to 40 dB are reserved for a quiet classroom (without speech). Thiery and Meyer (1988) (in Dreossi and Momensohn-Santos (2005, 252)) state that:

> there is a recommendation [in Brazil] that the mean noise level inside a classroom should be between 35 to 45 dB [as] levels between 50–65 dB (although acceptable) provoke a mild stress initiating the hearing discomfort vigilance and agitation.

[3]e.g., speech unintelligibility

[4]e.g., learners diagnosed with learning barriers

Zannin *et al.* (2012, 212; 214) compared their measurements to the recommendation from the Brazilian standard, the Norma Brasileira Regulamentadora (NBR) 10152, which established a level of 40 dB(A) for acoustic comfort in classroom but also deemed a noise level of 50 dB(A) as acceptable for teaching.

Chan *et al.*'s (2015, 3) study showed that, when compared to their Western counterparts, urban Asian school classrooms are more likely to have problems with background noise levels because Asian cities have denser populations, sometimes up to twelve times more when compared to cities in North America or Australia. Chan *et al.* (2015, 2) come to the conclusion that "little is known concerning the long-term effects of occupational noise exposure in [a] school environment", showing that Chinese literature is not yet as up to date as their Western counterparts with this research. The long-term effects of noise on health will be discussed in Chapter 2.3.

2.2.1.3 Reverberation Time

The size of the space as well as what activity the space was built for influence the average recommended reverberation time (Hassan, 2009, 134). This time parameter is tuned to the desired margin as a function of the intended purpose of the acoustic space, implying that a classroom should have a short reverberation time relative to a concert hall. Reverberation time is also influenced by room volume as well as the absorption materials present in the room.

The reason long reverberation times are such a problem in schools can be explained by Neuman *et al.* (2010, 342), as their study tested the speech recognition of learners under the age of twelve. The study argues that speech recognition in young learners is not fully developed and long reverberation times and high background noise levels therefore impact their ability to follow speech. This has a direct bearing on their academic achievement. Hygge (2014, 19) also documented the negative effect of reverberation on younger learners' listening comprehension. In addition, poorer performance in children's verbal tasks has been found in indoor classroom settings with high indoor ambient noise and reverberation times (Klatte *et al.*, 2013, 1). Learners with barriers to learning are more severely affected by reverberation. As part of the Americans with Disabilities Act of 1990, the U.S. Access Board agreed to research the problem of noisy and reverberant classrooms. They set out to ascertain whether learners with disabilities were more negative affected by poor classroom acoustics than learners without disabilities (Nelson, 2000, 354).

Nelson and Soli (Nelson, 2000, 354) believe that children in virtually every classroom can benefit from improved acoustics. Many people are surprised when they are made aware that even a 'small' excess noise or reverberation can seriously degrade learning (Lubman and Sutherland, 2004, 12). Background noise levels are also influenced by high reverberation times, as the noise can be 'amplified' by the addition of reflected sounds, and can increase overall sound levels in a room by up to 15 dB(A) (Hassan, 2009, 691). These noise levels also distorts speech intelligibility, which can lead to voice fatigue (Sound Reduction Systems, 2013, 4) since a teacher would naturally try to compensate by raising his/her voice, thereby exacerbating the problem.

Reverberation time is measured in seconds, and unless otherwise specified, the measurement refers to fully furnished, unoccupied classrooms and excludes open-plan classrooms. While evaluating the time values in subsequent sections it should be noted that reverberation time is frequency dependent. For practical reasons the reverberation time at frequencies of 512 or 1000Hz is typically used as a single number to quantify the acoustic properties of a space (Hassan, 2009, 134).

United States of America

According to Nelson (2000, 354) there is overwhelming evidence suggesting that US classrooms are too noisy and reverberant.

The Acoustical Society of America (1998, 1) and Nelson *et al.* (2002, 3) both state that the recommended target for occupied classroom reverberation time in America is less than 0.6s.

ASHA's initial preferred reverberation time for a classroom stipulated that it should not exceed 0.4s, but it was later amended to a maximum reverberation time of 0.6s (Knecht *et al.*, 2002, 65). Neuman *et al.* (2010, 336), Lubman and Sutherland (2004, 13), Shield and Dockrell (2003, 11), and Hassan (2009, 689) prefer the use of ANSI's value with a maximum reverberation level of 0.6s measured at 500, 1000 and 2000 Hz octave bands.

United Kingdom

England's national standard, BB93, recommends a reverberation time of less than 0.6s for primary school classrooms (Sound Reduction Systems, 2013, 3). Shield and Dockrell (2003, 12) also uses this reference level, and explains that it was amended from between 0.5 and 0.8s in BB87 to less than 0.6s in BB93.

Australia and New Zealand

According to the Australia/New Zealand Standard published in 2000 the reverberation time of an unoccupied primary classroom should be between 0.4 and 0.5s (Wilson *et al.*, 2002, 7). The Association of Australian Acoustical Consultants (2010, 9) based their reverberation time on ASHA's preferred level of between 0.4 and 0.5s. These ASHA values are now outdated, as are the values of the Australia/New Zealand Standard. The New Zealand Audiological Society's (2015, 3) newer suggestion comes close to the old Australia/New Zealand Standard; preferring a reverberation time of between 0.4 and 0.6s when measuring in single octave frequency bands (125 Hz to 5 Hz).

India

A test conducted by Armstrong Ceiling Solutions (4) showed that high reverberation time leads to at least 25 % of a teachers' words to be lost to the learners. "Trying to hear in a poor acoustical environment is like trying to read in a room with the lights off: stress increases, concentration decreases and learning is impaired".

The National Building Code of India (2007) stipulates that the acceptable reverberation time for a classroom is between 0.75 and 1.2s (John *et al.*, 2014, 36). Roy (2016, 9) states that Indian criteria dictate a maximum of 0.75s for reverberation, but Armstrong Ceiling Solutions, (7) dictates a maximum of 1s according to Indian standards, showing that there is a discrepancy with the research used by the researchers.

The study done by Armstrong Ceiling Solutions, (7) in India proved that there is a preference to adopt the global ANSI standard to compensate for weak national legislation. The study used ANSI as baseline for an unoccupied furnished classroom with a volume under 10,000 ft^3 (approximately 283 m^3) to have a reverberation time of 0.6s, and for a classroom between 10,000 and 20,000 ft^3 (approximately 566 m^3) 0.7s.

Sweden

According to Hygge (2014, 2), the recommended reverberation time in Sweden is between 0.4 and 08s. Mealings' (2016, 3) referenced time comes close to this as he cites a time of less than 0.9s for a classroom. Knecht *et al.* (2002, 65) states that the reverberation time should fall within the limits of 0.6 to 0.9s (i.e., in between the values identified by Hygge and Mealing). Once again it can be seen that there is some ambiguity of noise laws within one country.

France

France has an acceptable level of 0.4–0.8s for reverberation time in rooms smaller than 250 ft^2 (23 m^2) (Mealings, 2016, 3; John *et al.*, 2014, 36), with a preference of 0.6 to 1.2s for rooms bigger than 250 ft^2 (23 m^2) (John *et al.*, 2014, 36).

Germany and Switzerland

A study done in Switzerland by Eggenschwiler (2005, 2) cites the German standard DIN 18041 as recommending a reverberation time of 0.8s. In Germany, the DIN 18041 standard establishes that reverberation time values should be represented as the average of 2 octave bands (500 and 1000Hz) (Zannin *et al.*, 2012, 217).

Citing a value (that is the average of the above DIN value) is John *et al.* (2014, 36), whose research showed that the preferred reverberation time of 0.6 to 1.0s is for classrooms bigger than 250 ft^2 (23 m^2) but smaller than 750 ft^2 (69 m^2).

Norway

Norway uses Standard Standard Norge (SN) 8175 which specifies a maximum reverberation time of 0.6s (Mikulski and Radosz, 2011, 782). Mealings (2016,

3) and Hygge (2014, 3) argue that the reverberation time should be less than or equal to 0.9s.

Finland

Finland has a standard called Standard Suomen Standardisoimisliitto (SFS) 5907 which suggests a reverberation time of 0.6 to 0.8s (Mikulski and Radosz, 2011, 782). The Finnish Ministry of the Environment provides a specification that a classrooms reverberation time should fall between 0.6 and 0.9s at frequencies ranging from 250 to 2000 Hz (Sala and Viljanen, 1995, 82). Mealings (2016, 2) references the same maximum reverberation time. Hygge (2014, 3) references a reverberation time value of between 0.5 and 0.6s, which is lower than the above mentioned three researchers.

Universally Accepted Standards

Berglund *et al.* (1999, 43) conducted research for the WHO and cite a preferred classroom reverberation time of 0.6s. Zannin *et al.* (2012, 217), Berglund *et al.* (1995, 37), and Klatte *et al.* (2010, 2) also cite this as their reference value.

Lubman and Sutherland (2004, 13) state that according to ANSI, the maximum reverberation time for a classroom smaller than 10,000 ft^3 ($\sim$ 283 m^3) should be 0.6s, and for a classroom between 10,000 ft^3 ($\sim$ 283 m^3) and 20,000 ft^3 ($\sim$ 566 m^3) should be 0.7s. This level was also cited by Neuman *et al.* (2010, 336), Shield and Dockrell (2003, 11), and Hassan (2009, 689).

It is evident that, other than established standards such as the WHO, ANSI, ASHA and BB93, in certain cases reverberation time varies within one country's research.

Table 2.2: International Unoccupied Reverberation Time [Berglund *et al.* (1999, 43), Knecht *et al.* (2002, 65), Eggenschwiler (2005, 2), Hassan (2009, 689), Estrada-Rodriguez (2009, 441-2), Mikulski and Radosz (2011, 782), Sound Reduction Systems (2013, 3), Hygge (2014, 2), John *et al.* (2014, 36), New Zealand Audiological Society (2015, 3), Mealings (2016, 3), and (Roy, 2016, 6)].

Country	Standard	Unoccupied Reverberation Time(s)
International	WHO	0.6
America	ASHA	0.6
America	ANSI	0.6
England	Building Bulletin 93	< 0.6
Australia and New Zealand	AS/NZ 2107 (2000)	0.4–0.6
Germany and Switzerland	DIN 18041	0.8
Sweden		0.4–0.8
Finland	SFS 5907	0.6–0.9
France		0.4–0.8
Poland	NEN 5077	0.8
Norway	NS 8175	0.6–0.8
Denmark		< 0.9
Brazil	NBR 10152	0.5–0.7
Portugal	NBR 12179 (1992)	0.6–0.8
Mexico		< 0.6
Japan		0.6
China		0.8

2.2.1.4 Speech Intelligibility

Speech intelligibility is simply defined as the degree to which speech can be understood in a setting (Hassan, 2009, 712). SNR is defined as the ratio of signal 'loudness' relative to noise 'loudness' and can be expressed using the decibel unit of measurement. Hassan (2009, 712) explains that there are many factors that affect speech intelligibility, including environmental noise (noise coming from both inside and outside a room), noise made by people (background noise level), and excessive reverberation. As previously stated:

SNR can mathematically be defined as: $\mathrm{SNR} = \frac{Signal}{Noise}$.

Signal in this case refers to the teachers' voice, Noise refers to the background noise (Dreossi and Momensohn-Santos, 2005, 252). Both signal and power need to be measured in the same bandwidth and at equivalent points.

Knecht *et al.* (2002, 66) state that to critically evaluate how well an individual can hear and understand speech, there are three well-established factors that have to be quantified:

1. occupied background noise level
2. reverberation time
3. signal-to-noise ratio (SNR)

The first two parameters were discussed in the previous section, and SNR will be discussed in this section.

According to Zannin *et al.* (2012, 205) SNR is an acoustic descriptor that needs to account for reverberation time, background noise, and the source's direction to determine the perception of speech. SNR influences speech intelligibility directly. The higher the reverberation time and background noise within a classroom, the lower the SNR results will be. Evidence has shown that reduced SNR diminishes understanding and learning, especially for children with hearing disabilities or other special needs. The main function of a classroom is for a teacher to act as an efficient mediator of knowledge, and if children are unable to understand what the teacher is trying to communicate, the function of a classroom is impaired (Evidence-Space, 2015, 2). It is established that SNR directly links to learners' concentration and performance. Age is also an influencing factor, as younger children need better SNR values (Neuman *et al.*, 2010, 336).

The noise generated from inside and outside a classroom bounces off walls, floors and ceilings, distorting the teacher's instructions and limiting learners' comprehension.

> In a disturbance-free environment, normal speech levels fall between 47 dB (normal private vocal effort) or 52 dB (normal public vocal effort) or 57 dB and 62 dB (loud) or 67 dB (very loud) (measured at a distance of 1 m from the speaker) (Hassan, 2009, 712).

An example given by Hygge (2014, 7) to explain this phenomenon is that when a teacher is speaking at a level of 65 dB(A), which is deemed a 'raised' voice, in a classroom that has normal sound reflections this level will drop to $\approx$ 52 dB(A) from about 6m into the classroom.

Chan *et al.* (2015, 3) cites the WHO and ANSI's values for occupied classroom SNR values to be between 55–65 dB(A). Houtgast (1981) and Bradley (1986b) (in Berglund *et al.* (1999, 18)) state that if the level of speech increases the sound level measurement by 15 dB or more, speech intelligibility at 1m distance will be close to 100%. The calculation will be expressed as $SNR_{dB} = P_{signal,dB} - P_{noise,dB}$.

Studebaker et al.'s (1999) (in Nelson *et al.* (2002, 7)) tests clearly demonstrate that if background noise is above 69 dB(A), listeners will struggle to understand speech.

2.2.1.5 Maximum Work Day Noise Level Exposure

In 1978 it was documented by ISO that levels of noise exposure for an 8-hour working day should not exceed 90 dB(A) (Ginn, 1978, 86). Over the following years this value has dropped to 85 dB(A).

In Australia it is accepted that if noise exposure is kept at around 85 dB(A) during an 8-hour working day, most people will be reasonably protected from long-term hearing damage. This does not imply that safe working conditions exist at noise levels below 85 dB(A), it only means that the value represents an acceptable level of risk for an average working day (Safe Work Australia, 2011, 1). Sweden also cites a noise level of < 85 dB L_{Aeq} (over an 8-hour period) as the accepted workplace noise limit (Kihlman *et al.*, 2014, 3).

The following criterion relates to all countries within the European Union (EU): The Finnish Centre for Occupational Safety (2006, 1) states that if noise levels exceed 80 decibels in the workplace, employers are required, by law, to provide their employees with hearing protection. If the noise level is 85 dB(A) or above, wearing hearing protection is obligatory. The hard limit for workplace noise is 87 dB(A) and under no circumstances may workplace noise levels exceed this value without wearing protection.

The National Institute for Occupational Safety in America (NISOH) has a recommended exposure limit (REL), of 85 dB(A) for an 8-hour working day. When measuring this level one has to consider the time-weighted average (Hassan, 2009, 65). Hlasa (2006, 1) states that an employer is prohibited from allowing any employee to enter a high noise zone, unless the employee is wearing some type of protection for their hearing.

Table 2.3: International Maximum Work Day Noise Level Exposure [(Ginn, 1978, 86), (Finnish Centre for Occupational Safety, 2006, 1), (Hassan, 2009, 65), (Safe Work Australia, 2011, 1), (Kihlman *et al.*, 2014, 3)].

Country	Standard	Maximum Exposure Level dB(A)
International	ISO	85
Australia		85
Sweden		85
EU		85
America	NIOSH	85

According to Hassan (2009, 37) being exposed to high noise levels (of above 90 dB) is dangerous because such high levels can lead to pain in the ears, temporary hearing damage and possibly permanent hearing damage.

2.2.2 South African National Noise Legislation

In South Africa, most easily enforced noise laws are those legislated by provincial municipalities regarding disturbance of the peace and occupational safety.

In South Africa the primary law for noise and acoustics is regulated by the National Noise Control Regulations (NCRS, 1992), which falls under the Environmental Conservation Act. These regulations generally only apply to externally generated noise and are currently the only legally enforceable laws in South Africa (Sound Research Laboratories South Africa, 2011, 1).

The City of Tshwane (2004) conducted an international and national study of noise laws to increase current noise perceptions of the public. The City of Tshwane Metropolitan Municipality (2004, 11) found that there is a need for the South African public to take note of the important lessons learned by developed countries regarding noise exposure, as they have more research available, and that many of the international and national noise level standards that were initially set are inadequate and outdated (City of Tshwane Metropolitan Municipality, 2004, 11).

The City of Tshwane Metropolitan Municipality (2004, 16) identified a gap in South African literature as there is no clear guidance regarding acceptable standards for maximum ambient noise levels. This, in turn, makes the legal interpretation of specific regulations difficult when having to apply it to a specific set of transgressions. This gap often limits the jurisdiction of authorities when they attempt to effectively enforce the law.

One of South Africa's biggest noise legislation challenges, is the lack of implementation and distribution of relevant information to governing parties, which hampers legislation implementation. Schedule 5 of the Constitution has given provinces the responsibility to administer these regulations themselves. According to Sound Research Laboratories South Africa (2011, 1), to date only three provinces (i.e., Western Cape, Gauteng, and Free State) have taken it onto themselves to implement noise laws within their jurisdiction. The other provinces still revert accountability to the national NCRs. According to the City of Tshwane Metropolitan Municipality these provinces are not liable to enforce these specifications, and thus, law implementation has not been taken seriously.

A study done by Jongens (2002, 5), regarding road noise from two national roads (N1 and N2) in the Western Cape, indicates that South Africa has adequate noise laws pertaining to environmental noise but lacks transparent legislation pertaining to permitted noise levels inside of buildings.

The Department of Environmental and Cultural Affairs (1998, 5) and the City of Tshwane Metropolitan Municipality (2004, 35) state that current legislation regarding noise inside of buildings dictates that no person shall:

> erect educational, residential, hospital, church or office buildings in an existing township in a controlled area, unless acoustic screening measures

> have been provided in the buildings to limit the reading on an integrating sound level meter, measured inside the buildings after completion, to 40 dB[(A)]: provided that any air-conditioning or ventilating system shall be switched off during the course of the noise measurement.

These noise specifications are ambiguous, as the ambient noise level is derived from the type of activity that needs to take place within the building. The requirement to switch off any air-conditioning or ventilation systems is also problematic as ambient noise is normally defined as a collection of sounds that is ever-present in a building, both of natural and manmade origin (Hassan, 2009, 47).

The City of Tshwane Metropolitan Municipality (2004, 10) hypothesises that noise standards are lacking in certain parts of the world, including South Africa, because when noise pollution is compared to other environmental pollution factors it is not seen as a subject that needs urgent attention, as noise does not cause major accidents or present immediate physical danger. Other forms of environmental pollution have led to serious accidents, after which legislation was then adapted. However, 'noise never killed anyone'. Unfortunately this leads to the perception that noise pollution is a more 'acceptable' form of pollution, which will have to change if real progress is to be expected in noise legislation, especially affecting the learning sector. South Africans need to be made aware of the detrimental effects that exposure to high noise levels has on health outcomes (Ehlert, 2017, 1).

One South African study investigating school-based noise levels, comes close to the current study's aims. The test conducted by Van Tonder *et al.* (2015, 2) measured noise levels using a noise visual feedback system to indicate to learners when they were creating too much noise. The researchers made their measurements by using software called SoundEar II and SoundShip. The device showed three different Light Emitting Diode (LED) displays according to the noise level in the classroom. The researchers did not indicate what the green, yellow, and red LED lights' applicable noise measurement level was, only what the description of colour implied to the learners. The results from these tests indicated that in one school, where three classrooms activities where measured over a period of 36 hours, noise levels in the classroom reached at least 70 dB(A) 33 % of the time in the baseline period (Van Tonder *et al.*, 2015, 1). Van Tonder *et al.*'s (2015, 4) tests averaged 68 dB(A) over a period of 36 hours, with minimum levels reaching 62.5 dB(A) and maximum levels reaching 98 dB(A). This supports a possible hypothesis that the concept of 'too noisy classrooms' is also applicable in the South African context. A disadvantage of this method was that learners were initially distracted by the LED lights, although as they became used to the lights they no longer paid any attention to them.

The study showed that the maximum noise level recorded exceeded the preferred occupied level of 65–70 dB(A). Legislation states that noise levels should never exceed 70 dB over the teaching period and not exceed 80 dB at any time (T & R Interior Systems, 2014, 55). By increasing the sound level measurement by an additional 10–15 dB(A) so that it can be heard in the classroom environment, a teacher will start to feel the strain of this excessive use of his/her voice and may develop voice-related problems.

Van Tonder *et al.* (2015, 5) did not find sufficient noise laws in South Africa to compare their results against, so the study made use of the ASHA 2006 standard to obtain a baseline level for their tests. According to the specification that they used, an empty classroom's noise level should fall between 30–40 dB, and when learners are inside the classroom (quietly behaving themselves) the noise level should not to exceed 50 dB (Van Tonder *et al.*, 2015, 5).

When conducting their research, the City of Tshwane (2004, 8) did not reference a South African standard for ambient noise levels, but rather used the WHO's definition of 35 dB L_{Aeq} for the relevant ambient noise level of a classroom. The South African Department of Environmental and Cultural Affairs (1998, 5) also identified a lack of enforceable noise laws inside buildings, as most standards generally only apply to external noise. This leads to the conclusion that South Africa does not have its own legislation regarding acceptable noise parameters in classrooms, and that South African researchers are therefore forced to rely on international standards.

The impression created by the reviewed literature is that there is no national noise standard. Surprisingly this is not the case. There are specifications, but each one has its own ambiguities that need to be discussed. The South African National Standard (SANS) is defined by Venter (SAPPMA, 2016, 1-2) as a standard that specifies the performance requirements and testing of products to ensure compliance to applicable specifications. This body is not well known by the general South African public (SAPPMA, 2016, 1).

This unfamiliarity of the SANS is supported by Van Tonder *et al.* (2015), since the study made no mention of any South African noise legislation. The consulted legislation was of international origin. The City of Tshwane Metropolitan Municipality (2004, 15) a reason for this lack of knowledge is that although SANS has updated its definitions and guidelines in terms of noise, and despite introducing by-laws (representing a major advance for local authorities), the laws are completely reactive in their application since the maximum penalty specified is an inadequate deterrent. Even when the by-laws are consulted, it does not promote the level of complacency, and is ineffectual in their application.

The ineffectiveness of the by-laws could also be partly attributed to the notion that laws are specified, but not strictly enforced, leading to builders not being aware of these laws when building a structure. This becomes apparent when researching SANS, and reading an article published online called that points out this confusion: "SABS, SANS or SATAS? SAPPMA Clarifies Confusion

Regarding Certification Bodies[5]".

SAPPMA (2016, 1) explains that many industry role players, municipalities and the general public do not understand the meaning of the term 'certification body', and do not know what the national standard and its functions are. This confusion can be attributed to the fact that the South African Bureau of Standards (SABS) was previously involved in the writing, development, and distribution of SANS specifications, and these national specifications were published under the name of the SABS (SAPPMA, 2016, 1). However, the SANS took over the publication of these specifications from the SABS, and the standards were renamed to the SANS standards. Adding to the general confusion is the fact that SABS in Pretoria still makes SANS standards available from their headquarters.

SANS documents are hard to come by and are expensive, as each standard must be purchased separately. The copyright laws of the standards led to a restriction on referencing the required method of measuring. The restriction was observed throughout countless South African literature. For example, Mizan *et al.* (2014), Aldridge *et al.* (2009), and Van Tonder *et al.*'s (2015) studies only mention compliance with a specified international standard.

According to Venter (SAPPMA, 2016, 1) a SANS standard can be either written locally or created by adopting an international (usually ISO) standard. By reviewing the specific specifications' notes and bibliography (of standards consulted for this study) it is clear that SANS standards are all derived from international standards (namely the ISO, NR and NC curves). In the SANS documents, only the first page refers to the South African standard, and this is immediately followed by an ISO report explaining the specifications application. However, there is a statement on the cover page stating that the national standard is identical to that of the particular ISO standard, and was adopted with their permission.

SANS 10103:2008 (South African Bureau of Standards, 2008a) specifies that the maximum ambient noise level in an unoccupied classroom be 35 dB(A). These values are to be taken for a design equivalent continuous rating level of $L_{Req,T}{}^{a}$[6]. This parameter accepts the A-weighted sound pressure level $L_{Aeq,T}$ over a defined time period, taking into consideration adjustments for tonal character and time of day.

The consulted documents do not refer to any original South African literature (meaning no original research has been conducted within a national capacity). It is not clear whether conclusions were drawn regarding whether these values are applicable in the South African context, as each country has unique challenges (e.g., funding) that could influence these values. This has been a source of debate in other studies, as South Africa has a well-known

[5]http://www.sabuildingreview.co.za/press/440/press-releases/sabs-sans-or-satas-sappma-clarifies-confusion-regarding-certification-bodies

[6]This unit of measurement does not correspond with any reviewed literature.

problem with infrastructure and overcrowding in schools. This is largely confirmed by Berglund *et al.* (1995, 70):

> In many cases monitoring may show that noise levels are considerably higher than established guidelines. This may be particularly true in developing countries, and the question has to be raised as to whether national standards should reflect the optimum levels needed to protect human health, when this objective is unlikely to be achieved in the short- or medium-term with available resources.

It is true that certain first world countries do not yet have their own prevalent standards, and where they do have their own standards, international sources are often still consulted. South Africa cannot realistically be compared to these countries as they have more resources, more support, and the necessary infrastructure to aid them in complying with international standards. It is difficult to implement these specifications in South Africa, due to a lack of funding, which may not even always be available to richer first world countries. That being said, the current study will regard the international criteria for noise laws to be relevant to South Africa, until such time that South Africa can conduct national testing to prove that these specifications are realistic criteria for South Africa.

Thus, it is seen that South Africa has yet to clarify or provide governing bodies with the necessary tools for the the implementation of legislation. An overview of only a few SANS standards were provided in this review, and it is not necessarily the case that other specifications have the same point of reference.

2.2.2.1 National Maximum Work Day Noise Level Exposure

The South African Occupational Health and Safety Act, Act 85 of 1993, states that no employer shall allow any employee to work in an environment with a noise level equal to or exceeding 85 dB(A) L_{eq}[7] (Hlasa, 2006, 1). Other South African literature also supports this statement: if there is continuous exposure to noise levels exceeding 85 dB(A), it can lead to temporary and/or permanent noise induced hearing loss (Mizan *et al.*, 2014, 7; City of Tshwane, 2004, 5).

2.2.3 Conclusion

Of the international sources that were consulted, the most comprehensive noise laws were those introduced in the US in 2002, and in England and Wales in 2003 (Shield *et al.*, 2015, 178). The literature reviewed in this chapter showed that even within the same country, noise laws are still widely disputed, indicating just how difficult it is for a researcher to decide which guideline/baseline to

[7] This is in line with the research discussed in Chapter 2.2.1.5.

reference. Research into appropriate ambient noise levels and reverberation times has been weakened by earlier publications where the noise laws were too slack, too strict, or amended, as shown by ASHA and BB87. A possible reason for inconsistencies is the fact that noise laws are being revised and updated on a regular basis to address inadequate acoustics in buildings all over the world.

Lubman and Sutherland (2004, 14) gives an interesting view regarding why more is not being done to fix the problems that schools are experiencing, explaining that there is also a lot of politics involved with school building contracts all over the world. Industry lobbyists can indirectly pressure school planners, thereby promoting their own interests. According to Lubman and Sutherland (2004, 14) there was an instance where an influential industry group advised schools that noise levels of up to 50 dB(A) in unoccupied classrooms are adequate for learning. This shows that there are corrupt industry groups chasing private gain and wealth while disregarding the needs of learners and teachers.

The reviewed literature showed that when a country does not have strong legislation on which to base findings, it is commonly accepted practice to revert to, or supplement, the international standards compiled by WHO, ANSI and ASHA.

2.3 Health Concerns

Many studies have been conducted to investigate how noise affects health[8]. Many people are still unaware of the effects of noise, and believe that learners and children are able to adapt to the daily noise levels they are exposed to. The WHO has extensively documented the effect of excessive noise on learners' performance in schools (Zannin *et al.*, 2012, 214). Among others documented effects are:

1. slow language learning,
2. difficulty in written and oral language,
3. reading skill limitations, and
4. problems with vocabulary composition.

[8]Berglund *et al.* (1999, 31), Knecht *et al.* (2002, 70), Shield and Dockrell (2003, 1), Summers (2003, 1), Dockrell and Shield (2004, 24), Schneider *et al.* (2005, 14), Dockrell and Shield (2006, 2), Estrada-Rodriguez (2009, 437), Association of Australian Acoustical Consultants (2010, 3), Neuman *et al.* (2010, 337), Zannin *et al.* (2012, 201), Clark *et al.* (2012, 2), Klatte *et al.* (2013, 2), Evidence-Space (2015, 1), Escobar and Morillas (2015, 1), and Mealings (2016, 1) all document the various and far reaching effects noise has on children's scholastic achievement.

2.3.1 Barriers to Learning

Barriers to learning can be described as anything that creates a hurdle in a child's ability to learn effectively. It is possible for a learner to experience more than one type of barrier throughout their school career. Barriers can be either intrinsic (e.g., ADD), societal (e.g., abuse), environmental (e.g., poverty), or systemic (e.g., the school system). All these barriers are represented within the South African education system and therefore the documentation of these effects is essential to be able to educate the country. CertainTeed (2011, 5) believes that existing noise issues in the classroom are a barrier to learning that our society can ill afford.

Excessive noise in the classroom affects the learning ability and general health of learners, especially in cases of chronic noise exposure. Clark *et al.* (2012, 2) found evidence that noise has an effect on a child's cognitive development and functioning. Therefore, appropriate education can not be provided in a classroom with excessive noise and reverberation (Nelson *et al.*, 2002, 2). This is the primary reason for noise standards regulating noise levels and reverberation times for classrooms. The importance of classroom acoustics is highlighted by Kintsch (1988) (in Klatte *et al.* (2013, 2)), who states that effective listening in a classroom setting "requires semantic and syntactic processing of complex oral information while developing a coherent mental model of the story meaning". A reason given by Shield and Dockrell (2003, 1) to explain why tasks are severely effected by noise is that most tasks involve facets of language, such as reading. This type of task places a high demand on cognitive processing as it requires an integration of learners' attention, problem solving, and memory skills in order to successfully complete the task. Dockrell and Shield's (2006, 22) research showed that irrelevant speech (background noise) also has a large impact on learners' working memory as this noise competes with the target verbal material supplied by the teachers. Both reading and spelling, where the processing of text involves working memory processes, are particularly vulnerable to this effect. When noise occurs in the form of speech, learners focus on the sound as their brains try to process and understand it, deflecting attention away from other activities in the class. In this case there are two streams of communication competing against one another. The reason that language is most adversely affected in children is because younger children still perceive phonological word representations as holistic in nature, whereas young adults perceive language in phoneme units (Klatte *et al.*, 2013, 1). Clark *et al.* (2012, 4) explain that unwanted sound can impair cognitive performance in two separate ways, namely by:

1. interfering with the deliberate processes that are needed to successfully complete the specific focal task, or

2. interrupting the execution of the processes.

Estrada-Rodriguez's (2009, 438) research showed that learners who were exposed to noise while completing tasks had a higher error rate as well as a tendency to desert their tasks before completion due to the disruption of cognitive tasks. Learners who cannot hear what is being taught in a classroom tend to lose concentration as they are not a part of the proceedings taking place in class (Association of Australian Acoustical Consultants, 2010, 3), thereby negatively affecting student progress. Noise in a classroom also leads to discipline and cooperation issues for the teacher (Knecht *et al.*, 2002, 70). Studies done by Berglund *et al.* (1999, 31), Shield and Dockrell (2003, 1), Dockrell and Shield (2004, 24), Dockrell and Shield (2006, 7), Neuman *et al.* (2010, 337), Clark *et al.* (2012, 1), and Klatte *et al.* (2013, 4) have documented how noise affects different cognitive tasks such as reading, recognition, attention, understanding, problem solving, and memory (short and long term). Mealings (2016, 1) documented that children who were taught in classrooms with poor acoustic properties had poorer literacy and numeracy skills than children who were taught in classrooms with adequate acoustic properties. The study also showed that this phenomenon influenced learners' options of qualifying for tertiary education, leading to them having comparatively lower paying jobs. A noisy learning environment can therefore have a direct influence on learners, potentially stunting their development in childhood, and culminating in negative, long-lasting effects as adults.

Learners' cognitive abilities are not the only processes that suffer under noisy conditions; some symptoms manifest physically. Clark *et al.* (2012, 3), Zannin *et al.* (2012, 201), and Dockrell and Shield (2006, 7) documented the following symptoms:

1. learner frustration
2. learned helplessness
3. impaired attention
4. increased arousal
5. noise annoyance
6. decreased motivation
7. sleep disturbance, and
8. strained oral communication leading to fatigue.

In practice, young inexperienced listeners are regularly confused during educational communication becasue it frequently occurs in less-than-ideal conditions, such as more than one person speaking simultaneously (Evidence-Space, 2015, 1). Younger learners are easily distracted by meaningful speech around them, as their ears notice familiar words, diverting their attention. A reason why 'outside' noise affects younger learners so much is because they have not yet acquired the ability to filter out irrelevant noise, and this leads to a loss of attention. Any irrelevant sound may capture a learner's attention and cause a disruption of the learning activity (Klatte *et al.*, 2013, 3). Keeping learners' attention depends on the learners' age and ability to maintain their attention, as well as the characteristic of the unwanted sound. Examples of sound that can divert attention include the slamming of doors, change of voice in a speech stream, and noise transmission from adjacent rooms. Learners of a younger age are more severely affected by this phenomenon because their cognitive functions are not as automated as those of an adult. Therefore, the younger the child, the better the listening conditions required. Various tests have been performed to identify at what age a child's listening ability is most affected, although this has proved difficult. However, most tests have shown that learners below 15 years old are the most affected (Nelson *et al.*, 2002, 2; Dockrell and Shield, 2004, 3; Neuman *et al.*, 2010, 343) as they are still developing mature language and need environments where verbal messages can clearly be discerned to avoid compromised understanding (Nelson *et al.*, 2002, 2-3). One measurable parameter, linked to the quality of an educational environment, is reverberation time. Longer reverberation times have a debilitating effect on learning as they impair the discernibility of spoken words, especially since younger learners have not yet mastered the precedence effect. The precedence effect, which develops during childhood, refers to one's the ability to largely suppress the echo-like effect of sound bouncing off reflective surfaces (Nelson *et al.*, 2002, 4). A test conducted by Knecht et al. (2002) (in Nelson *et al.* (2002, 7)) showed that even if the reverberation time in a classroom is only moderate, it can still cause vowels to 'smear' over consonants, creating confusion when trying to determine consonants and pauses in speech, thereby having a pronounced effect on the intelligibility of the spoken word.

Noise as a barrier to learning has already been discussed, but what about learners predisposed too other barriers to learning when they enter schooling? It has been established that many children without hearing deficits, and being taught in their home language, already struggle to learn in noisy situations (Nelson *et al.*, 2002, 3). Other cognitive learning barriers that learners may experience include learning disabilities, listening difficulties, language learning problems, behaviour problems, reduced cognitive skills, hearing loss, a speech understanding handicap, auditory processing disorders, and chronic illnesses (Nelson *et al.*, 2002, 2; Summers, 2003, 1).

Neurobiological research by Cunningham *et al.* (2001) (in Nelson *et al.* (2002, 7)) in children with auditory learning problems showed that children who have a barrier to learning have an even harder time understanding speech sounds in a suboptimal acoustic environment. The data was derived by measuring brain responses to key speech sounds that were identified as being 'difficult'. The study showed that children with documented barriers to learning were not more affected, compared to neurotypical children, when it came to discriminating speech from similar sounds in quiet situations. The study did, however, find that children with barriers to learning performed more poorly in their discrimination of these same sounds in noisy situations than other children. The study drew the conclusion that:

> The brain responses from the children with learning problems showed reduced neural precision and did not faithfully convey the representation of the noisy speech sounds to the brain. These results support the general impression that background noise causes excessive difficulty for children who have learning disabilities and attention deficit disorder (Nelson *et al.*, 2002, 7).

An barrier to learning particular to South Africa, is that in many parts of the country learners are not being educated in their home (or even second) language. Research compiled by Nelson *et al.* (2002, 3-5) showed that children who have a poor vocabulary in the language utilised for education, or who are not taught in their home language, are even more vulnerable to impaired cognitive understanding due to background noise.

A socio-economic factor that contributes to learning barriers, especially in poorer communities worldwide (including South Africa) is classroom facilities. This will not be discussed in detail, but a short overview will be provided to acknowledge its effects on learners.

Government is faced with the difficult question of how to fulfil the unique needs of rural communities (Gardiner, 2008, 7). In many poor, third-world countries, children are experiencing barriers to learning as they do not have adequate facilities in which to learn. The conditions of poverty that plague these underdeveloped communities are reflected in the quality of available education (Gardiner, 2008, 9).

Children who do not have access to any facilities have had to develop different modes of communication, as they spend more time in the outdoors, with limited access to communal indoor spaces (such as schools). This does not necessarily equate to a second-rate education, as there are many advantages to this method of teaching if done correctly (Chantrell, 2015, 1; Dillon, 2010, 3).

One indicative parameter that applies to this study, reverberation time, would not factor into an educational environment devoid of walls and/or a ceiling. Rather, the learners' hearing ability would be impaired by the absence of reverberation and sound reinforcement normally associated with a traditional 'classroom' layout. This results in teachers having to strain their voices (i.e., producing higher sound levels) than in a traditional setting to make themselves audible to all the learners.

2.3.2 Effects on Teachers

The teacher is also affected[9] by high levels of background noise and long reverberation times. It has been noted that teachers have to raise their voices if they work in an environment that has high background noise levels (Rantala *et al.*, 2012, 1).

Vocal stress, for example, is one symptom that affects many teachers. During teaching, extensive use of the teacher's voice is required, especially when having to compete with other teachers (in the case of inadequate sound insulation between adjacent classrooms, for example), placing teachers at high risk for developing occupational voice disorders (Dreossi and Momensohn-Santos, 2005, 254). Teachers are also burdened with additional activities such as tutoring, lunchroom monitoring, teaching extracurricular activities, and parent-teacher conferences, leaving few opportunities to rest the voice.

Laurinolli (2012, 1) and Wilson *et al.* (2002, 6) found that modern teaching methods can be one reason for teachers' voice disorders. Pupils are no longer required to sit quietly and listen to their teacher all day, rather, they are encouraged to be actively involved in learning activities, with more team work assignments being required (Wilson *et al.*, 2002, 6). Wilson *et al.* (2002, 6) found that there is great value in group activities as it encourages 'incidental learning' where learners learn from one another, but good hearing conditions are essential for these types of activities as communication remains a crucial element. On the flip side, it is evident that changes in teaching methods have contributed to learning barriers, causing stress for both teachers and learners. A study done by Oticon in New Zealand (T & R Interior Systems, 2014, 6) found that group activities add strain to a teacher's voice as half of the teachers in the study indicated that they had to considerably raise their voices during these type of class activities (possibly leading to nodules on vocal chords). This is the type of teaching method that is currently encouraged by the South African school curriculum, the Curriculum Assessment Policy Statements (CAPS). The focus of this type of curriculum is on continuous assessment involving frequent group tasks encouraging regular communication between learners.

If a teacher is constantly raising his or her voice while teaching, another effect may present itself:

> Educational psychologists have known for some time that as a teacher raises his/her voice level, the tension and anxiety among children in the class is heightened. The prime example is when a teacher needs to raise their voice in a forceful manner to get the attention of a child

[9] Knecht *et al.* (2002, 70), Nelson *et al.* (2002, 2), Schneider *et al.* (2005, 76-7), Dreossi and Momensohn-Santos (2005, 254), Association of Australian Acoustical Consultants (2010, 4), Laurinolli (2012, 1), Rantala *et al.* (2012, 1), Zannin *et al.* (2012, 216), Sound Reduction Systems (2013, 5), Chan *et al.* (2015, 10), and Mealings *et al.* (2016, 2) have documented vocal disorders and its impact on teachers.

> misbehaving in the back of a classroom. All the children feel the stress of such a verbal encounter. It is also well known that a loud, forceful command for some children can have the opposite response to the desired behaviour. In general, children are known to respond best to a natural, conversational voice level (Bebb, 2009, 2).

According to Schneider *et al.* (2005, 76-7) teachers often have the added stress of having to compete with environmental noise to maintain learner concentration. Nelson *et al.* (2002, 2) and the Association of Australian Acoustical Consultants (2010, 4) stress that teachers should be able to teach using a natural (i.e., not straining) teaching voice. This will minimise long term strain, preventing possible damage that could threaten their ability to continue with their profession.

The Concerned About Classroom Coalition (1) explains that in Canada, as well as globally, absent teachers are costly for the education system. The use of substitute teachers interrupts the learning process for learners, who usually need time to adjust to new circumstances. Zannin *et al.* (2012, 216) distributed a questionnaire at a school to see if teachers are affected by voice disorders. The data showed that 21 % of the interviewed teachers reported the need to take a leave of absence from teaching due to noise-related health problems such as vocal fatigue. The main hindrances were constantly raised voices, overall fatigue, and vocal fatigue. An earlier survey by Smith et al. (1998) (in Nelson *et al.* (2002, 8)) yielded similar results, showing that in American schools, 20 % of teachers indicated that they had had to miss work due to voice related problems.

Apart from vocal strain, Schneider *et al.* (2005, 51), Kudesia and Tiwari (1994, 11), and Fletcher and Munson (1933, 82) propose that noise can also affect teachers in other ways: fatigue, hearing loss, tinnitus, social isolation, sleeplessness, alertness deficiency, and poor attention span. Research conducted by Schneider *et al.* (2005, 72) and Kristiansen *et al.* (2012, 1) supports the notion that high noise levels have an effect on the health of teachers, as it showed that high noise levels increase post-work irritability. Teachers find it even more difficult to unwind and relax, adding to their overall stress levels. According to Sound Reduction Systems (2013, 5), high background noise levels that cause learners to lose focus, also generate more work on the teachers' side. These added stress levels, along with added workloads, prompt teachers in a direction away from the teaching profession, directly affecting the wellbeing and academic outcomes of learners. In a country such as South Africa, which has a shortage of well-educated teachers, the outlook is particularly dire. A quotation from a Task Force of the WHO (1993), (in Kihlman *et al.* (2014, 4))

> identified the following specific health effects: interference with communication, noise-induced hearing loss, annoyance responses, and effects on sleep, cardiovascular and psychophysiological systems, performance, productivity and social behaviour.

Disturbingly, the City of Tshwane (2004, 6) and Schneider *et al.*'s (2005, 9) research found that there is also a correlation between high noise exposure and increased admissions to mental hospitals. General natural reactions to loud noise exposure include dilating pupils, a racing heart, muscle tension, and adrenaline secretion (Finnish Centre for Occupational Safety, 2006, 1). Repeated exposure to such conditions can lead to headaches, nausea, fatigue, and irritability, thereby reducing the efficiency of the worker and increasing the likelihood of accidents (Hassan, 2009, 64).

Another, less serious side effect of frequent loud noise exposure is the tendency for teachers to speak louder outside of work compared to teachers with less noisy classroom environments (Mealings *et al.*, 2016, 2). Teachers constantly have to make vocal adjustments in order to project their voice and maintain classroom control (Dreossi and Momensohn-Santos, 2005, 254-5; Knecht *et al.*, 2002, 70), and this is even more common in schools with disciplinary challenges.

2.4 Noise Survey

There are many different types of noise, including environmental, transportation, electronic, and noise created by people. In modern times it is very difficult to work and live in an isolated location where there is no intrusion from these noise sources. Therefore, people have adapted to live and work in noisy areas.

Testing for background noise levels, occupied noise levels, and reverberation times are some of the standard tests that are conducted in a building to identify and quantify a possible noise problem. John *et al.* (2014, 34) measured ambient noise level in two ways: (1) by leaving all windows open to obtain a realistic value, and (2) by closing all windows to see how much noise reduction was provided by the windows.

However, before any tests can be performed, the employees need to be informed of the purpose of the noise survey, namely to scientifically identify what the noise levels and reverberation time within the school are, under both occupied and unoccupied conditions. This will help to determine whether a school's noise levels are above the recommended value, and if that is indeed the case, whether they exceed the maximum average permissible level for a workday. Mealings *et al.* (2016, 17) encourage the use of multiple and varying methods when assessing the acoustic conditions of classrooms as this provides a more comprehensive view of the situation.

In order to for data to be reliable and truthful, it needs to be collected according to ISO noise law, encompassing both international and national laws. The collection of primary data in the current study is of utter importance as it is the only way to truly form a valid opinion of this unique problem. The data of this study was collected through extensive testing of more than one space and through various methods, including measuring speech intelligibility, reverberation time, and ambient noise levels.

The following standards are regarded while testing in the school to ensure that the values are valid.

- The reference value for the ambient noise level, according to the WHO, ANSI, ASHA, SANS and BB93, is 35 dB(A).
- The reference value for the occupied classroom, according to the WHO and ANSI, is between 40 and 50 dB(A).
- The reference value for reverberation time in a classroom, according to the WHO, ANSI, ASHA and bb93, is 0.6s.
- The average levels of a workplace should not exceed 85 dB(A) for an 8-hour working day according to Occupational South African Law.
- The passageways and hall's ambient noise levels, according to NR Values, should not exceed 35 dB(A).

It is noted that pressure levels within the different frequency bands are of importance when doing sound intensity comparisons. However, in a classroom environment the distribution of sound pressures within the audible frequency spectrum stay more or less constant (T & R Interior Systems, 2014, 30).

2.4.1 Measurement Methods

2.4.1.1 Equipment and Software

The noise survey was conducted with a Sound Level Meter (SLM).

An SLM consists of a microphone, pre-amplifier, weighting network (applying an A, B, or C weighting scale), linear all-pass amplifier, external output, rectifier, calculation of output quantity, and display (Bies and Hansen, 2009, 103; Kudesia and Tiwari, 1994, 6). The display indicates the sound level in decibels. The microphone detects small air pressure variations present in sound and changes these into electrical signals. The signals are then passed through a weighting network (in the present case, an A-weighting scale) yielding the sound pressure level in dB(A) (Hassan, 2009, 72; Kudesia and Tiwari, 1994, 6).

The SLM takes the sound pressure level at a particular point in time in a location, but it is up to the researcher to determine the appropriate response setting. The meter has two settings to choose from, one is for a slow time response (S) and one is for a fast time response (F); the slow function is equivalent to 1 second and the fast setting to 125 milliseconds (Kudesia and Tiwari, 1994, 6; Berglund *et al.*, 1995, 21). If the sound being measured is relatively steady, it is appropriate to use the 'fast' response setting, while unsteady noise is measured using the 'slow' response. Where the noise level varies considerably and is not steady over the measurement period, measurements should be taken using long-term exposure (denoted as (L_{eq})) (Kudesia and Tiwari, 1994, 6). This study used the slow response function, over a specified time period, to measure the value of fluctuating levels within a classroom.

There are various instruments and types of equipment available with which to conduct testing and analysis. The most general (and popular) equipment and software is the brand Brüel and Kjær. Ten researchers employed the same instrumentation; Sala and Viljanen (1995, 84-5), Lundquist (2000, 1), Knecht *et al.* (2002, 67), Dockrell and Shield (2004, 14), Klatte *et al.* (2010, 6), Zannin *et al.* (2012, 205), Fidêncio *et al.* (2014, 157), John *et al.* (2014, 36), Chan *et al.* (2015, 5), and Escobar and Morillas (2015, 3). Only in one study was the same model (type 2260) used, showing that there isn't a preference for a specific model.

When conducting a noise level test, it is good policy to calibrate instruments, internally and externally, before and after each measuring period. "The microphone is calibrated so that sound pressure levels may be determined in accordance with reference pressure" (Hassan, 2009, 6). Berglund *et al.* (1999, 13) explain that "[s]ound pressure meters can be calibrated using small calibrated sound sources". These devices are placed on the measurement microphone and produce a known sound pressure level (SPL).

There has been debate about whether calibration is really necessary before and after each set of measurements, (Ginn, 1978, 109; Hassan, 2009, 76; Escobar and Morillas, 2015, 3), or whether devices should be calibrated daily (Berglund *et al.*, 1995, 31-2; Berglund *et al.*, 1999, 13). It is because of this variation in method that Franks (2001, 191) suggests that the calibration date of each instrument should be noted.

In modern times it is unnecessary to haul bulky and expensive measuring equipment and software around, as society has become part of a booming global technological age where smartphones are more technically advanced than computers from a few years ago. The validity of a sound meter app on a smartphone, which can be used to measure noise levels accurately, can now be proved. An article by Kardous and Shaw (2015, 10) states that "for smartphone apps to gain acceptance in the occupational environment, the apps must meet certain minimal criteria for functionality, accuracy, and relevancy to the user in general and the worker in particular". Sound measuring instruments and sound level meters have to meet the requirements as set by ANSI. Smartphone applications need to be selected according to the following criteria: they must have the ability to report an A-weighted sound level, a 3–dB or 5–dB exchange rate level, a slow and fast response setting, and must make provision for the measurement of an equivalent continuous sound level average (L_{eq}) or a time-weighted average (TWA) (Kardous and Shaw, 2015, 10-11).

Using an application (SoundMeter) developed by Faber Acoustical[10] on an iPhone 6 enables a researcher to conduct tests conveniently within the application. Kardous and Shaw's (2015, 13) study showed that certain sound measurement applications for Apple smartphones are considered accurate and reliable for use in certain noise assessments. Using this application is a valid method of measurement as its features include the tools needed for testing: it can measure in an A-weighted scale, it can measure the equivalent continuous noise level (L_{eq}), it has an internal and external (aux) microphone, and it can be calibrated (Kardous and Shaw, 2015, 10). These tools make this application convenient and ideal for the current study's testing purposes.

From all the applications that Kardous and Shaw (2015, 11) tested, they found that the SoundMeter application provides the closest measurements to the actual values derived with a standard SLM. The application's mean value was the closest to the reference value when compared to any of the other applications. The MicW i436 external microphone is a valid microphone to use for testing as it complies with ANSI's requirement of a type 2 measuring instrument with an accuracy of approximately 2 dB(A) (Kardous and Shaw, 2015, 10). The MicW i436 external microphone is an omni-directional microphone used for measurements. It complies with the IEC 61672 class 2 sound level meter standard (Kardous and Shaw, 2015, 12). At the time of testing, the SoundMeter application was the best application available on the market. When combining the SoundMeter application with the MicW i436, the mean difference was only off by -0.52 dB(A) from the reference value of the type 1 SLM. This shows that the application, in combination with an iPhone, had one of the narrowest distributions of difference in results when compared to other applications and phone models.

Kardous and Shaw's (2015, 12) study showed that Android-based applications lack the accuracy found in their counterpart IOS software. Kardous and Shaw's tests were done on a large scale, making use of 420 samples proving the reliability of the findings.

Calibration of an SLM, as required by the South African Bureau of Standards (2008*c*), prefers the reference sound pressure level of 94 dB. However, if this value is not within the measurement range of the instrument, then either 84 dB or 74 dB would be acceptable. The standard requires valid reasons for making measurements according to a certain rationale (methodology) as this will influence the validity and consistency of results. According to the South African Bureau of Standards (2008*c*, 9) a type 2 SLM should be accurate within approximately 1 dB, and type 1 within 0.7 dB. No modifications to the SLM are permitted and it must only be used under the circumstances it was made for (terms of use). If there is any terms of use ambiguity, one must always refer to the manufacturer's guide.

South African Bureau of Standards (2008*b*) specifies that when using an

[10]http://www.faberacoustical.com/apps/ios/soundmeter/

integrating-average SLM, one should measure the equivalent continuous sound pressure level (L_{eq}). This specification is used for steady, intermittent, fluctuating and impulsive sounds. In accordance with SANS 658, all time averaging tests should be carried out using an A-weighted scale.

An integrating-averaging SLM differs from a normal SLM in that it can measure much longer times (even hours) than a normal SLM. The equivalent (*eq*) setting on the SLM gives equal weight to all sound present in the measuring period, whereas a standard SLM gives priority to the most recently occurring sound.

According to the Department of Environmental and Cultural Affairs (1998, 7), the person who is taking measurements needs to make sure that:

> the measuring instruments comply with the requirements for type 1 instruments in accordance [with] IEC 651, IEC 804 and IEC 942 [and] the acoustic sensitivity of sound level meters is checked before and after every series of measurements by using a sound calibrator, and shall reject the results if the calibration values before and after such check differ by more than 1 dB(A).

According to ANSI S1.4 (Kardous and Shaw, 2015, 10), the total allowable error for an SLM is approximately 1.5 dB for a type 1 instrument, and approximately 2.3 dB for a type 2 instrument. Tests done by Kardous and Shaw (2015, 10) with the SoundLevel app in conjunction with the MicW i436, showed a mean difference of -0.52 dB(A) from the reference value, bringing it more in line with a type 1 instrument.

2.4.1.2 Ambient/Unoccupied Noise

There are procedures, preparations, and rules of thumb that need to be followed before testing can begin. Bies and Hansen (2009, 106) explain if one is using a microphone on a stand to conduct tests, it is good practice that the stand should not be placed on a surface that vibrates, as vibrations may produce spurious signals that affect testing. Another method is to mount an SLM on a tripod to keep it steady while conducting measurements (Franks, 2001, 191). All the tests in the literature below were measured using an SLM, but many researchers failed to indicate their parameters or rationale. If certain steps are followed and documented, it makes the noise survey easier.

It is important to indicate, by making a marking on a sketch, where the microphone and the noise level reading on the SLM are placed (Hassan, 2009, 76). These placements need to comply with certain requirements to make them suitable for testing. An SLM is placed above each point marked on the floor in the classroom (Knecht *et al.*, 2002, 67). Hassan (2009, 76) explains that to get more accurate survey results, as many measurements as possible should be made to acquire data. A study done by Hlasa (2006, 33) in South African abattoirs, also indicated the sampling points on a map of the institute. Sala and Viljanen (1995, 85) used an SLM at eight locations for their testing. The current study models its method (by also indicating sampling locations on a map) after these studies.

There are different opinions regarding when, and under what circumstances, to conduct tests in a school. Zannin *et al.* (2012, 214-5) and Franks (2001, 190) made measurements while normal activities (teaching) in the school were conducted around them. Zannin *et al.* (2012, 214) made their measurements in an empty classroom while background noise was originating from classes near the area of testing. In order to obtain a sample of a normal day's activities, Estrada-Rodriguez (2009, 441) conducted their sound level tests in an unoccupied classroom at the same five points under three different periods: before classes, during recreation, and during lunchtime. The Institute for Enhanced Classroom Hearing, (5) believes that the measurements should be as authentic as possible and include noise from adjacent classrooms. The survey of Shield *et al.*'s (2015, 178) parameters specified that the ambient noise level excludes noise derived from elsewhere in the school by other teaching activities and equipment (computers), but if present it may include noise from ventilation systems and external sources.

China specifies that background noise should be evaluated in an unoccupied classroom during the school day, and that doors and windows should be closed, and all appliances should be 'off' (Roy, 2016, 7). Zannin *et al.* (2012, 214) conducted measurements with classroom windows open in order not to deviate from the school's daily routine. Other researchers tend to find a balance between these parameters, as John *et al.* (2014, 34) measured their ambient noise levels in two ways: (1) by leaving all windows open to obtain a realistic value, and (2) by closing all windows in order to see how much noise reduction is provided by windows. De Giuli *et al.* (2014, 27) measured background noise in unoccupied, furnished classrooms after school hours in Italy. The current study will also take measurements after school or over a weekend when no one is present on the premises.

In accordance with South African law the SABS' code of Practice Law 0103 states that the ambient noise level should be taken when no alleged disturbing noise is present. This measurement must be taken for a period of at least 10 minutes after a meter is put into operation (City of Cape Town, 2016). According to this SANS standard, normal activities within the building are not permitted when the ambient noise level is measured in South Africa. This is difficult as ambient noise is defined, in the document, as noise encompassing sound from many sources including noise from the source under investigation. SANS 10103 does however allow the normal building services such as ventilation and air conditioning to be working.

Microphone placement while conducting tests is of utter importance, as is documenting the length of the measurements taken. Without a rationale behind the testing, the tests will not be valid. Escobar and Morillas (2015, 3) measured background noise by placing the microphone in the middle of the room. To determine the average measurement value within a classroom, it is necessary to document the number of samples as well as the duration (e.g., five samples of one minute each). Zannin *et al.* (2012, 205) suggests that these periods should be three minutes long. Escobar and Morillas (2015, 3) measured background noise levels over a period of five minutes. Lundquist (2000, 1-2) made measurements for a period of ten minutes in an unoccupied classroom.

Escobar and Morillas (2015, 3) placed a microphone at a height of 1.2m (corresponding to a seated person) and 1.5m (corresponding to a standing person). Hassan (2009, 76) agrees with the height level of 1.5m for a person in a standing position, but recommends 1.1m for measurements when people are seated. Lundquist (2000, 1-2) does not give a parameter of the height, and only explains that the height of the microphone was in an asymmetrical position corresponding to the ear height of the learners. According to South African specifications, the microphone of an integrating impulse sound level meter must be placed at least 1.2m, but not more than 1.4m, above the floor and at least 1.2m away from the wall (Department of Environmental and Cultural Affairs, 1998, 7-8).

2.4.1.3 Occupied Ambient Noise

Conducting ambient noise level tests inside a classroom provides valuable information as it helps to create an authentic perception of the space. The Institute for Enhanced Classroom Hearing's (5) research indicated that before 2005, all references and recommendations pertaining to background noise were only related to unoccupied classrooms. This meant that all previous studies ignored the reality of student generated noise.

Shield *et al.* (2015, 180) conducted occupied ambient noise level tests using a microphone at a standing height of 1.55m. A study done by Fidêncio *et al.* (2014, 157) in Egypt, placed their equipment at a height of approximately 0.975m in the middle of the classroom. This height corresponded with the height of a student's ears while sitting. A microphone was also placed at the height of the teacher's head. Shield *et al.* (2015, 180) used a measuring period of three to five minutes, depending on the stability of the noise level.

According to T & R Interior Systems (2014, 27), measurements are generally taken from learners' desks at the four corners of the classroom, as well as in the middle and the middle back of the room. Zannin *et al.* (2012, 207) directed microphones at the learners, this is the typical position of the teacher.

If one is experiencing constant noise, a relatively short measurement period will suffice to give an approximation of ($L_{eq,30}$). Fidêncio *et al.* (2014, 157) suggests a period of ten minutes at each location while the class is in session. Lundquist's (2000, 1-2) measurements were conducted for twenty minutes in occupied classrooms.

The reason many of these occupied noise level periods are so short is because measurements are not being made in the minutes before and after children enter and leave the classroom. Shield *et al.* (2015, 181) incorporated this in their tests by taking the typical length of a class, and excluded the time spent on non-teaching related activities. These measured lessons' noise levels were averaged arithmetically to provide a single figure for each classroom.

2.4.1.4 Measuring Reverberation Time

The reverberation time has to be measured in a furnished, unoccupied classroom, as learners present in the room will dampen the sound reflections, as people act as absorptive surfaces within the space. When reflected sound waves come into contact with these absorptive materials (especially materials with a high density), most or all (depending on its absorption coefficient) reflected sound waves are absorbed or minimally reflected. With these added parameters of absorption, the reverberation time will be influenced (decreased).

The general definition of reverberation time is the amount of time it takes for the original sound pressure level in a room to decay by 60 dB, this is known as RT60 (Kefauver, 2001, 191). This decay is measured in seconds, or in the case of a small non-reverberant room, in milliseconds. Brüel and Kjær (1988, 8) and Noise Meters Inc. (2017, 1) have explained that taking longer measurements is difficult in a real environment as background noise can be present.

Studies need to stipulate the decay period over which the reverberation time was measured. It is suggested to use either RT40, RT30, or RT20; in each case the numbers are an indication of how much the room noise needs to decay, and it is then possible to extrapolate this decay to 60 dB (Brüel and Kjær, 1988, 8; Noise Meters Inc., 2017, 1). As these types of studies can be loud and disruptive, a study done by De Giuli *et al.* (2014, 27) measured reverberation time after school hours to remove all sources of background noise. John *et al.* (2014, 34) also suggests that reverberation time should not be measured on days where the weather (e.g., wind or rain) could influence the testing.

According to Brüel and Kjær (1988, 8), one needs to generate a steady sound source within a room in order to measure reverberation time. After the sound source is stopped, measurements can be made to evaluate the decay in sound pressure level within the room. After a sound-source is initiated in a room with a microphone, the sound pressure level does not instantly reach a steady level (Hassan, 2009, 696) because reflections need time to build up in the room in order to give adequate time for the first reflection, as well as for the subsequent reflections, to reach the microphone. This proves that reverberation time is influenced by the relative positions of the sound source and the microphone.

There are different methods that can be employed to excite a room with noise. One of the easiest, and most inexpensive and convenient ways of measuring reverberation time is by either exciting a room/hall with a loud clap, starting pistol, or bursting a balloon (Mealings, 2016, 3). However, there are better methods of measuring reverberation. Brüel and Kjær (1988, 8) suggest that the method of using a loudspeaker to emit noise in frequency bands is a good method of excitation. Ginn (1978, 123) suggests that another

> method of excitation is to use electronically generated noise consisting of a wide band of frequencies delivered to the room via an amplifier and a loudspeaker. Two types of wide band noise are in common use; white noise which has constant energy per unit of frequency and pink noise whose energy content is inversely proportional to frequency (i.e. -3 dB per octave or -10 dB per decade). It is usual to filter wide band noise into octave or third octave bands before delivering the signal to the loudspeaker in order that a greater sound pressure level can be obtained in the frequency band of interest for a given loudspeaker with a given power handling capacity.

The reason why white and pink noise are so effective as sound sources for testing reverberation time is because (a) white noise is a wide band of random noise with a constant level per hertz over the entire frequency spectrum, and (b) pink noise is a wide band of random noise with a level decreasing by 3 dB per octave. Random noise refers to a signal containing all the frequencies of the spectrum with a random amplitude distribution. This attenuation is necessary to allow a constant energy (Brüel and Kjær, 1988, 8). Noise Meters Inc. (2017, 1) and Kardous and Shaw (2015, 11) also used pink noise as an excitation tool.

Zannin *et al.* (2012, 202-3) conducted reverberation tests using the interrupted noise method. This method involves exciting the room with pseudo-random pink noise and then measuring the decay to the room's response. One can generate pink noise within the 20 Hz–20 kHz frequency range for tests. According to the South African Bureau of Standards (2014), when using pseudo-random noise to conduct tests, it must be stopped randomly.

As mentioned above, the placement of the sound source and microphone(s) also influence the values of the room.

> To avoid exciting only some of the normal modes of the room, the sound source is usually placed in a corner where every mode has a pressure maximum. The receiving microphone should be placed at several positions in large rooms and auditoria because the reverberation time can vary from place to place. If necessary, the measured times should then be averaged for each frequency band by one of the following methods: (a) a single microphone moved from place to place; (b) several microphones scanned by a multiplexer; (c) a single microphone on a rotating boom (Hassan, 2009, 299).

A test conducted in China by Peng *et al.* (2016, 236) placed a sound-source in each classroom at a height of 1.5m above the floor in the front of the room, as this is the general position of a teacher. Neuman *et al.* (2010, 338) and Mikulski and Radosz (2011, 782) also placed the height of the speaker at this level for the same reason. Neuman *et al.* (2010, 338) placed the loudspeaker in the front of the classroom, at a distance of 1.2m from the front wall and equidistant from the side walls. Placing measurement equipment at a distance of 5.5m from the loudspeaker simulates a student sitting at the back of the classroom.

Harvie-Clark and Dobinson (2013, 4) conducted the reverberation tests by placing the speaker more than 1m away from any wall at any time, at a height of 1.2m above the floor. Measurements were made by starting 1m away from the speaker, and then at 0.5m intervals. Knecht *et al.* (2002, 66) placed an amplifier and speaker at the left-hand corner in the classroom, on the floor, while obtaining measurements. In Poland, Mikulski and Radosz (2011, 782), placed two measuring points for the reverberation time: (1) where the student closest to the teacher is located, and (2) where the student furthest from the teacher is located to get an holistic view of the classroom.

According to the South African Bureau of Standards (2014), the frequency bands that need to be covered range from 250Hz to 2 000 Hz for a survey. For a quick estimate, T & R Interior Systems (2014, 30) suggests that the reverberation time of a classroom can be calculated for a single octave band for frequencies in the 1000 Hz. If the tests fall within the accepted reverberation time, it is likely that in the other ranges it will also be acceptable. Neuman *et al.* (2010, 336) and Knecht *et al.* (2002, 67-8) made use of ANSI's recommendations when selecting frequency bands that needed to be measured, and measured at 500, 1000 and 2000 Hz octave bands. Zannin *et al.* (2012, 218) measured at 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz, and, based on WHO standards, used the average of these values. Neuman *et al.* (2010, 339) measured almost exactly the same frequencies as Zannin *et al.* (2012), but added 8000 Hz to that list. These results were also averaged. English *et al.*'s (2014, 23) frequency range covered the measurements for all one third octave bands from 50 Hz to 5 000 Hz.

Researchers suggest documenting the layout of the classroom, as well as the volume of the classroom when taking measurements (John *et al.*, 2014, 34). Knecht *et al.* (2002, 67) preprogramed the SLM to allow a delay of 10s, in order for the researcher to leave the room before measurements were made, to rule out human absorption.

One normally measures reverberation time using an analyser that records the decay after the excitation, and calculates the time (T) for each frequency of the spectrum that is under investigation. However, Noise Meters Inc. (2017, 1) recommends that the reverberation time can also be calculated by measuring it with an SLM. But measuring it with this piece of equipment, the first 5 dB of decay is ignored, and it must be avoided measuring lower than 10–15 dB(A) above the background noise. It is very difficult to measure RT60 as the background noise level will have to be very low and the noise source exceptionally high. Therefore, it is easier to rather measure RT20 or RT30. This requires that RT30 should be measured 45 dB above the background noise, and for RT20 the background level should be above 35 dB (Noise Meters Inc., 2017, 1).

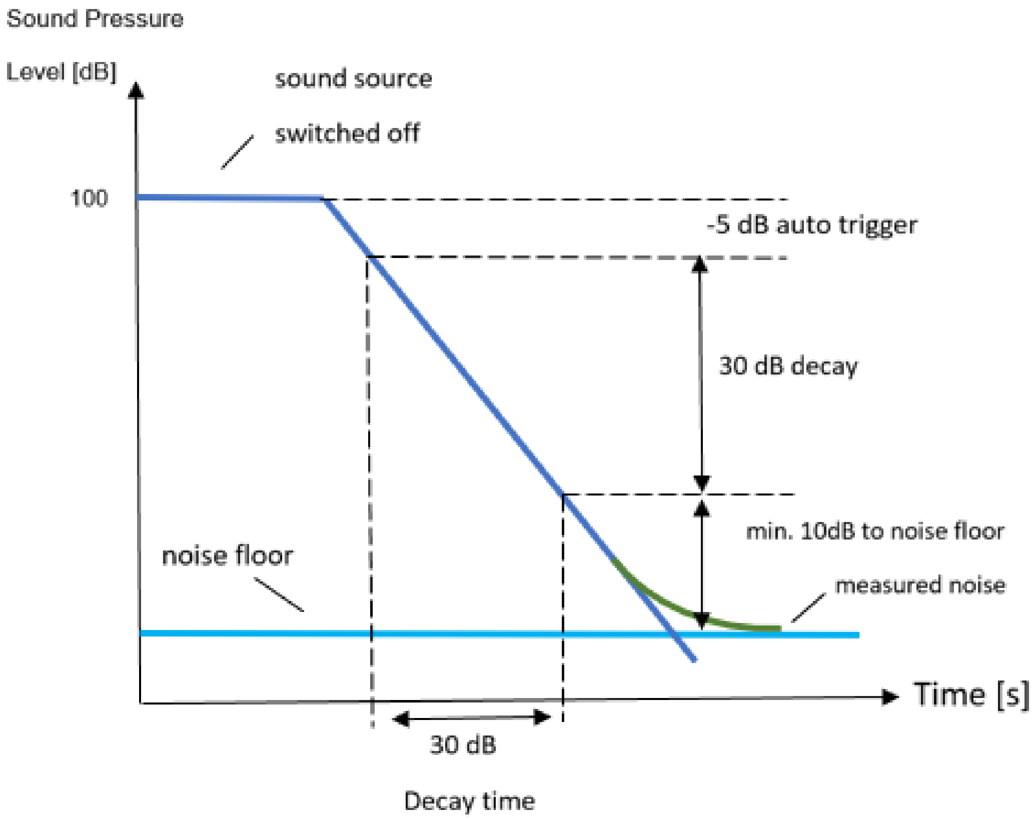


Figure 2.1: Measuring Reverberation Time T30 (NTi-Audio, 2018)

2.4.1.5 Airborne Sound Transmission Measurement

To test how much noise is transferred between classrooms a speaker can be placed in an adjacent room emitting pink noise. The level of pink noise is measured in the control room with the SLM and compared with the level of the adjacent room. By quantifying the noise leak into the adjacent classroom, sound insulation is measured. When teachers leave doors open during lessons the sound insulation between adjacent classroom is severely impaired (De Giuli *et al.*, 2014, 35). English *et al.* (2014, 22) conducted such a test by measuring the airborne sound insulation between the two rooms to see how much sound transmission takes place between walls.

2.4.1.6 Structure Borne Transmission Measurement

The maximum impact sound pressure level (expressed in $L_{'nT(Tmf,max),}$) allowed for primary school classrooms is 60 dB (Sound Reduction Systems, 2013, 3). There are various methods of measuring impact sound. Only two methods are outlined:

Negreira (2013, 43) explains that an ISO tapping machine is constructed out of five steel hammers, each one hitting the floor with two taps per second, altogether providing ten taps per second. This translates to one hit every 0.1s with a short delay between hits. English *et al.* (2014, 23) measured impact sound by placing a standard tapping machine in six different positions on the floor, at fixed and randomly distributed locations. The sound pressure level in the room directly below was measured by means of a rotating microphone at two positions. The tapping machine simulates footstep noise, but not very accurately as the effect of the tapping machine on the floor is much more pronounced than normal footsteps. This is necessary if the sound pressure level in the receiving room is to be high enough for accurate measurement (Brüel and Kjær, 1988, 31).

Another, lesser known method to measure sound structure borne transmission noise was developed by Japanese researchers. The Japanese Standards Association (JSA) (Japanese Industrial Standards (JIS A 1418-2)) utilises a 3 kg rubber tyre that is dropped from a height of 300 to 900 mm. The resulting blow produces a peak force of 1250–2400 N. This method was developed to simulate children jumping up and down (Negreira, 2013, 44). Again the SLM is used in adjacent rooms to measure transmission.

2.4.1.7 Noise Education Measurement

Another method of noise reduction that must be considered and therefore tested is noise education. A study done by Hay (1995) (in Dockrell and Shield (2006, 6)) in seven different primary schools showed what a difference noise education and discipline can make to overall noise levels. The study showed that in empty classrooms the levels ranged from 35 to 45 dB(A) L_{Aeq}, and from 58 to 72 dB(A) L_{Aeq} in classrooms where children were working and talking. Interestingly the lower noise levels were measured in classrooms that had an experienced teacher with the higher levels being more prominent in classrooms with a trainee teacher.

Evidence-Space (2015, 1) surveyed 140 primary schools, and found that the main source of noise in a primary school classroom generated by the pupils themselves while they were taking part in a range of classroom activities. Shield and Dockrell (2003, 3) substantiate this finding. Another study that links with these findings showed that learners identified noises that annoyed them the most to be self-produced, such as conversations in class and dragging of chairs and tables (Estrada-Rodriguez, 2009, 438-9). To gauge the validity of this suggestion, the current study, measurements will be taken in occupied classrooms during test conditions. This value will then compared against the 'normal' occupied classroom level to see whether there is a noticeable difference in values.

Chapter 3

Research Design

3.1 Research Design Overview

3.1.1 Mixed Methods Approach

The main question that the current study aimed to answer was whether the noise levels present at Rietenbosch Primary (during school hours) are above the recommended limits outlined in previous literature. Secondary questions included (a) what the cause of the noise problem is, and (b) how it is transferred throughout Rietenbosch Primary. It was also important for the current study to address whether the level of noise in the school infringes on productive teaching and if (or to what extent) teachers and learners have been affected by the noise. Lastly, the current study aimed to investigate whether noise problems are exacerbated by the building design, the people inside of the buildings, or a combination of both.

The current study utilised a problem-oriented research approach to investigate the nature of Rietenbosch Primary's noise problem, and what can be done to solve this problem. To answer the main research questions, this study needed to employ a mixed methods approach (i.e., a combination of qualitative and quantitative research methods).

Kumar (2014, 19) explains that a mixed methods approach is more than a mere methodology; it is a philosophy that has grown in popularity over the last 20 years because it keeps developing and evolving with time to keep it relevant (Creswell, 2009, 203).

There are various opinions about what exactly a mixed methods approach entails. According to Kumar (2014, 21), the first view is that a mixed methods approach means that quantitative and qualitative approaches are combined in the methodology of a study[1]. According to Creswell and Plano Clark (2011) and Morse and Niehaus (2009) (in Shannon-Baker (2016, 321)), this approach

[1]Teddlie and Tashakkori 2009; Tashakkori and Teddlie 1998; Bryman 2004; Cresswell and Clark 2007 (in Kumar (2014, 21)) agree with this definition.

involves using both paradigms (a quantitative and qualitative approach) which "can take place in the philosophical or theoretical framework(s), methods of data collection and analysis, overall research design, and/or discussion of research conclusions". However, other researchers believe that a mixed methods approach can only involve one paradigm, but can use two or more methods (Gilbert (2008); Cronin et al. (2007) in Kumar (2014, 21)). Therefore, for a study to be considered to be using a mixed method approach, the methods used can be from both the paradigms or only one of them as long as more than one data collection method is used.

A mixed methods approach is beneficial because, through this combination of methods, it can render a study's results more reliable and valid (Kumar, 2014, 16). Burke Johnson et al. (2007) (in Almalki (2016, 291)) believe that the combination of both qualitative and quantitative research methods helps to broaden the depth and breadth of the understanding of the research question. The integration of the two paradigms also allows for "a more complete and synergistic utilization of data than do separate quantitative and qualitative data collection and analysis" (Wisdom and Creswell, 2013, 1), because it uses the strengths of qualitative and quantitative research by selecting the best methods (regardless of the paradigm) to answer the research questions (Kumar, 2014, 14; Creswell, 2009, 203). In turn, by building on the strengths of the individual methods, the weaknesses of the methods can be overcome (Shannon-Baker, 2016, 320). Even if the methods only belong to one paradigm, combining them can lead to enhanced accuracy, validity, and reliability of the results (Kumar (2014, 22); Creswell (2009, 203)).

Kumar (2014, 25) expands on the advantages of the method:

> The rationale underpinning the mixed/multiple methods approach is primarily based upon two beliefs. The first relates to the ability of the methods of a paradigm to provide accurate answers to all your research questions in all situations. The second relates to the belief that the use of more than one method in most situations will provide a better and more complete picture of a situation or phenomenon than a single method alone.

Using the two paradigms in combination helps the researcher to better understand the research problems (Creswell and Clark (2007, 5) in Kumar (2014, 20)), and can therefore lead to more meaningful conclusions.

The other advantages of a mixed methods study will now be listed:

1. It allows for a comparison of quantitative and qualitative data, which can be useful for seeing whether the two data sets contradict each other (Wisdom and Creswell, 2013, 3).

2. It makes use of a sequential mixed method "in which the researcher seeks to elaborate on or expand on the findings of one method with another

method" (Creswell, 2009, 14). This can refer to either starting with a qualitative interview followed up by a quantitative survey, or vice versa.

3. The participants are given a chance to express their point of view. The method therefore "give[s] a voice to study participants and ensure that study findings are grounded in participants' experiences" (Wisdom and Creswell, 2013, 3).

4. It can be used to answer a broader range of research questions and strengthen evidence for a conclusion as there is more data to analyse (Kumar, 2014, 14).

5. It allows for scholarly interaction and methodological flexibility as it is adaptable to many study designs (Wisdom and Creswell, 2013, 3).

6. It gives researchers the opportunity to obtain a more complete picture from the data than using either paradigm alone (Creswell, 2009, 17).

However, the method also has some limitations:

1. It can be challenging to implement as it increases the complexity of the data gathering. Therefore, data collection needs to be carefully planned and implemented to guarantee that it will succeed (Wisdom and Creswell, 2013, 4).

2. It can be challenging to integrate the two different types of data during the analysis phase.

3. Because of all the planning involved, this method can have a number of researchers working on the project at the same time which could lead to disagreements (Wisdom and Creswell, 2013, 4).

4. Mixed methods research studies are normally labour intensive and therefore often require more resources and time for data analysis (Wisdom and Creswell, 2013, 4).

Below follow methods of both qualitative and quantitative research that can be employed in the study.

Qualitative research is mainly concerned with human behaviour, and the researcher seeks to understand the participants' points of view (Graff, 2016, 48). This method can also be used to investigate whether people experience a particular problem, and, if so, how the problem affects them.

Quantitative research focusses on the collection of numerical data, and the researcher is expected to be objective, hypothesis driven, and free of bias (Graff, 2016, 47).

Survey research is a method that can be considered for the current study. "Survey research provides a quantitative or numeric description of trends, attitudes, or opinions of a population by studying a sample of that population" (Creswell, 2009, 12). According to Willis *et al.* (2010, 183) survey research is one of the easiest methods by which to gather factual information. This method is "essentially trying to elicit information from a limited number of individuals who are presumed to have the information" (Hofstee, 2006, 122) necessary for the research. A questionnaire works well as a data collection tool in survey research.

Questionnaires can be used to get an understanding of people's experience. It is an easy method of collecting standardised information from numerous people for comparative purposes, and can collect both quantitative and qualitative data. Research can be conducted in stages (sequentially) to make it more manageable.

In survey-based research it is important to be careful about what type of questions are being asked, how these question are asked, the sample size, ethical considerations, and time and cost factors (Hofstee, 2006, 122).

The advantages to using a questionnaire are that:

1. It is useful to measure parameters for a group of people (e.g., average age, working years).

2. It is a low-cost method (Kothari, 2004, 100-1).

3. The data can be compared to other data sets to reach conclusions (help build a picture of the issue).

4. It is easier to reach a larger number of people than with interviews.

5. The respondents are able to use their own words (in open-ended questions) and have adequate time to complete the answers.

6. It makes respondents easier to approach as it does not require face to face discussions (Kothari, 2004, 100-1).

The main disadvantages to questionnaire-based research are that:

1. A questionnaire is inflexible as it cannot be amended after it has been distributed (Kothari, 2004, 101).

2. Questionnaires do not always allow the researcher to interact with or observe respondents (Hofstee, 2006, 133).

3. The completion rate is often both low and slow, as this method depends on participant co-operation (Kothari, 2004, 101).

4. Participants can answer with ambiguous replies or omit to give a reply (Kothari, 2004, 101).

A method similar to questionnaires that could be used, to gather information from the grown-ups in the school, is that of interviews. But for the following reasons it was not considered to be the best fit for the research.

1. There could be ethical issues as teachers might feel self-conscious to give an honest opinion in regards to questions about their health.

2. Teachers would have had to make extra time available for an interview, after already complaining of a too-high workload.

3. It is often a costly and time-consuming excursion for the researcher.

4. The number of interviews that could have been conducted would be far less than the number of questionnaires that could be distributed.

Another method that was considered was that of observation. The researcher can document observations while collecting quantitative data. For example, while the noise survey is conducted the researcher needs to be present in the classroom for occupied classroom measurements. Possible observations could therefore include when learners are perceived to be the quietest, whether noise escalates through the day, or when the loudest noise is perceived. This would help to determine possible explanations for noise surges or lack of high noise levels in the quantitative data.

However, there are ethical concerns with this method as people under observation need to be informed (need to know about the study's purpose) that they will be under observation and, need to sign consent forms.

Another method that was considered was that of a case study. A case study examines a single case in a structured way (through various data collection procedures) by testing the hypothesis one has formulated for the case. This type of research is normally hindered by time and activity constraints over a sustained period of time (Stake (1995) in Creswell (2009, 13)). Willis *et al.*' (2010, 209) definition of a case study is that:

> Case studies are odd inventions because they aren't really a specific research method. Instead, they are really a conceptual *container* that is large enough for you to put in all sorts of methods [...] A case study is not about collecting a certain type of data; it is about why you are doing research.

The case study can be used to investigate the school by applying the hypothesis to the scenario.

In a case study Hofstee (2006, 123) warns that one risks losing focus, and needs to ensure that results are generalisable and subjective in order to make it comparable against other research. As this approach is generally difficult to do successfully on its own, because it normally elicits subjective results, it is often combined with other techniques (Hofstee, 2006, 123).

The advantages of a case study are as follows:

1. It assists with the formulation of a relevant hypothesis along with applicable research that helps to test it (Kothari, 2004, 115).

2. Case studies expand on generalised knowledge and broaden the knowledge base (Kothari, 2004, 115).

The disadvantage of this method is that:

Case study situations are generally unique which makes the gathered data seldom comparable to other data sets (Kothari, 2004, 116).

The majority of previous studies in this area have used a noise survey to collect noise measurements. A noise survey is conducted in an area where it is expected that noise is potentially hazardous.

The noise survey data was compared against reference values from previous literature to see whether the average noise levels of the classrooms are above the recommended level. For the purpose of the current study, it was sufficient to only compare the averages in order to test the hypothesis.

To make the survey manageable, only certain classes were selected for testing. It would have been difficult and expensive, both in terms of time and resources, for one researcher to survey all the classrooms for an extended period of time, as the school writes tests and exams periodically.

To ensure reliability and validity of the data, which is an essential consideration in research, there has to be a way to reproduce the data collection. The methods of data collection (i.e., a questionnaire, observation and a noise survey), are explained in detail in the sections below. The points of measurement, which are each accompanied with the selected height and accurate placement representation within the classroom, adhere to guidelines set out in previous literature, and can be found in Appendix C.

Although the noise survey was only conducted at Rietenbosch Primary, and the results therefore cannot be generalised, previous research has shown that excessive noise in schools affects teaching all over the world. This study can therefore be used as a benchmark for similar tests conducted in South African Schools. Still, consideration must be given to the fact that Rietenbosch Primary's main problem will differ from standardised schools due to the unusual layout of the school building.

3.1.2 Mixed Methods Methodology

A mixed methods approach was used to investigate the noise problem in Rietenbosch Primary School. An embedded mixed method design was used as it allowed one data set (questionnaire) to play a supportive, secondary role as the focus is based primarily on the other data set (noise survey). The implementation of this methodology took place as follows:

1. Firstly, data collection by means of questionnaires explored when and in what way teachers find noise to be most disturbing in the school. It was important to investigate how teachers experience a noise problem at the school, and how they are affected by it.

2. Sequentially, the primary data set reported on in this study were measurements generated with the use of instruments (i.e., iPhone 6s, MicW i436) and software (i.e., SoundMeter). The results of these measurements were used to quantitatively ascertain whether the noise level in Rietenbosch Primary is frequently above the recommended levels for teaching.

The reason for collecting both qualitative and quantitative data was to combine the strengths of both types of data and to provide a means of validating conclusions through comparison of the two data sets.

The questionnaire gave teachers an opportunity to voice their concerns regarding the noise levels in the school, as well as to document their personal health problems arising from work-related stress. The school was visited on a number of occasions before the questionnaire was compiled to make sure it was applicable to the current study. Informal interviews were conducted with the principal, deputy principal and teachers who were specifically identified as being affected by high noise levels in the workplace.

Primary data was collected at the school by performing various sound tests in pre-determined spaces (e.g., ambient noise level tests and occupied noise level tests). Measurements (ambient noise levels, occupied noise levels, and reverberation time) provided an overview of the extent of the school's noise problem.

Quantitative data was considered the most valuable type of data because direct comparisons could be made to current noise law guidelines. The questionnaire observations are less reliable than the noise survey since a questionnaire may yield results that are either biased or too difficult to analyse as it is subjective (Hofstee, 2006, 132).

3.1.3 Hypothesis

Measurements taken inside classrooms of Rietenbosch Primary will show that unoccupied and occupied ambient noise levels, occupied noise levels, and reverberation times inside many classrooms are not within the recommended limits.

3.1.4 Data Gathering

The study made use of two data collection methods: one qualitative (subjective) and one quantitative (objective).

Measurements were taken inside classrooms (both unoccupied and occupied), the hall, and passageways. Pink noise was used as a method of excitation to measure reverberation time of the hall and classrooms. During testing inside a classroom, the location and time of day were noted.

Instrumentation used for testing adhered to regulations set out by international and national laws (in order to substantiate the validity of measurements).

This study made use of an experimental design as the researcher manipulated one or more variables in the school in order to control and measure changes in other variables. The schools' tonal character was documented by observing the teachers' and learners' reactions to the noise. Observations involved watching (a) teachers' teaching methods, and (b) learners during break and when a teacher left the classroom. These observations had the benefit of possibly providing an answer to one of the key research problems: whether people in the school were too noisy (possibly due to lack of discipline) or whether the building amplifies the noise, or whether noise levels are the result of a combination of these two variables.

3.2 Questionnaire

Teachers have found it increasingly difficult to teach in the noisy climate present at Rietenbosch Primary. The questionnaire contained both open- and close-ended questions to allow teachers to provide their own accounts and perceptions, and voice their concerns about the noise situation. In some cases, the teachers were given the option to state the threshold of their symptoms by specifying values to varying scales.

To an extent, the questionnaire was based on a certain bias (used as a point of reference) for questions regarding noise, and some questions could thus be perceived as 'leading'. The reason for the bias is that the noise problem in the school is known and acknowledged by teachers and learners, so the aim of the study was to establish the extent of the problem and determine to what degree it infringes on teaching.

The motivation behind the questionnaire was to make it possible for teachers to indicate to the researcher what type of noise tests needed to be performed in the school. It had the additional benefit of collecting data about possible health risks to which the teachers are exposed. All questions were presented in both Afrikaans and English to facilitate the teachers' understanding of the questions. In addition, teachers were encouraged to contact the researcher for further explanation if any questions were unclear.

Using questionnaires to draw general conclusions about the effects of noise on teachers and learners has been validated by researchers such as Wilson *et al.* (2002, 9), Aldridge *et al.* (2009, 150), Ana *et al.* (2009, 2), Zannin *et al.* (2012, 207), Igwebuike and Ajuar (2013, 112), John *et al.* (2014, 34), and Mealings *et al.* (2016, 6).

3.2.1 Description of Questionnaire Methodology

Each teacher at Rietenbosch Primary was given a questionnaire to capture their concerns and opinions regarding perceived noise levels within the school. Out of the 36 teachers employed at the school during the study, 30 teachers completed the questionnaire. The employees were informed of the purpose of the questionnaire before completing it. Only teachers or assistant teachers (i.e., no learners) completed the questionnaire.

Some of the questions were related to age and to health concerns to investigate whether there is a noticeable relationship between age, health and noise levels. Questions specifically related to health included whether there are any signs of voice exertion incurred from teaching, any hearing loss, or any other noise related health symptoms. Other questions were related to teachers' feelings about their individual teaching conditions; particularly in terms of what they find particularly annoying. There were also questions related to whether teachers feel that the noise problem originates in their classroom, or in surrounding classrooms.

Teachers were given the opportunity to mention any other noise that affects the listening experience in their classroom. Examples of classroom noise were provided to determine whether the noise is generated from inside or outside the building. The questionnaire further aimed to investigate the learners' response to the perceived noise (via the point of view of teachers); whether they lose concentration, and whether their scholastic achievements are notably influenced by noise factors. Teachers were given a list of possible noise sources (e.g., transportation, mechanical, electronic, entertainment, nature or people) to determine the typical noise sources at the school. They were also asked to rate which sources were most disruptive from each of the noise sources listed. Teachers were also asked to explain when, and why, they perceive the best listening conditions for teaching.

Simple statistical analyses of the data were conducted to draw conclusions. The mean, median, mode and the standard deviation were calculated. The data was also represented in the form of bar charts to see what the most frequent symptom/ experience was. More advanced statistical analyses were undertaken for certain questions where qualitative data was collected to see whether there were links between age and symptoms and if some groups were more likely to convey certain attributes.

Finally, the questionnaire tried to ascertain whether or not the noise element in the school is exacerbated by the people present in the school or if the school is 'noisy on its own' due to high ambient noise levels.

3.3 Noise Survey

The study endeavoured to evaluate whether teachers in Rietenbosch Primary were exposed to higher noise levels than the maximum occupied noise level permitted while teaching.

A time-weighted average of the noise levels was taken during an average school day. The ambient noise measurements were conducted with closed doors. Materials within the classrooms (doors, walls, ceiling, floors) as well as their volumes were documented. The data acquired from rooms with a similar volume, both occupied and unoccupied, were compared against one another. Testing in classrooms was conducted over different periods during the day (before first break, after first break, after second break), and while different classroom activities were in progress.

While measurements were being conducted the layout of the room and the location of the classroom within the school was documented. The occupied noise level was dependent on what type of activity was taking place inside the classroom.

The following specifications were consulted during measurements: The unoccupied ambient noise levels in classrooms were compared to the following standards; the WHO, ASHA, ANSI, and SANS. The appropriate value of an unoccupied classroom is 35 dB(A). The appropriate occupied classroom value was ascertained by consulting the standards of the WHO, ANSI, ASA and AAAC. The preferred level for occupied classes while silent activities are taking place is 40–50 dB(A), and is 65–70 dB(A) when a teacher is conducting activities. After researching various appropriate reverberation times for primary school classrooms, the value recommended by ASHA, ANSI, BB93, and the WHO is 0.6s.

The ethical concerns regarding the noise survey were avoided by ensuring that:

1. The headmaster pinpointed classes that were selected for observation.
2. The teachers of these classes were asked to consent to be a participant in the study.
3. It was explained that participants would be under observation during the data gathering period.
4. Participants were again, personally, informed of the purpose of the study[2].

[2]See Section 3.4 Ethical Considerations for more detail.

3.3.1 Measurement Methodology

3.3.1.1 Equipment and Software

The noise measurements were taken with an iPhone 6s in conjunction with a MicW i436, using software called SoundMeter. An iPhone was used as the application and microphone are compatible with IOS interfaces.

The MicW i436 was inserted into the iPhone 6s microphone jack as an external microphone. After launching the SoundMeter application, the weighting scale was set to A and the response set to L_{eq} to render an equivalent average value.

The play button on the top left of the screen was used to start the measurement process and selected again to pause the measurement. If the play button was pressed again, the previous measurement was recorded over. The peak value and elapsed time of the measurement was indicated on the bottom left of the screen. The L_{Aeq} value was indicated centrally on the application as well as visually in the right-hand column, with the peak value indicated in red.

The calibration process was validated by making sure that the iPhone (device) and microphone (input) was calibrated separately with the I/O Configuration, at the preferred level of 94 dB(A). This calibration process measurement was verified by checking it against a RadioShack SLM. In the study the time (T) value parameter in the formula $L_{Aeq,T}$ changed with the parameters of testing. It varied between one, three, and five minutes. The units were set to Pa at all times.

Screenshots of every measurement were taken and documented in a notebook to serve as a physical backup, making it possible to recheck measurements at a later time.

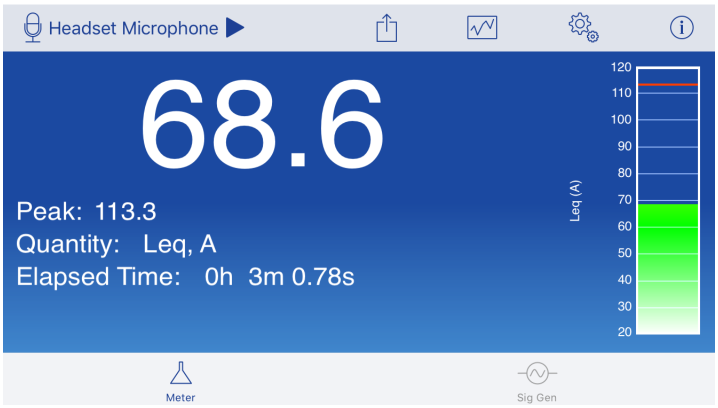


Figure 3.1: Screenshot of SoundMeter Application

3.3.1.2 Ambient Noise Levels

Measurements were taken in eleven, specifically selected classrooms[3], on both the ground floor and first floor, in all three parts of the school. During testing the microphone was kept at the prescribed height of 1.2m, and was placed in a location that ensured it was more than 1.2m away from any wall. The ambient noise levels were measured over a period of five minutes in the selected classrooms, with no one present in the school. All ambient noise level measurements were taken according to this procedure, unless otherwise specified.

Ambient noise levels in occupied rooms were measured using the same parameters as the ambient noise levels. in unoccupied rooms. Only a few classrooms could be measured for the ambient noise level under occupied conditions as it was rare that a teacher had a free period. The doors were kept closed while taking measurements. The ambient noise levels taken under occupied conditions were compared against the ambient noise levels taken under unoccupied conditions.

3.3.1.3 Occupied Noise Levels

The tests for noise levels under occupied conditions were conducted during a normal school day, over a period of two weeks, in the same eleven classrooms that were sampled for the ambient noise measurements. Each classroom's noise level was measured in the morning, after first break, and after second break. The data from these different times was then compared to see if noise levels were rising or diminishing throughout a normal school day. The tests took into consideration that classroom noise levels varied from moment to moment depending on what activity was taking place (e.g., group work, or the teacher lecturing). For this reason, the tests were conducted across several hours, over the course of a few days to find a mean value for school. Each classroom's data was analysed individually, as well as collectively to see during which period learners were the noisiest. Both a peak noise value for each classroom and the classroom's average noise value was identified. All ambient noise level measurements were made on the same day within minutes of each another.

Because each classroom's layout and circumference differed, no classroom's plotted measurement points were identical. However, the plotting of these measurement points stayed within the parameters of the placement specifications: six measurement points in the classroom placed in the four corners, the middle and middle-back of the room. The measurement points were marked with stickers on the floor, covered with extra clear tape to protect the markings. The measurements taken at each point were 3 minutes in length.

The microphone was placed at the height of learners' ears (0.975m for learners in grade R-3 and 1.1m for learners in grade 4-7), as well as placing the microphone at the height of the teacher's head (1.5m). Stickers were placed

[3] In order to cover the whole school.

on the tripod that indicated the different measuring heights in order for the researcher to be able to change between different height settings quickly. In the case of any uncertainty, the height of the measuring equipment was confirmed using a measuring tape.

The study had to measure long-term noise exposure, such as would be present in school hours, as opposed to measuring short periods of noise. The appropriate unit of measurement for the test was denoted as $L_{Aeq,T}$. Therefore, the SLM response was set to fast response as it was taken over a continuous equivalent period. After each set of measurements the equipment was calibrated. The school periods were 30 minutes per lesson. The average measurement time of a lesson, once non-teaching related activities were excluded, was approximately 18 minutes.

3.3.1.4 Reverberation Time

Reverberation time was measured in unoccupied, furnished classrooms.

While reverberation tests were conducted, a sound-source was placed in classrooms at a height of 1.5m in the front of the room and 1.2m from the front wall and equidistant from the side walls. This represented the general position of a teacher. The SLM was placed 1.2m above the floor and kept more than 1.2m from the walls.

A loudspeaker emitting pink noise at a level of 80 dB(A) was used for reverberation time measurements. The method used to measure the reverberation time was RT20. The noise was given enough time for reflections to build up in the room before the measurement was taken. The sound source was then stopped and the decay in sound pressure relative to the time passed was then measured with the SLM (elapsed time was recorded once the noise level dropped by 20 dB). This time (in seconds) was then extrapolated to RT60.

3.3.2 Noise Level in Relation to Teachers Voice

In an effort to establish how audible a teacher's speech was perceived to be while teaching, it was necessary to measure the occupied ambient noise of a quiet classroom, and then measure noise levels while the teacher was lecturing, with only their voice present in the classroom. The larger the difference was between sound levels, the better the speech intelligibility.

Measurements of the occupied ambient noise of a quiet classroom were taken while the SLM was placed at the level corresponding with that of a learner's ear. While measuring the teacher's voice, the SLM was placed at a height of 1.5m to correspond with the height of a teacher.

Occupied classroom measurements were collected during different periods of the day, with the first and second value measured in the same classroom consecutively. The measurement period for this test was one minute, and was derived by using the average equivalent level. During these measurements, noise from the passages was still present as normal activities were still taking place in the school.

The described classroom conditions were not realistic, and not a true test of SNR, but the measurements were completed to see whether noise had a noticeable difference on ideal speech intelligibility levels.

3.3.3 Testing Noise Education

Two classes that had already been tested were specifically selected for noise education testing as they were adjacent to (either above, below, or next to) classrooms that were conducting exams. The school was therefore under test conditions until after second break. This was the ideal situation under which to determine what effect noise education could have on the noise problem. All adjacent classroom doors were closed.

The effects of noise education were calculated by taking the average noise level in each classroom (under normal conditions) and subtracting it from the same classrooms' (test conditions) average.

The setup procedure of equipment was kept identical to the measurement procedure for ambient noise levels.

3.3.4 Testing Sound Insulation

A sound source was placed in the hall, with the same parameters that were used to measure reverberation. The only changed parameter was that of time, as the average equivalent was set to 20s. This setting was selected as the noise was constant and could easily reach a steady value. A speaker emitting pink noise was once again used to excite the hall and was given 10s for the reflections to build up.

This test was completed to verify whether the sound pressure level drops, if the volume of the speaker was kept at a constant level of 80 dB(A), when taking measuring in different parts of the school.

All the passages and five classrooms located in the applicable passageways were measured at this constant level. These tests were completed over the weekend under unoccupied conditions.

If the sound level in an adjacent classroom was high, it showed that there was inadequate sound insulation between classrooms.

3.3.4.1 Sound Impact Noise

Sound Impact Noise was measured in five classrooms. Three tyres of different weights (2.2 kg, 4 kg, and 5.1 kg) were dropped from a height of between 300 and 900 mm in a classroom. The tyres were dropped in second floor classrooms and measurements were taken in the room directly below with the SLM.

The three tyres simulated learners of different weights jumping in the room above. The measurements were taken with the short response setting as there was no long noise exposure.

If the sound level in the classroom below (ground-floor) was high, it showed that there was inadequate sound insulation between the floors.

3.4 Ethical Considerations

Prior to providing the questionnaire to the teachers and conducting noise tests in the school, ethical clearance was obtained from the Humanities Research Ethics Committee of University of Stellenbosch. The investigation required adult human participants to complete a questionnaire. Noise tests were conducted in the buildings, and required no assistance from the teachers. Each participant was presented with two forms: one outlining the purpose of the research, and the other a consent form. The participants' anonymity was ensured by having the teachers place their completed questionnaires in an enclosed box at the school's reception.

Prior to the questionnaire completion and noise testing, the researcher spoke to all the teachers to explain the aim of the study, as well as what involvement in the study would entail.

Teachers were asked to complete the questionnaire in their own time and not to include their names to protect their anonymity. Teachers were also informed that there was no pressure to answer any questions they did not feel comfortable with, and were given the option to discontinue the questionnaire at any time.

Before noise testing was completed in the classrooms, teachers were told that the testing would be as unobtrusive as possible. Teachers were asked to explain to learners that the researcher was only there to observe their classes. It was deemed counterproductive to tell learners that the researcher was doing noise tests as this may have influenced their behaviour and thus influenced the noise testing results.

Appropriate times were discussed with different teachers in different parts of the school, to ensure the researcher observed a normal day's teaching. Unoccupied classes were also used to conduct some tests while the classes were busy with other activities.

3.5 Budget

Stellenbosch's Department of Music, specifically Stellenbosch University's Studio, provided the necessary sound equipment and hardware to complete the study. SoundMeter, the software needed to conduct the noise survey, was bought at the expense of the researcher. The researcher accepted the responsibility of costs associated with the postgraduate study. The researcher had access to the necessary literature, standards, sound equipment, and hardware needed for the study.

Chapter 4

Results

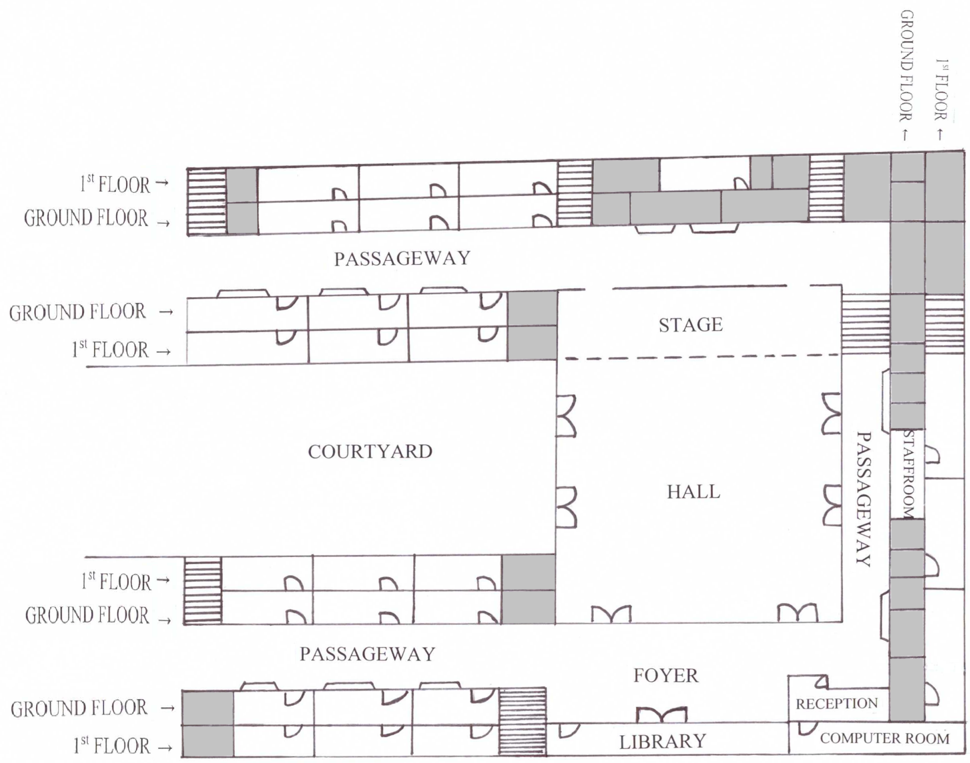
This chapter presents the results from both the questionnaire and the noise survey.

4.1 School Building Properties

Rietenbosch Primary School was built in 1989 by the previous government in a 'non-white' area, and had an unorthodox architectural design (refer to Figure 4.1). According to the school's history, it was built in the last phase of the Apartheid regime by the Coloured Persons' Representative Council[1]. The possibility therefore exists that the acoustic considerations did not undergo much scrutiny as it was built in a non-white area (Gardiner, 2008, 7).

Interestingly, the school did not initially have tiled floors, as funds ran out before this feature could be completed. Tiles were later installed in certain areas, and although it is possible that this addition contributed to the school's noise problem, as tiles are very sound reflective, no complains of increased noise disturbances were made around the time of installation.

[1]The Coloured Persons' Representative Council was established in 1969 to represent coloured individuals during the Apartheid era, but had limited legislative power. Each representative held their seat for five years, and was in control of coloured affairs in the coloured community, but had no real power outside of these areas.



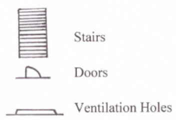


Figure 4.1: Rietenbosch Primary Floorplan

4.2 Noise Propagation Analysis

The assembly hall is an open plan structure, which is not the standard 'government issue' design[2]. It is located in the centre of the school, and it was built as an open-plan auditorium with passageways leading out from the corners of the hall to classrooms. This design is inherently very reverberant and noise-generating activities taking place in the hall are experienced as 'bothersome' inside classrooms.

[2]Where the hall is adjacent or separated from the school.

Figure 4.2: Open Plan Layout of Hall

There is only one wall separating the classrooms closest to the assembly hall (first floor classes) as the passage has been left 'open'. The classrooms on the ground floor are separated from the assembly hall by two walls, but due to the ventilation holes between the ground and first floors, sound propagates unimpeded between the floors. The architectural design adds no barriers against sound propagation. The reflective smooth and flat ceilings, floors, and walls means that the acoustic environment exhibits the very undesirable characteristic of long reverberation times, low dampening, and excellent noise propagation to the farthest reaches of the building. It is believed that the noise propagation problem can largely be attributed to the layout of the school.

Hassan (2009, 92) explains the noise propagation properties as follows:

> sound is transmitted from one room to another indirectly, through adjoining parts of the structure. Continuous walls between floors, columns or any other continuous structural elements will act as flanking paths for [...] sound.

Teaching is classified as a noise-sensitive activity. Therefore, the Australian Building Codes Board (2016, 18) explains that it is good practice to situate noise-sensitive classrooms away from noisy areas. This implies that the layout of Rietenbosch Primary School is problematic, as the noisiest part of the school,

Figure 4.3: Open Plan Layout of School

the assembly hall, should either have been located at the edge of the school or adjacent to the school; it should definitely not have been placed in the middle of the school with many open passageways.

When learners are busy with activities in the courtyard, the wall dividing the courtyard and assembly hall leaks sound into the assembly hall, which then propagates through the entire building reaching the classrooms on the far ends of the school. An (unsuccessful) attempt to reduce noise levels involved planting a variety of trees in the courtyard, in the hope that the trees would absorb some of the noise. However, this method generally does not work well, with Hassan (2009, 635) explaining that

> in general, vegetation will affect the propagation of low-frequency sound by ground absorption, which can be enhanced in wooded areas due to the high porosity of the ground resulting from tree roots and fallen leaves, erosion, etc. High frequency propagation is affected by scattering [noise] by tree trunks, branches and even partially by leaf absorption.

Also, although it is true that trees can provide some noise absorption due to their foliage, the absorption is heavily influenced by the density and height of the trees. "A band of trees several hundreds of metres deep is required in order to achieve significant attenuation" (Hassan, 2009, 637). To date the trees planted at the school have not grown dense enough to reap any possible benefits, and it is doubtful whether there would be a significant improvement even if more trees were planted.

Compounding the overall problem, the original layout of the school was altered to accommodate more children as the demands of teaching changed. School management was forced to change rooms designed for other purposes (e.g., subjects such as needlework and woodwork) into classrooms. Originally the ground floor layout was similar to that of the first floor (i.e., only one wall separated the classroom from the assembly hall), but the teachers donated money to build an additional wall on the ground floor. The additional wall that was built in the hall, after the completion of the school, was built in such a way that there were openings in the brick wall. According to Hassan (2009), insulation in walls and windows should be a priority if one wants to impede noise propagation. The attempt of the additional wall, to attenuate the noise levels in the ground floor classrooms, was largely unsuccessful. Mainly because doors were not added to all the entrances of the newly formed passage, and where they were added, they did not provide adequate sound absorption because they had hollow cores. CertainTeed (2011, 11) explains that

> hollow core doors are poor sound blockers. When privacy is a key consideration, doors should be solid wood or have insulated cores, and should be gasketed to prevent sound from passing between the doors and the jamb or sills.

Additionally, the doors located on the ground floor of the hall have glass missing, and there is no rubber sealing at the bottom or sides of the doors. By adding rubber seals to a doorframe a door can be made significantly more airtight, which will improve sound attenuation (Bies and Hansen, 2009, 271). The ventilation openings, which ensure sufficient air replacement and circulation, are deemed to be the main contributor to this unwanted acoustic noise propagation. Therefore, another solution for air ventilation openings is necessary, as the current situation is not practical in terms of sound blocking. However, the air ventilation openings (and doors) is a small matter when compared to the open second floor that offers no barrier against noise.

A quick, non-specialised, reverberation test was conducted at Rietenbosch Primary by executing one loud clap (with the hands) and listening for any signs of an echo. This was done in the empty school building and it was clear that the general reverberation phenomenon in the school is quite significant, as previous research suggests that no noticeable echoing should be perceived in an educational building.

In Rietenbosch Primary School, noise sources are primarily attributed to learners and teachers going about their daily classroom and school activities. Unfortunately, time did not allow for investigations into how these noise sources at Rietenbosch Primary equate to other academic institutions, and particularly other primary schools.

Another complaint by teachers is that they can hear what is being taught in the classroom adjacent to their classroom, as well as what is discussed by people walking in the passageways. What they describe is termed 'noise transmission'. The effectiveness of the sound insulation provided by the classroom walls is therefore quite poor. Teachers have noted that learners often get distracted by noise when doing tasks, as conversations taking place outside of the classroom can be clearly heard and understood.

Adding to the frustrations of the teachers on the ground floor is the fact that audible impact noises, caused by the activities taking place in the classrooms above them, are of a disturbing magnitude. According to Inoue *et al.* (2000, 1), floor impact sound is one of the noise sources that elicits the highest rate of complaints among people.

The source of the noise in Rietenbosch Primary School varies between noise generated in (a) classrooms, (b) adjacent passageways, and (c) the hall. It has been identified that the noise travels through the school by means of the ventilation openings on the first floor and the long passageways that lead from the hall. The noise is then heard by the learners and teachers in their classrooms.

4.3 Questionnaire

4.3.1 Questionnaire Data Analysis

The data analysis gave the following results:

Question 1 – Teachers were asked to state their age:
The average age of teachers at the school was 40 years old. The oldest person working in the school was 64 years old and the youngest was 23 years old. The modal age was 24 and the median age was 36 and a half years. The standard deviation (σ) was 14.4 and the spread was 41 years.

Question 2 – Teachers were asked how long they had been working at Rietenbosch Primary:
The average number of years that teachers had been working at the school was five and a half years. The longest period a teacher had been working in the building was 24 years and the shortest period was one month. The modal timeframe was four and three years. The median was three and a half years. The standard deviation (σ) was 6.1 and the spread was 23.9 years.

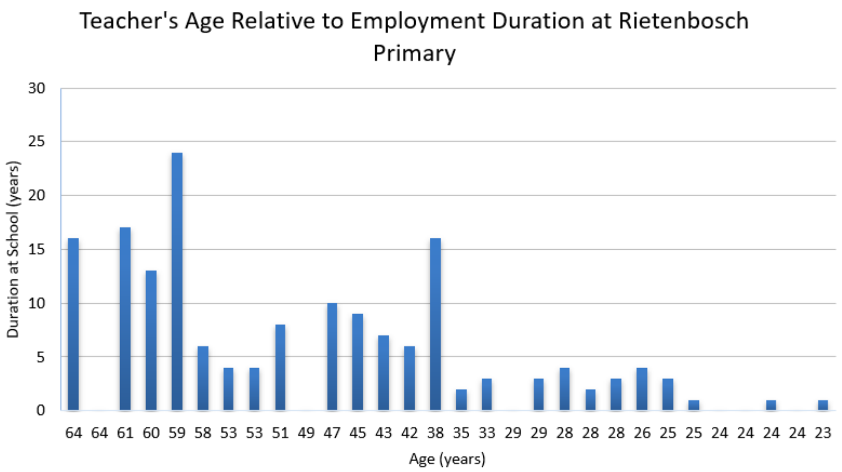


Figure 4.4: Teacher's Age and Employment Duration

Question 3 – Teachers were asked whether (in relation to noise) they needed to ask learners to quieten down repeatedly:
Twenty-eight teachers answered yes, and only two answered no. The majority of teachers (93 %) indicated that they experience a noisy classroom.

Question 4 – Teachers were asked whether they noticed if learners' performance was affected in noisy situations:
The majority of teachers (97 %) indicated that they believed that their students' performance was negatively affected in noisy situations.

Question 5 – Teachers were asked whether their classroom had good listening conditions:
The majority of teachers (79 %) indicated that they felt that their classroom did not have good listening conditions.

Question 6 – Teachers were asked to explain their answer to Question 5 by giving an example (or examples):
Most teachers indicated their teaching was influenced by bothersome noise propagating between classrooms.

There were some common examples among teachers of good listening conditions:

- 7 % of teachers indicated that their classrooms had good listening conditions.
- 4 % of teachers blamed overcrowded classrooms for noise problems.

There were also common examples of bad listening conditions:

- 59 % of teachers indicated that noise from passages, adjacent classrooms and the floors above or below was heard in their classrooms while they taught.
- 30 % of teachers indicated that noise from the hall could be heard in their classrooms.
- 19 % of teachers indicated that noise coming from inside their classes disturbed learning.
- 7 % of teachers indicated that the learners moving between classes caused noise.

Question 7 – Teachers were asked whether it seemed as though the background noise originated in their classroom or transferred from adjacent rooms:
The majority of teachers (86 %) indicated that in their opinion the school was noisy when teaching, and they experienced noise coming from their own classroom as well as from adjacent rooms.

Question 8 – Teachers were asked to explain their answer in Question 7:
The majority of teachers (96 %) indicated that they perceived the most disruptive noise as coming from outside their classroom, while the other 4 % of teachers indicated that disturbing noise was only coming from inside their own classrooms.

Question 9 – Teachers were asked to disclose anything else they felt affected their class' listening experience:
Nineteen teachers gave additional examples of what affects their listening experience, some examples were:

- 32 % of teachers pointed to the lack of discipline/noise education.
- 26 % indicated that noise coming from outside the building (caused by non-teaching actions such as cutting grass, polishing of floors, workers in the passages, and the grade R learners moving towards the playground) was problematic.
- 21 % voiced their displeasure over their perception of the acoustics of the building (architecture).
- 16 % identified the hall as adversely affecting teaching.
- 5 % indicated that the staffroom's acoustic character was inadequate for meetings.

Question 10 – Teachers were asked whether any of the sources mentioned was present while teaching:
All of the teachers agreed that they experienced environmental noise produced by, for example, vehicles, people, mechanical and electronic devices, nature, and people participating in entertainment activities.

Question 11 – If teachers answered yes to Question 10 they were asked to list which sources were disturbing teaching:
Teachers were asked to indicate what sources of noise were present while teaching:

- Transportation noise: None of the teachers indicated that this type of noise disturbed them.
- Noise produced by people: 93 % of teachers indicated that this type of noise disturbed them.
- Noise produced by mechanical and electronic devices: 25 % of teachers indicated that this type of noise disturbed them.
- Entertainment noise: 21 % of teachers indicated that this type of noise disturbed them.
- Noise from nature: None of the teachers indicated that this type of noise disturbed them.

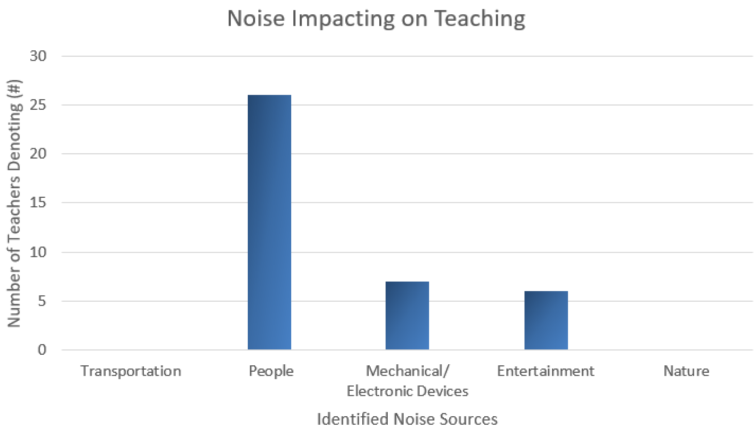


Figure 4.5: Sources of Noise

Question 12 – Teachers were asked whether their voice felt strained when they reached home after work:
82 % of teachers indicated that their voices were strained after a day's work.

Question 13 – Teachers were asked whether they sometimes suffered from voice loss:
70 % of teachers indicated that they sometimes suffered from voice loss.

Question 14 – Teachers were asked whether they had personally noted any signs of hearing damage while working at Rietenbosch Primary:
76 % of teachers indicated that they have experienced signs of hearing damage. The symptoms that were most frequently experienced were noise-induced headaches/migraines, and requiring people to frequently repeat themselves while talking in a group setting.

Question 15 – Teachers were asked to list an example (or examples) if they indicated yes in Question 14:

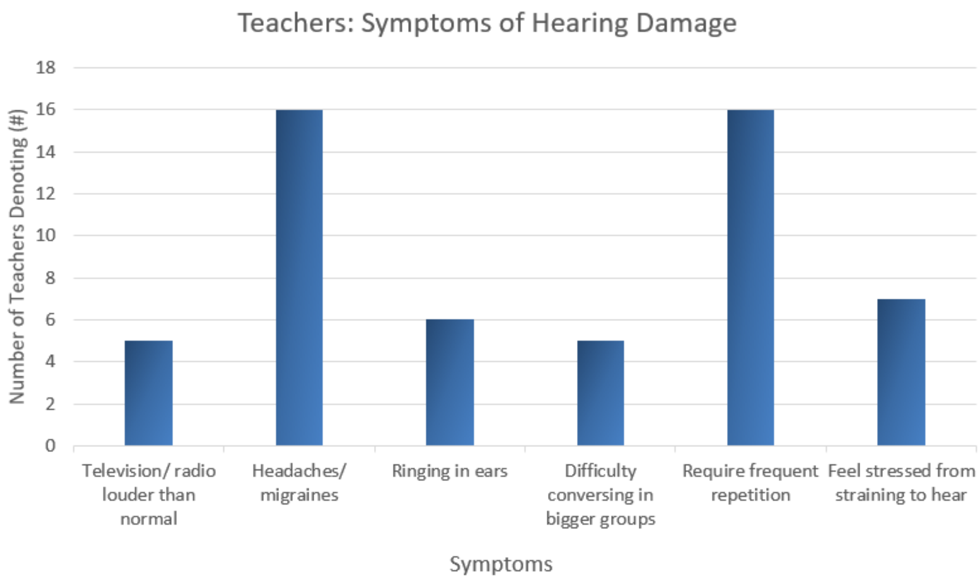


Figure 4.6: Signs of Hearing Damage Noted by Teachers

This data (of perceived hearing damage) was then compared to Question 1 and 2, to see whether age and time working at the school has any correlation with the effects of hearing damage.

- The average age for teachers experiencing hearing damage was 36.7 years,
  - ◇ with the modal age being 28 and 24 years old and
  - ◇ the median age being 31 years
  - ◇ the standard deviation (σ) was 12.9 and

 - ◇ the spread was 40 years
 - ◇ the average age was lower than the overall average (40) of teachers at the school

- The average length of time that the teachers had been working at the school was 5 years and one month,
  - ◇ the modal length of time was 3 years and
  - ◇ the median was 3 and a half years
  - ◇ the standard deviation (σ) was 4.2 and
  - ◇ the spread was 15 years and 8 months
  - ◇ the average teaching time-period was lower than the overall time-period average (5 and a half)

Question 16 – Teachers were asked whether they had experienced or were experiencing any of the symptoms (listed in the questionnaire), and they were to indicate the severity on a scale from 1-7: 100 % of teachers who completed the question indicated that they experienced symptoms associated with job-related stress.

Lack of energy: 96 % of the teachers indicated that they experienced symptoms associated with lack of energy:

- 26 % of them indicated that it was very hindersome.
- 22 % of them indicated that it was noticeable.
- 15 % of them indicated that it was unbearable.
- 15 % of them indicated that it was hindersome.
- 15 % of them indicated that it was moderate.
- 4 % of them indicated that it was barely perceived.
- 3 % of them indicated that it was not perceived.

Voice exertion: 96 % of the teachers indicated that they suffered from voice exertion:

- 26 % of them indicated that their voice exertion was perceived as moderate.
- 22 % of them indicated that their voice exertion was very hindersome.
- 19 % of them indicated that it was almost unbearable.
- 18 % of them indicated that it was hindersome.

- 7 % of them indicated that it was barely perceived.
- 4 % of them indicated that it was noticeable.
- 4 % of them indicated that it was not perceived.

Low job satisfaction: 93 % of the teachers indicated that they experienced low job satisfaction:

- 23 % of them indicated that it was barely perceived.
- 19 % of them indicated that it was moderate.
- 19 % of them indicated that it was very hindersome.
- 12 % of them indicated that it was hindersome.
- 11 % of them indicated that it was noticeable.
- 8 % of them indicated that it was barely noticeable.
- 8 % of them indicated that it was unbearable.

Lack of Motivation: 93 % of the teachers indicated that they suffered from lack of motivation:

- 30 % of them indicated that it was very hindersome.
- 18 % of them indicated that it was barely perceived.
- 15 % of them indicated that it was moderate.
- 15 % of them indicated that it was not perceived.
- 11 % of them indicated that it was noticeable.
- 7 % of them indicated that it was hindersome.
- 4 % of them indicated that it was almost unbearable.

Sleep disturbance: 100 % of teachers indicated that they suffered from sleep disturbances:

- 36 % of them indicated that it was hindersome.
- 25 % of them indicated that it was noticeable.
- 11 % of them indicated that it was moderate.
- 11 % of them indicated that it was unbearable.
- 7 % of them indicated that it was barely perceived.

- 7 % of them indicated that it was very hindersome.
- 3 % of them indicated that it was not perceived.

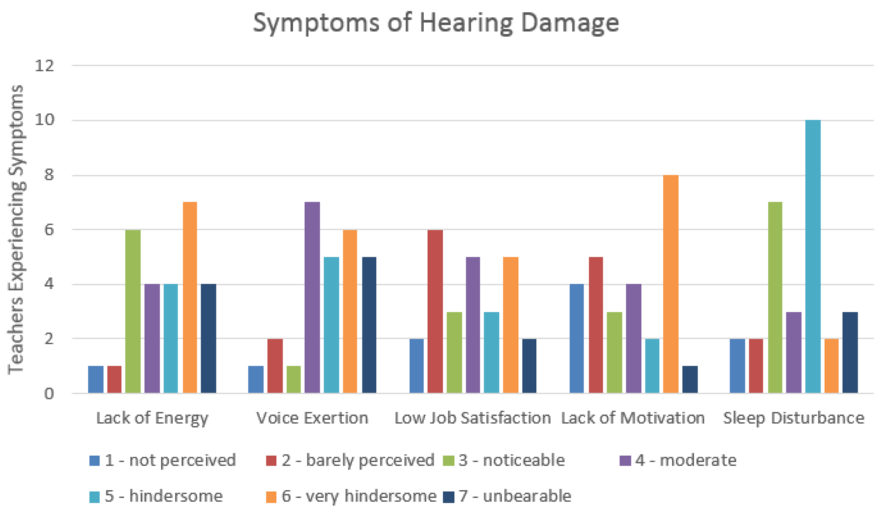


Figure 4.7: Teachers Perceived Symptoms of Job Related Stress

The symptoms that the most teachers experienced were generally on the scale of hindersome, very hindersome and/or unbearable.

- 16 teachers indicated that they suffered from voice exertion.
- 15 teachers indicated that they regularly suffered from a lack of energy and sleep disturbance.
- 11 teachers indicated that they had a lack of motivation and
- 10 teachers indicated that they had low job satisfaction.

Question 17 – Teachers were asked to indicate whether they had high blood pressure:

- 73 % of teachers indicated that they did not have high blood pressure.
- 20 % of teachers indicated that they had high blood pressure.
- 7 % of teachers indicated that they were uncertain whether they had high blood pressure.

Question 18 – If teachers indicated yes in Question 17, they were asked to state whether it developed during the time that they taught at Rietenbosch Primary:
Of the 20 % that indicated that they had high blood pressure:

- 50 % of the teachers indicated that it did not develop during the time that they had been teaching at Rietenbosch Primary.
- 25 % of the teachers indicated that it began during the time that they had been teaching at Rietenbosch Primary.
- 25 % of the teachers indicated that they were uncertain when it started.

Question 19 – Teachers were asked to indicate how often learners complained that they could not hear what teachers were saying while teaching:

- 43 % of learners sometimes complained that they could not hear what teachers were saying.
- 27 % of learners complained moderately that they could not hear their teachers.
- 17 % of learners never complained about intelligibility.
- 10 % of learners frequently complained that they could not always hear what was being taught.
- 3 % of learners always complained that they could not hear what the teacher was saying.

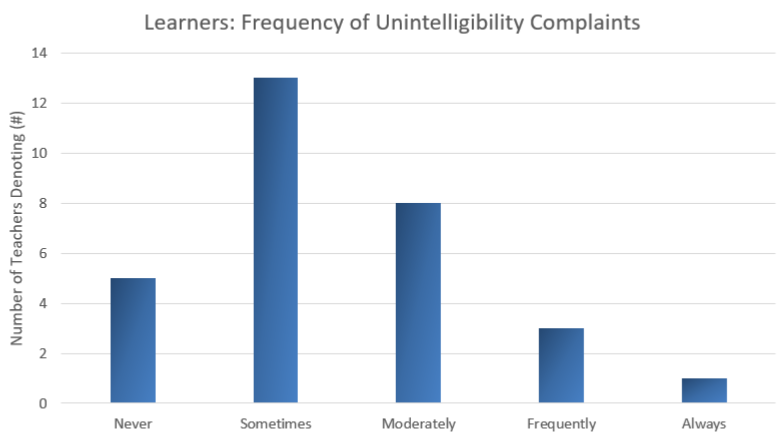


Figure 4.8: Complaints Regarding Speech Intelligibility

Question 20 – Teachers were asked whether learners could always see their face:
93 % of teachers indicated that learners always saw their face while they were teaching.

Question 21 – If teachers answered no to Question 20, they were asked whether it influenced learners' hearing ability and whether they have been asked to repeat questions multiple times:
17 % of teachers indicated that projecting towards the board negatively affected the learners' hearing ability, forcing them to ask the teachers to repeat questions.

Question 22 – Teachers were asked whether they noticed if learners frequently lost concentration:
87 % of teachers indicated that learners frequently lost concentration because of the high noise levels.

Question 23 – If teachers answered yes to Question 22 they were asked whether they noticed an impact on learners' work achievement:
Teachers noticed that learners' grades and work achievement had been negatively affected by the noise-related learning barriers. Many teachers noted that learners struggled to complete tasks. Sometimes tasks were only partially completed or were not completed at all. However, it is difficult to link these observations directly to the noise problem as completion of tasks can be influenced by more than one factor.

Question 24 – Teachers were asked whether learners ever complained about headaches induced by noise:
52 % of teachers indicated that learners had complained about headaches induced by noise.

Question 25 – If teachers answered yes to question 24 they were asked to indicate how frequently the headache complains occurred:

- 0 % of teachers indicated that learners sometimes complained about headaches induced by noise.
- 29 % indicated that learners only moderately complained of headaches caused by the noise.
- 21 % of teachers indicated that learners say that they frequently experienced headaches.

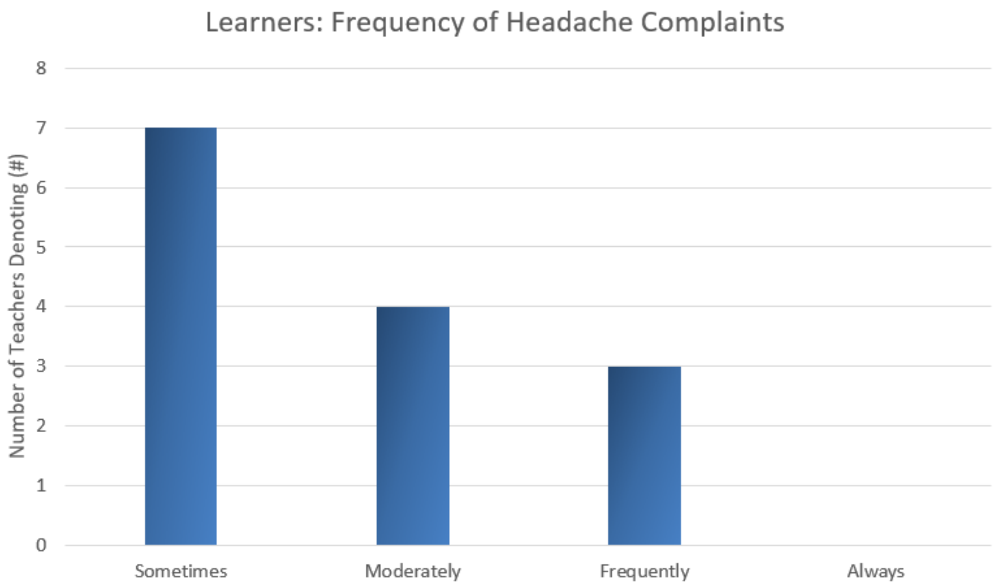


Figure 4.9: Frequency of Complaints Regarding Headaches

Question 26 – Teachers were asked to indicate when they experienced the best listening conditions:

- 50 % of teachers indicated that they experienced the best listening conditions in the mornings, from when school started until first break.
- 21 % of teachers indicated that they experienced the best listening conditions when there were less people in the school.
- 14 % of teachers said that they felt that the best listening conditions were when learners were completing tasks or writing exams.
- 7 % indicated that teaching was easiest when there were no activities taking place in the hall.
- 4 % of teachers said the best listening conditions occurred when there were less distractions in the building.
- 4 % of teachers said the best listening conditions occurred when learners were behaving.

4.3.2 Questionnaire Results

Question 1:
The results did not show a clear relationship between hearing damage and a teacher's age.

Question 2:
Results showed that both newer and older employees were equally affected by the perceived noise. However, newer teachers appeared to be slightly more irritated by the noise than teachers who had been working in the building for more than five years.

Question 3:
The two 'no' answers could be seen as anomalies/outliers as both teachers had been working at the school for less than two months.

Question 4:
Teachers indicated that learners would start a task, become distracted by noise present outside or inside the class, and not complete it. Teachers also indicated that learners frequently asked about activities taking place in the hall. These hall-based activities affected attention levels for long periods of time, especially if the activity in the hall was interesting and/or long lasting.

The above results substantiate the findings of previous research that noise affects learners' cognitive function by causing a high level of task desertion, which could affect scholastic achievement.

Question 5:
Most teachers felt that their classroom experience was negatively affected by noise.

Question 6:
Teachers generally indicated that there were three main causes of noise:

1. Noise from passages, adjacent classrooms, and floors above or below the classroom.

2. Noise from activities in the hall.

3. Noise from within the classroom (generated by learners) was irritating.

Teachers generally indicated that the noise in the school was so loud that they had to continuously raise their voices while teaching.

Teachers complained that the noise echoed throughout the school (and its hallways), easily penetrated the walls, which caused distractions in class. They indicated that learners struggled to concentrate, as learning never took place in near-silence. Troublingly, teachers also indicated that when they taught, and outside noise was present and loud, they had difficulty hearing what learners were saying/asking. They believed this noise generally came from other classrooms around and above them, as well as from the passages, as conversations could be clearly heard and discerned from inside the classroom.

Question 7:
This question substantiated that teachers had problems with noise originating in their classrooms as well as noise coming from adjacent classrooms.

Question 8:
Taking away wider noise parameters (those presented in Question 6), limiting them only to noise present in their classroom and adjacent rooms. Teachers stated that disturbing noise came predominantly from outside their classrooms. Many of the teachers' comments identified the same issue, namely that when learners were silent in class, they still heard a lot of noise from other classrooms, which distracted them. Many of the same examples were given as an answer to Question 6: Learners and teachers could hear what was being taught in the classes next to them. Teachers found it frustrating that if they left their door open, they could not teach at all because of the noise leaking into their classrooms.

Examples of areas where teachers believed noise originated from (listed in order of popularity) were:

1. Adjacent classrooms and hallways/passages on the first and second floor.
2. The hall
3. Inside their own classroom
4. The parking lot

The lack of learner discipline was another stated cause of noise. Teachers said that sometimes the noise was more regulated and other times it resulted in chaos.

Question 9:
The top three complaints were:

1. Lack of discipline/noise education
2. Noise originating from outside the classroom
3. Perception of acoustics/architecture (long reverberation).

Question 10:
The results of this question confirmed that noise from different sources was present in the classrooms.

Question 11:
As could be seen from the data, 93 % of teachers felt that the most disruptive noise was produced by people around them. Many teachers listed inappropriate

laughing and talking (i.e., a lack of discipline) coming from outside and inside the classroom. Another source listed by nine teachers (32 %), was impact noise created by tables and chairs. This noise originated from both inside and outside their own classrooms.

The second most disturbing noise was generated either by mechanical or electronic devices. Out of the 25 % of teachers who indicated that this type of noise was problematic, 71 % pinpointed the intercom as the most disturbing source of noise in this category. As this type of noise had previously been deemed 'disturbing' by more than one international study, bells and warning signals have a maximum permitted sound level (L_{Ap}) of 65 dB as prescribed by occupational safety (New Zealand Audiological Society, 2015, 3). However, it is not clear from previously published South African literature whether the country has legislated a maximum permissible level for these sources of noise.

Other examples of device noise included loudspeakers and lawnmowers. The third most disturbing noise that influenced teaching, indicated by 21 % of the teachers, was that of entertainment noise. Out of the 21 % of teachers that indicated experiencing this type of disturbance, 67 % listed the noise source as the hall. Examples of activities included sport activities, concert rehearsals, drama rehearsals, and music rehearsals taking place during school hours.

Teachers did not perceive any noise resulting from transportation or nature inside their classrooms.

Question 12:
Results indicated possible signs of vocal stress which could lead to vocal disorders.

Question 13:
Results indicated possible signs of vocal stress which could lead to vocal disorders.

Question 14:
Results showed that many teachers reported signs of hearing damage.

Question 15:
Results suggested that the teachers' biggest problem was voice exertion, followed closely by a lack of energy and sleep disturbances. As these symptoms could indicate exhaustion, they could lead to low levels of job satisfaction and a lack of motivation when it comes to teaching. This could influence a teacher's decision to stay in the workforce, or to possibly search for other forms of employment.

Three teachers gave additional information about their personal experiences of health disorders influenced by noise.

- One teacher claimed that he/she was no longer able to hear very well in group settings, the passages, or the staffroom of the school.
- Another teacher stated that he/she often felt exhausted as he/she needed to speak loudly for extended periods of time.
- The last teacher claimed that the constant loud noise was causing breathing problems[3].

It could be said that the teachers' symptoms could be influenced not only by noise but by natural hearing loss that comes with age, and aging. However, the three teachers ages were, respectively:

- 60
- 24
- 24

Therefore, surprisingly, these individuals did not fall within the older age group.

Another factor that needed to be considered was how long they had been teaching at the school, namely:

- 13 years
- 11 months
- 4 months

These time periods indicated that there was no clear relationship between how long they had been teaching at the school and the perceived severity of symptoms.

No correlation was found between older ages and longer appointment periods, disapproving (in this instance) the theory that older teachers who had been working in the noisy space the longest would be the worst affected by the noise.

Question 16:
The responses suggested that the teachers' biggest problem was voice exertion, followed closely by both lack of energy and sleep disturbances.

Question 17:
The percentage of teachers who had high blood pressure was marginal.

[3]The teacher did not specify but this could indicate a panic attack.

Question 18:
Out of the six teachers (20 %) who indicated in Question 17 that they had high blood pressure, only two teachers (25 %) indicated that it developed while they were employed at Rietenbosch Primary. Two teachers (25 %) indicated that they were uncertain about when their high blood pressure began. There was no clear indication in this study that high blood pressure, caused by stress, was prevalent in teachers due to excessive noise.

Question 19:
Subjective results (acquired from teachers) showed that learners could not always hear their teachers, showing that unintelligibility was an issue at Rietenbosch Primary. Due to listening tasks being encouraged by the South African CAPS curriculum, and these tasks becoming more complex by grade, learners' ability to identify phrases and mental processing (especially in the short-term) could be impaired if they cannot hear or understand their teachers (Klatte *et al.*, 2010, 2-3).

Question 20:
Results showed that directionality of speech was important, especially in a noisy environment as noise propagates forward from the source.

Question 21:
As a point of interest three of the five teachers indicated that learners asked them to repeat themselves, even though speech was directed towards the learners.

Question 22:
A correlation with answers to Question 4 was found; that learners' performance was affected in noisy situations.

Question 23:
There were inherent barriers to learning in the school as some learners (e.g., who were not diagnosed with a learning barrier or have a hearing problem) also experienced concentration problems. The learners were often more interested with what was happening outside than the learning taking place in the classroom, and therefore missed important information. Teachers felt that many learners were prone to being distracted due to the noise, as task instructions needed to be repeated several times before they understood what they were required to do.

Zannin *et al.*'s (2012, 216) study suggested that certain activities suffered more than others when noise was present, including teacher explanations (46 %), reading (23 %), and the writing of exams (23 %).

Question 24:
The data, of how many learners were experiencing headaches due to noise, was only a subjective estimate as it was noted that learners sometimes feigned an illness to get out of certain tasks.

Question 25:
There was no clear indication whether learners truly experienced headaches due to noise.

Question 26:
A few teachers gave their opinion regarding why the school was perceived to be quieter in the morning than, for example, after a break. Teachers believed that children were quieter/calmer in the mornings as they had just arrived at school and were still sharp and focused on the day's activities. They believed that after break (playtime) learners went into an 'excited state of mind' and were rowdy and undisciplined as they wanted to extend playtime. It often took the teachers a period or more to calm them down again, and then when it was the period just before second break learners became restless as they were mentally preparing for the break. The same pattern of behaviour occurred after second break until the final bell rang. The effect could be seen as a cyclic phenomenon and not a linear ascending line as noise levels were not rising consistently through the day.

The top three best listening conditions were therefore reported to occur:

1. in the early mornings,
2. when the school was at a lower capacity, and
3. when learners were busy completing tasks or writing exams.

4.4 Noise Survey Measurements

The noise survey was conducted over a period of two weeks. Occupied noise tests were conducted during school hours, while normal school activities were taking place. Tests requiring an unoccupied building were conducted over a weekend.

4.4.1 Measurement Locations

The researcher chose to survey a sample of eleven classrooms (numbered randomly from one to eleven) out of the 32 classrooms of the school. Some properties of the classrooms were as follows:

1. There was an average of 33 learners per classroom

2. Ten classrooms had thin curtains
3. Six classrooms were furnished with carpets (these classrooms were for children in grade R–3 as their curriculum requires them to work on mat-related tasks)
4. Two of the classrooms were specifically for learners with diagnosed barriers to learning
    a) These two classrooms were larger than the standard classrooms and completely covered in carpet
    b) They were also located in the same area of the school
5. Classroom locations (right wing):
    a) Three classrooms on the first floor
    b) Two classrooms on the second floor
    c) Two additional classrooms on the second floor adjacent to the hall, near the staffroom
6. Classroom locations (left wing):
    a) Two classrooms on the first floor
    b) Two classrooms on the second floor

Refer to the figure below for the eleven classrooms that were surveyed:

4.4.2 Measurement Results

4.4.2.1 Volumetric Measurements

Volume measurements of all the sampled classrooms were made as well as placing stickers of the measuring points on the floors (see Appendix C).

All classrooms were within the 10 000 ft^3 ($\sim$ 283 m^3) to 20 000 ft^3 ($\sim$ 566 m^3) margin. This meant the reverberation time and ambient noise level could be compared to the values specified for this size room in documented noise standards.

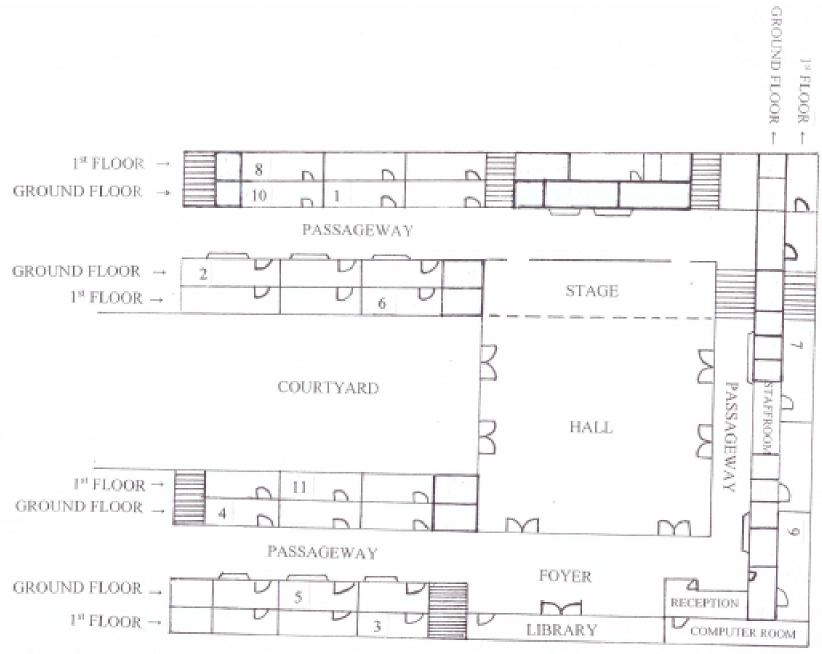


Figure 4.10: The Eleven Classrooms Surveyed

Table 4.1: Volume of Sample Classrooms

Classroom	Volume (m^3)
1	113
10	113
8	117
4	141
3	143
6	143
11	143
5	144
2	145
9	154
7	160

4.4.2.2 Unoccupied School: Unoccupied Ambient Noise Levels

The table below details the results of ambient noise level measurements.

Classrooms

Most of the classrooms were surveyed for the ambient noise level measurements as many teachers deemed their classrooms to be ‘noisy’ even when learners were quiet.

The preferred level for an unoccupied classroom is 35 dB(A).

Table 4.2: Ambient Noise Level of Classrooms

Classroom	Average dB(A)	Peak dB(A)
1	36.0	55.2
2	35.8	53.3
3	36.2	67.2
4	35.9	55.9
5	35.4	57.4
6	37.1	58.5
7	37.4	64.3
8	35.8	63.2
9	36.2	57.9
10	35.7	57.1
11	35.4	59.8

Passageways

The ambient noise levels of the passages were measured utilising the same procedure used in the classrooms.

The equivalent average noise level of a passageway is recommended to be equal to, or lower than, 35 dB(A).

Table 4.3: Ambient Noise Levels of Passageways

Area of School	Average dB(A)	Peak dB(A)
Passageway near classroom 1	38.9	64.4
Passageway near classroom 4	40.7	68.1
Passageway near classroom 6	38.3	61.7
Passageway near classroom 8	38.9	70.2
Passageway near classroom 11	40.7	70.1
Passageway near staffroom	37.7	67.8

Reverberation Time

Reverberation tests were only completed in a few classrooms, as the questionnaire indicated that reverberation was only perceived to be present in the hall and passageways. The reverberation time of the hall was also measured.

The reverberation time of a classroom is recommended to be 0.6s.

Table 4.4: Classroom Reverberation Time

Classroom	Reverberation Time(s)
1	0.4
2	0.6
5	0.6
7	0.6
8	0.7
9	0.5
10	0.4

Sound Insulation

Table 4.5: Sound Insulation Between Passageways and Classrooms

Classroom	Passageway (dB(A))	Inside Classroom (dB(A))	Insulation (dB(A))
Classroom 1	65.1	57.0	8.1
Classroom 6	65.3	42.4	22.9
Classroom 5	61.9	42.5	19.4
Classroom 7	78.4	57.0	21.4
Classroom 11	66.3	46.5	19.8

Sound Impact Noise

The sound impact noise of 5 classrooms was measured.

Table 4.6: Sound Impact Measurements

Classroom	Tyre 1 (2.2 kg)	Tyre 2 (4 kg)	Tyre 3 (5.1 kg)
1	62.2	66.7	72.4
2	63.1	68.9	72.9
4	57.9	60.4	61.6
6	64.9	69.8	71.4
10	63.7	69.2	72.6

The sound impact noise of a classroom is recommended to be below 60dB(A).

4.4.2.3 Occupied School: Unoccupied Ambient Noise Levels with Normal Activities in School

Classrooms

These measurements were made while teachers had an off period.

Table 4.7: Ambient Noise Level of Classrooms with Normal Activities in School

Classroom	Unoccupied Ambient Noise Level dB(A)
1	52.8
5	60.1
7	47.1
10	54.9
11	44.6

Passageways and Hall

Ambient noise level tests were measured inside passages and the hall while normal classroom activities were taking place in the school.

Table 4.8: Ambient Noise Levels of Passageways

Area of School	Average dB(A)
Passageway near classroom 4	69.7
Passageway near classroom 6	67.9
Passageway near classroom 8	38.9
Passageway near classroom 11	68.8
Passageway near staffroom	73.0

The average occupied ambient noise level in the passages averaged 63.7 dB(A) where the average ambient noise level of the unoccupied passageway was 39.2 dB(A).

4.4.2.4 Occupied School: Occupied Ambient Noise Levels

Classrooms

Ideally classroom values should not exceed 65 dB(A), as this value represents a voice not burdened by vocal strain. At levels of 75 dB(A), especially if present for long periods of time, a teacher will be at risk of developing voice-related problems (Eggenschwiler, 2005, 3).

The average noise level for each classroom is represented below.

Table 4.9: Average Noise Level (dB(A)) of Occupied Classrooms

Classroom	Morning	After First Break	After Second Break	Average	Peak of Day
1	71.5	68.9	72.1	70.8	113.3
2	69.7	71.2	70.2	70.4	112.5
3	69.1	67.0	68.5	68.2	113.3
4	69.6	69.5	67.0	68.7	102.2
5	76.2	74.5	71.9	74.2	115
6	62.7	67.5	69.3	66.5	100.7
7	71.4	74.2	65.8	70.5	107.4
8	67.5	70.3	70.7	69.5	106.9
9	65.5	67.5	71.2	68.1	102.7
10	69.3	64.3	60.8	64.8	102.7
11	67.2	69.1	70.0	68.8	113.4

Passageways

Passageways were also measured during breaks to see how high noise levels could reach if learners were left unattended.

Table 4.10: Passageway Noise During Break (dB(A))

During First Break	During Second Break	Average
77.7	82.6	80.2
83.4	81.4	82.4
86.8	82.7	84.8
79.0	88.0	83.5

4.4.2.5 Occupied Ambient Noise Level in Relation to Teachers' Voices

The subtraction value was high (except for Classroom 6), indicating that teachers' voices could be heard above the background noise with ease. This showed that speech intelligibility was good, although teachers are at risk for developing voice disorders.

4.4.2.6 Noise Education Results on Ambient Noise Levels

The noise education data was collected on a day when the whole school was under strict instructions to keep quiet because learners were writing tests.

Table 4.11: Speech Intelligibility

Classroom	Silent/Quiet Classroom dB(A)	Teacher Speaking in Classroom dB(A)	Subtraction Value
1	45.0	63.9	18.9
2	40.9	64.2	23.3
3	44.1	65.1	21
4	48.3	63.4	15.1
5	46.5	70.8	24.3
6	49.5	58.6	9.1
7	46.2	66.5	20.3
8	43.9	64.1	20.2
9	40.2	58.6	18.4
10	44.6	57.3	12.7
11	41.3	68.9	27.6

Occupied Classrooms

Table 4.12: Noise Education Average (dB(A))

Classroom	Morning	After First Break	Average
1	61.1	71.3	66.2
2	63.8	67.9	65.9

Passageways

The effects of noise education were also measured in the passageways to see how noise education affected the occupied ambient noise level.

Table 4.13: Noise Education Passages Average (dB(A))

Area of school	Floor	Morning	After First Break	Average
Passageway staffroom	Ground floor	58.7	65.7	62.2
Passageway classroom 1	Ground floor	54.8	64.7	59.8
Passageway classroom 7	First floor	53.9	64.7	59.3
Passageway classroom 8	First floor	59.7	66.1	62.9

Chapter 5

Discussion of Analysis and Results

5.1 Questionnaire Deductions

The questionnaire showed that noise at Rietenbosch Primary School is predominantly caused by people inside the building. All of the teachers who completed the questionnaire indicated that they experience environmental noise in their classroom. This shows that teachers are, subjectively, experiencing ongoing noise leakage from other sources into their classrooms. Almost all of the teachers (97%) noticed that the noisy environment have a negative impact on the performance of learners. Teachers elaborated by stating that:

1. learners do not complete tasks,
2. learners need task instructions to be frequently repeated in order to complete tasks,
3. learners often ask teachers to repeat themselves often,
4. learners frequently lose concentration,
5. they struggle to keep learners' attention, and
6. lessons must be paused frequently to regain learners' attention.

These examples of effects on learner performance are indicative of the teaching barriers experienced in Rietenbosch Primary's classrooms.

The teachers believe the main noise sources are the adjacent classrooms (leaking in from both floors) the passages and hall. This supports teacher opinions that noise is predominantly generated from adjacent classrooms and activities in the hall.

Vocal strain was identified, which places teachers at increased risk of developing voice disorders. It was noted that the high noise levels forces teachers to raise their voices for long periods of time (subsequently contributing to the overall noisy environment). Again many teachers indicated that they believe the noise present in their classroom is generated because of a lack of discipline in adjacent classes. Dockrell and Shield's (2006, 6) tests support this finding, since their research identified the significant impact classroom management and organisation can have on the acoustic environment of a classroom and the school. If all teachers focused on discipline within their own classrooms, an overall positive effect would be noticeable in the school.

The data from questions 19, 20, and 21 indicated how teaching is negatively influenced by students being unable to hear and understand teachers. It showed how these factors work together to detract from the learning taking place in the classroom. Teachers indicated that they experience the best listening conditions in the mornings before first break.

Responses to questions 12, 13, 14, 17, and 18 are in line with previous literature describing the effects of noise on employees health. Teachers have subjectively experienced health-related symptoms, such as hearing loss and voice exertion, as a consequence of the noisy work environment. Other described symptoms and side effects included:

1. headaches or migraines,
2. requiring frequent repetition in group discussions,
3. stress caused by straining to hear others,
4. having to ask learners to repeat themselves.

Learners also noted that they sometimes struggle to hear what teachers are saying and have experienced noise-induced headaches. Thus, it is believed that the noise levels in the classrooms are above the recommended level for teaching. Questions 12, 13, and 16 showed that teachers are at high risk of developing voice disorders because of vocal exertion.

Learners exhibit some signs of hearing damage (seen in answers to Questions 19 and 25), for example, they often ask teachers and learners around them to repeat themselves. It is also hypothesised that learners exhibit signs of stress (headaches) caused by noise. Although the percentage of learners exhibiting these symptoms is not high, it is still worth noting since it seems they are experiencing symptoms related to noise. It must also be considered that young people are either not as protective of their hearing as older generations or are unaware of how to protect it. Thus these results may have been influenced by various circumstances such as their housing conditions, hobbies, and music listening methods.

Many teachers explained how noise affects the teaching atmosphere in their classrooms; it particularly affects learners' ability to focus. They explained that learners frequently lose concentration as they enjoy listening to the noise coming from adjacent classrooms. These distractions lead to further discipline problems within their classrooms. It was also noted that many dedicated learners become frustrated when the noise affects their concentration and they often ask their peers to quieten down. Teachers often struggle to keep learners' attention, and try to remain in control by raising their voice. It was also noted that at times of severe distraction teachers are forced to pause their lessons to regain the learners' attention. Teachers complain that the noise influences their classroom atmosphere, which influences the learning environment and results in a disruptive classroom.

Answers to Questions 3, 4, and 5 are in line with previous literature that indicates that learners who go to school in a noisy environment do not perform as well as those in schools with better listening conditions. Frequently, noise disrupts learners' concentration, which leads to inferior work output. It can therefore be concluded that the noise inside Rietenbosch Primary does indeed influence learners' achievements.

5.2 Noise Survey

A number of tests were conducted at Rietenbosch Primary to gain insight into the acoustic properties of the school and classrooms.

Initially, learners were intrigued by the researcher taking measurements in the occupied classrooms. This soon subsided after teachers explained that the researcher was merely there to test classroom properties. The younger learners easily blocked out the oddity of someone moving around taking measurements, while older learners tried to evoke a reaction (e.g., by pulling faces and asking questions) from the researcher.

5.2.1 Unoccupied Measurement Results

Ambient Noise

It was noted that certain areas of the school are noisier than others. These areas were identified as the hall and the left wing. A possible reason for these higher noise levels could be that these areas have a road on either side of them. One of these roads is a main road that carries significant traffic during the day. When ambient noise levels were measured it was noted, by looking at the peak values, that transportation noise, in the form of car acceleration or cars with faulty exhausts, echoed noticeably throughout the hall.

Ambient noise levels were measured in classrooms with their doors open, but the values were not notably different than when the doors were closed.

As discussed in the literature review, the equivalent average noise level of a classroom should not exceed 35 dB(A) – as per requirements of the WHO, ANSI and ASHA. It is evident from the results that none of the classes adhere to this requirement, although six of the eleven classrooms only exceed this value by a small margin. Measurements could not confirm that classrooms with carpets had a lower ambient noise level compared to classrooms without carpets. Classroom measurements did not surpass 38 dB(A).

Unoccupied Passageway and Hall Ambient Noise Results

The average noise level of the passageways was measured as 39.2 dB(A), which exceeds the recommended level of 35 dB(A). This value is more than 3 dB(A) higher than the recommended value, so it is a noticeable difference.

The averages of the classrooms and passageways were compared, showing that (on average) passageways' noise levels were 3.1 dB(A) more than that of classrooms.

The recommended ambient noise level of a hall should not exceed 35 dB(A). The ambient noise level was measured as 39.2 dB(A). Once again this is a noticeable difference.

The passages are significantly more vulnerable to sound than the classrooms, as noise accumulating in the hall leaks into all open passages as there are no walls or other sound barriers present. This observation was supported by the fact that the ambient noise level of the hall and the passageways were the same.

A comparative study was done, in the same passageway used for ambient noise measurements, when an especially noisy car was passing on the highway. The average equivalent value rose from 38.3 to 45.9 dB(A) indicating the effect of the proximity of the highway on ambient noise levels.

Reverberation Time

Ten of the eleven classrooms' values fell within the parameters specified (0.6s); while the final classroom was slightly above the recommended level. The average reverberation time of the sampled classrooms was 0.5s.

An assembly hall has a recommended reverberation time of 0.8–1.2s. The hall was measured to be 4.62s. This value exceeds the maximum allowable reverberation time (of 1.2s) for a hall by 3.42s. It is almost four times longer than the recommended level and almost three times as long as the maximum value.

It can be deduced that, although the classrooms had reverberation times mostly 'just' within recommended limits, the hall (and inadvertently the passages) had very long reverberation times. This supports the views of the teachers that the school hall is a very reverberant space, and that it exacerbates noise in the school.

Sound Insulation

The classrooms' average amount of sound insulation (by measuring reduction in SPL) was 18.3 dB(A). This was determined by taking one measurement with the doors open and once with the doors closed. A possible reason for Classroom 1's low insulation value (of 8.1 dB(A)) is that it had a broken door that did not close properly.

The classroom directly adjacent to the hall had the highest value (i.e., 57.0 dB(A)). Therefore, classrooms closest to the hall were more adversely affected by the lack of a second wall between them and the hall. The passageway walls do offer some sound insulation from the noise (to the value of between 13.7 and 18.1 dB(A)).

Sound Impact

Impact sound measurement tests showed that the classrooms have inadequate sound impact insulation between floors.

The average value of tyre 1 was 62.4 dB(A), tyre 2 was 67 dB(A) and tyre three was 70.2 dB(A). It must be noted that the tyre that weighed 5.1kg did not have such a significant effect when compared to the tyre of 4kg, since the larger surface compensates for the increased mass.

The classroom that offered the best impact sound insulation was Classroom 4. This classroom was the only fully carpeted room, which could explain why the absorption value was higher. Three of the classrooms did not have carpets and Classroom 6 was only partially carpeted, although this did not have a significant effect.

The maximum allowed impact sound level in a classroom is 60 dB(A). Comparing the above averages it is evident that the classrooms do not have adequate impact sound insulation. The sound impact values were approximately 20 dB(A) above the ambient noise level, and in some cases even louder than occupied noise values. It can thus be deduced that, because sound impact noise levels are so high in the classrooms on the ground floor, the ceiling of the ground floor does not offer adequate insulation between the floors. Teachers' opinions in the questionnaire could therefore be supported; irregular loud impact noise from the floor above could be distracting to learners in ground floor classrooms.

5.2.2 Occupied School: Unoccupied Classrooms

Unoccupied Classrooms Ambient Noise Level Results

The average of the measured values was 51.9 dB(A), compared to an unoccupied ambient noise level of 36.1 dB(A). A possible cause of higher ambient levels could be that (a) many classrooms had broken windows, and (b) noise from the passages leak into classrooms unimpeded.

Unoccupied Passageway Ambient Noise Level Results

The above reaffirms the notion that noise from the passageways propagates into classrooms, causing higher noise levels in these rooms.

5.2.3 Occupied School: Occupied Classrooms

Occupied Ambient Noise

The average occupied ambient noise of all the classrooms for the whole school day was 69.1 dB(A); almost 5 dB(A) above the recommended maximum levels prescribed by Eggenschwiler (2005, 3). All but one classroom exceeded the recommended value of 65 dB(A). Only Classroom 10 was within the 65 dB(A) limit for the whole day with a value of 64.8 dB(A). Classroom 5's level was especially high when compared to the rest of the sample classrooms, with an average value of 74.2 dB(A), almost reaching the maximum recommended value.

The data showed that most classrooms are subjected to high noise levels throughout the school day, although some are worse than others.

The average value in the morning was 69.1 dB(A). This increased to 69.5 dB(A) after first break, and then decreased to 68.9 dB(A) after second break. Values fluctuated immensely during school hours. In some classrooms (e.g., 6, 8, 9 and 11) levels would steadily increase towards the end of the day, while in other classrooms (e.g., 4 and 10) levels would steadily decrease. Other classrooms fluctuated without a clear pattern. It could therefore not be definitively shown that classrooms are louder after second break, compared to early mornings.

Peak noise levels were caused by sporadic events, such as children erupting into laughter, general disorder, teachers trying to control classes or objects falling in class. It must, however, be noted that peak values were excessively high, reaching 115 dB(A).

Passageway and Hall Noise During Breaks

The average value in the passages was 81.7 dB(A) during first break and 83.7 dB(A) during second break. This makes the average noise exposure level during breaks around 83 dB(A).

5.2.4 Teachers Voice in Relation to Noise

By raising their voices to be adequately audible above the occupied ambient noise level in classes, 81 % of teachers are adding vocal strain to their voices. It was, however, shown that most of the sampled classrooms have a good speech intelligibility value as the signal sound is sufficiently louder than the occupied ambient level.

The average of the teachers' voice levels in this study was 63.8 dB(A), which is 5.3 dB(A) lower when compared to the other tests that were taken in 'realistic' classroom conditions. This showed that teachers are working at a voice level that is above accepted comfort levels, causing straining of the vocal chords.

5.2.5 Noise Education

Classroom 1's average level diminished by 4.6 dB(A) and Classroom 2's by 4.4 dB(A) when compared to the occupied noise level. This is a marked difference, and brought the classes closer to the preferred level of 65.0 dB(A). Measurement parameters were unaltered from occupied noise level measurements.

The measured passageways were, on average, only 2.63 dB(A) less under these test conditions than under normal conditions, making this difference marginal (and not even noticeable). This indicated that although there is some noise transference between classrooms, the main leakage is due to the noise originating in the passages and hall, generated either by learners not writing tests, or other people moving within the school.

5.2.6 Observations

The building layout (including furnishings and finishes) was found not to obstruct noise propagation. Analysis showed that the classrooms have acceptable ambient noise levels implying that they exhibit decent sound insolation properties.

Parts of the school can be deemed 'louder' (i.e., having higher occupied ambient noise) than the other parts; these areas were identified to be the classrooms

1. adjacent to the hall and
2. in the left wing

The hall and passageways have ambient noise levels that can be deemed 'noisy'. It was shown that the hall (and inadvertently the passages) have very long reverberation times. The passageways are very reverberant of noise generated in the hall and the various ventilation openings present in the school are aggravating this problem. This causes unimpeded, excessive echoes throughout the school. The passageways are therefore noisier than the classrooms. Teachers have to talk more loudly in their classes because of the noise leaking in from passages. Originally the road traffic noise was not considered a problem as the overall noise in the school is so elevated that you cannot hear it under normal circumstances. However, when the ambient noise level was measured in the unoccupied school, one could clearly hear the cars on the highway close by.

The classrooms are shown to have acceptable reverberation times, which implies that the classrooms have enough sound absorptive materials. Occupied noise levels are, on average, higher than the preferred level of 65 dB(A), but lower than 75 dB(A) for long periods of time.

Unattended classrooms (e.g., when the teacher is called away or running an errand) regularly reached high noise levels (e.g., 85 dB(A) and above), caused by the unsupervised learners, for a period of a few minutes.

Although the noise education employed in classrooms can lower the overall levels slightly, it still does not solve the problem of the reverberant hall and passageways.

The sound insulation between the classrooms is adequate, but the sound insulation between the classrooms and passages could be improved to lower the overall noise level.

The maximum average noise level did not reach 85 dB(A) at any point during an eight-hour working day; the highest average for the testing period was 74.2 dB(A).

A rough estimate of the level of noise exposure for teacher and learners over a six-hour school day was calculated as follows: An estimated value of a 'normal' day is derived by averaging the values collected in the noise survey. This is a subjective value as it is acknowledged that one cannot simply add decibel values together from different measuring locations since the noise environment changes. Adding the levels[1] was done to estimate daily noise exposure at Rietenbosch Primary. The average exposure value for learners at the school is 75.9 dB(A). This value is comprised of the average occupied classroom noise level values (across all measured classrooms) added to the averaged break time values. This value shows that learners are exposed to high noise levels throughout an ordinary school day. South African law requires that people wear ear protection when levels reach an average of 80 dB(A) per day in their environment.

It can be concluded from the noise survey that although the school does have acceptable ambient noise levels, the effect of long reverberation times of the hall and passageways results in marginally unacceptable levels of ambient noise.

5.3 Questionnaire vs Noise Survey

The results of the questionnaire and noise survey support one another by both showing that noise predominantly leaks into the classrooms from outside sources. Teachers on the ground floor indicated that impact noise coming from their ceiling is very hindersome and frequently distracts learners. The noise survey concluded, by means of sound impact noise tests, that the insulation between floors is inadequate for the school environment.

Many teachers, with classrooms in different parts of the school, indicated in their questionnaire responses that the number one noise issue for them is noise leaking from the hall and passageways. The noise survey supported

[1] as measurements were made in the same frequency bands

these results as activities from the hall could clearly be heard inside surveyed classrooms. This is largely due the long reverberation times of the hall and passages, coupled with frequent activities inside the hall during teaching hours.

In some cases, it was noted that the noise level inside the classroom is not distracting, but the high noise levels in the passageway have a psychological effect on teachers (as indicated in questionnaire responses).

The questionnaire showed that many teachers suffer from voice-related health problems. The occupied noise values in the noise survey showed that average levels in classrooms exceeded 65 dB(A), a level that adds strain to the voice if maintained for long periods of time. The average occupied classroom noise levels nearly reached 70 dB(A), and studies have noted that at levels of 65 dB(A) and above, teachers' stress levels increase, posing a high risk of developing voice-related problems.

Teachers argued that the school gets noisier as the typical school day progresses, and that the best listening conditions are therefore in the early mornings. The noise survey did not provide clear support for this statement, as the sampled classes did not get noticeably louder throughout the day.

Teachers noted that if other teachers maintain discipline in their classrooms, listening conditions could improve. This theory was tested during a exam where the whole school was under strict instruction to keep quiet. The measurements and tests completed during the survey showed that although there was a slight decrease in the average noise levels, the overall school noise levels were barely affected.

The questionnaire showed that teachers feel learners can not always hear them above the ambient noise. The noise survey provided ambiguous results regarding this claim, since occupied ambient noise levels are within acceptable limits relative to teachers' voice. It must be noted that during the measuring period, activities in the hall did not reach levels that teachers referred to in the questionnaire since music classes were not taught in the hall during this time. Teachers indicated that while music is being taught in the hall, they cannot hear or be heard by most learners.

Teachers did not report noise derived from transportation or nature inside their classroom as disruptive. While unoccupied ambient noise tests were conducted in the school, the ambient noise level was greatly influenced by transportation noise coming from the nearby highway. This shows that the occupied noise levels in the school are high enough to drown out these noises, which would be heard and deemed a 'nuisance' under quiet circumstances. Thus, the main noise problem appears to originate within the school building itself.

5.4 Possible Solutions

There are four main solutions that could be implemented to mitigate the noise problem at Rietenbosch Primary School:

1. As suggested by Van Tonder *et al.* (2015, 1), visual feedback should be installed inside classrooms as this positively affects overall classroom noise levels and encourages positive behaviour from learners. Their tests showed that visual feedback could provide a cost-effective, non-invasive tool to create a more enabling and less noisy classroom environment. A similar solution would be to install an open source program called Bouncy Balls[2] on a desktop or laptop. The application makes use of the computer's built-in microphone. The more noise the learners create, the faster the balls start bouncing, and words such as 'SHHHH', 'TOO NOISY' and 'QUIET' appear on the screen (see Appendix D). If learners maintain a preferred noise level, the balls lie dormant on the bottom of the screen. The program does not need to be installed and can be accessed via an internet connection.

   Problems with these electronic solutions can arise, as the lights of the visual feedback system and the Bouncy Balls can distract learners while they should be working or listening. Van Tonder *et al.*'s tests showed that when learners got used to the stimuli, the effect diminished as their curiosity faded. However, there is the possibility that, at least initially, learners may intentionally make a lot of noise to see the balls moving along the screen or the lights flashing. In addition, this type of infrastructure (e.g., visual feedback LED lights) is not free since installation and maintenance is required. The applications also have to be used on an electronic device, and such devices are not currently present in the classrooms of Rietenbosch Primary because of security concerns.

2. A quick, cheap, and easy solution to the impact noise is to place perforated tennis balls under the legs of the desks and chairs on the first floor (Dreossi and Momensohn-Santos, 2005, 256). Teachers were complaining of the noise that moving chairs and tables made within their own classroom, as well as from classrooms above them. T & R Interior Systems (2014, 44) suggests adding rubber stops to the legs of all moveable furniture in the classroom. One study also suggested adding additional carpets to the floors to help mute impact sound, but concerns have been raised that it is a tripping hazard and is not recommended for classrooms due to possible legal ramifications.

3. Another option would be to add sound absorption materials to the school in general.

[2]bouncyballs.org

A test conducted by Roy (2016, 3) in 52 schools in Santiago, Chile shows the viability of adding absorptive materials. The study placed absorptive materials (e.g., foams and mineral wool) inside the school. It was shown that it was possible to shorten the reverberation time from 2.6s to 0.6s, and to reduce the ambient noise level from 66 to 38 dB(A) when utilising absorptive materials (Roy, 2016, 3). The sound absorption was so effective that it even lessened the noise of rustling papers, pens, and chairs.

Furthermore, T & R Interior Systems (2014, 54) states that spaces such as corridors and stairs (where many people move around) tend to be very noisy. Treating these spaces acoustically can greatly help to reduce noise and reverberation, and can lead to the whole school having a 'quieter' ambiance. If this can be done in Rietenbosch Primary it will help to reduce the amount of noise that leaks into classrooms. Some suggestions of acoustic treatment follows:

a) There are several absorbent fibreglass materials available, and these provide some of the cheapest, easiest solutions. For effective damping, CertainTeed (2011, 10) suggests a double stud construction wall, with either one or two fibreglass sound absorbing insulation boards. Fiberglass also diminishes direct transference of noise from one wall surface to the other, increasing the STC rating.

b) Another option for sound absorbing material is Maxiboard. This is a high-mass board with excellent sound insulation properties. It can be used to improve the sound absorption of stud partitions, masonry walls, ceiling systems, and concrete floor structures (Sound Reduction Systems, 2013, 5). This material is notably robust and suitable for a demanding school environment.

c) Also Plumb's (1992, 1) tests showed that Rockwool is a very good absorber as it has a smooth absorption coefficient, simple construction and is not very heavy. RW2 Rockwool is also very effective as a wide-band absorber (Plumb, 1992, 2).

d) A study done by Sala and Viljanen (1995, 81) suggests the use of mineral wood as an absorber. Mineral wool achieved a mean RASTI value of 0.75 or higher. For a high level of absorption it is necessary to use at least 30 % mineral wood and place it on two surfaces for maximum absorption of the room.

e) Glass-fibre and mineral-fibre materials exhibit good sound absorption properties, though they contribute to pollution and increasing carbon dioxide levels in the atmosphere during its manufacture. Furthermore, Zhu *et al.* (2013, 1765) has launched a study into bio-based products and considers that these may be the most ideal acoustic materials as, apart from its efficient sound absorption, they are affordable, sustainable, light weight and do not contribute to pollution levels. Presently the bio-based materials are composed of either completely natural or vegetable particles (Zhu *et al.*, 2013, 1765).

Therefore, there are many options in terms of materials that can be used for sound absorption, although it is debatable which of these is most effective. Unfortunately, all of the materials mentioned in this section are expensive and require a significant amount of labour and time to install. It is important that all safety instructions regarding the materials are adhered to, to ensure that it does not cause health problems arising from human contact with the fibres (Bies and Hansen, 2009, 285).

4. Another solution would be to reallocate classrooms away from where noisy activities (e.g., music classes) take place.

Chapter 6

Conclusions and Recommendations

6.1 Conclusions

Data for the current study was compiled using both subjective (questionnaire) and objective (noise survey) methods. The data clearly shows that there is a noise problem at Rietenbosch Primary School. Noise predominantly leaks into classrooms from adjacent classrooms and passageways and is present throughout the school on a normal school day. Ambient, unoccupied noise levels within the school are of acceptable levels. However, occupied noise levels were higher than acceptable limits, indicating that teachers are at risk of developing voice-related disorders. Many teachers indicated that they believe that they are experiencing health-related problems caused by high noise levels in their work environment.

Unoccupied and occupied ambient noise levels and reverberation time were measured in select classrooms. The data indicates that various areas of Rietenbosch Primary exceed the recommended values. When the study was undertaken it was initially assumed that occupied ambient noise levels were much higher than the recommended level, and that this was the cause of the school's noise problem. This assumption was based on initial reports by teachers but was proven false by the noise survey data.

The hall was shown to have an excessive reverberation time (more than three times the recommended maximum), which indicates that it is one of the main contributors to high noise levels in the school. It seems likely that if the hall and passageways are acoustically treated, noise levels throughout the whole school would be reduced to a more acceptable level.

Data from the noise survey showed that the school is well-built, but is let down by the design and layout of the spaces. The data also indicate that the school does not provide an adequate listening environment to learners. Measured noise levels indicated that learners and teachers are being subjected to noise levels that exceed recommended acceptable values. This can hinder learning, and cause stress and fatigue symptoms in teachers, and health-related problems for both teachers and learners. The levels observed during the noise survey indicate that teachers and learners at Rietenbosch Primary are susceptible to noise-induced general health problems.

The results of this study contribute to the international investigation into high noise levels in schools, and will hopefully initiate a conversation on this topic in South Africa so that people will begin to pay attention to the problem. This could lead to other researchers in South Africa conducting similar tests, and may contribute towards solving the problem of noise-related barriers to learning in schools.

6.2 Recommendations

Future research should improve on this study by investigating more schools throughout South Africa. It is also recommended that further research should be done at Rietenbosch into acoustic barriers. Future studies could also include having the researcher interact with the learners, as the teachers only provided subjective accounts of how learners perceived certain issues. Tests on vocal recognition could also be conducted in classrooms to ascertain the percentage vocal recognition of learners. These aspects fell outside the scope of this study (e.g., ethical clearance for interaction with learners was not applied for). How learners' scholastic achievements are influenced by the noise can also be researched. A hearing conversation project at the school could also be started to educate learners regarding the effects of noise. Such a project would make them aware of how valuable hearing is, and in turn could lead to learners changing their behaviours and habits when it comes to protecting their hearing.

This study could also be improved by researching noise levels in a few classrooms for a six-hour period, spanning over a few days. This would allow learners to become used to the researcher moving through the school, and draw less attention to the study. This comfortableness has a definite effect on data as teachers noted (after the measurements were made) that learners are much more disciplined while the researcher, an unknown person, was in the room. It can therefore be argued that measurements are, in some cases, a conservative representation of the reality of the situation. It is seen that younger learners became comfortable with the new arrangement much more quickly than did older learners.

The most practical, albeit expensive, solution to Rietenbosch Primary's noise problem would be to consult a company that does acoustical treatment of buildings to add more absorptive materials to the school's walls and floors. Another expensive method that could be implemented would be to change the layout of the hall so that it no longer propagates noise. It is, however, doubtful whether visual feedback in the classroom as a method would be successful as learners are known to disregard it after they become use to it. The school can then be evaluated again once acoustic measures have been applied to ascertain to what degree acoustic barriers have been removed and whether teachers still experience the symptoms noted in this study.

The impact of this study will be determined only at a later stage, once the school or sponsors have secured funds to implement acoustic solutions. The building itself should also be scrutinised to determine whether the school has sufficient space to rectify or upgrade walls. In addition, an alternative solution for air ventilation must be sought, since the current solution is not practical in terms of inhibiting sound propagation.

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Appendices

Questionnaire

Teachers' Perception of Classroom Acoustics

Instructions: Please cross either yes or no for each question and complete open-ended questions where necessary. Your honest participation in this questionnaire will be greatly appreciated. Please feel free to answer questions in Afrikaans.

Instruksies: Merk asseblief ja of nee met 'n kruisie vir elke vraag en voltooi oop vrae waar nodig. U eerlike deelname in hierdie vraelys sal baie waardeer word. Voel asseblief vry om die vrae in Engels te beantwoord.

1: Please state your age: 1: Noem asseblief u ouderdom: ____________

2: How long have you been working at Rietenbosch Primary? 2: Hoe lank is u al werksaam by Laerskool Rietenbosch? ________________

3: In relation to noise, do you ask your learners to quieten down repeatedly? 3: Is geraasvlakke so hoog dat u leerders herhaaldelik vra om stil te bly? ____

4: Have you noticed that children's performance in noisy situations has been affected? 4: Het u al ooit opgemerk dat kinders se prestasie beïnvloed word deur raserige omstandighede?

Yes/ Ja **No**/ Nee

5: In your opinion do you feel that your classroom has good listening conditions? 5: Volgens u mening voel u dat die klaskamer voldoende akoestiek het?

Yes/ Ja **No**/ Nee

6: Please explain your answer in question 5 by giving an example (or examples). 6: Motiveer asseblief u antwoord in vraag 5 deur 'n voorbeeld (of voorbeelde) te gee. ______________________________

____

____

7: In your opinion does it seem as though the background noise is based in the classroom or transferred from adjacent rooms? 7: Volgens u mening is die agtergrondgeraas afkomstig van aangrensende klaskamers of is die probleem in u klaskamer?

Yes/ Ja **No**/ Nee

8: Please explain your answer in question 7. 8: Motiveer asseblief u antwoord in vraag 7. ______________________________

____

____

9: Please disclose anything else that you feel affects your listening experience. 9: Verduidelik asseblief enige ander faktore wat u voel u luister ervaring beïnvloed. ______________________________

____

____

10: The following are sources of noise: transportation noise (e.g. cars, buses, aeroplanes, etc.); noise produced by people (talking, laughing, chairs moving, papers rustling); noise produced by mechanical and electronic devices (e.g. stereo, musical instruments, TV, etc.) or noise from nature (e.g. trees, birds, dogs, cats, etc.). 10: Die volgende bronne is vorms van geraas: vervoergeraas (bv. motors, busse, vliegtuie ens.); geraas wat afkomstig is van mense (praat, lag, stoele verskuif, geritsel van papiere); geraas van meganiese en elektroniese toerusting (bv. telefoon, interkom, grassnyer ens.); vermaaklikheids geraas (bv. radio, musiekinstrumente, televisie, ens.) of geraas afkomstig van die natuur (bv. bome, voëls, honde, katte, ens.).

Are any of the listed noise sources present while teaching? Is enige van hierdie geraasbronne teenwoordig teenwoordig terwyl u klasgee?

Yes/ Ja **No**/ Nee

11: If you answered yes in question 10, please explain how disturbing noise from the listed sources (and categories) is when you are teaching. 11: As u antwoord ja was in vraag 10, verduidelik asseblief hoe steurend geraas van die bogenoemde bronne (en kategorieë) is terwyl u klasgee. ______________________________

____

____

12: Does your voice feel strained when you reach home after work? 12: Voel u stem geaffekteer, soos hees of seer, na 'n dag van klasgee?

Yes/ Ja **No**/ Nee

13: Do you sometimes suffer from voice loss? 13: Word u soms deur stemverlies geaffekteer?

Yes/ Ja **No**/ Nee

14: During your period of teaching at Rietenbosch Primary have you personally noted any sign of hearing damage? For example: 14: Gedurende die tydperk wat u by Laerskool Rietenbosch gewerk het, het u al ooit self enige tekens van gehoorskade ondervind? Byvoorbeeld:

1. Turning the television/ radio louder than normal 1. Stel die televisie/ radio harder as normaal

2. Headaches/ migraines 2. Hoofpyne/ migraines

3. Ringing in ears 3. Konstante gefluit in die ore (tinitus)

4. Difficulty conversing in bigger groups 4. Vind u dit moeilik om in groot groepe gesprekke te voer

5. Require frequent repetition 5. Vra u dikwels mense om woorde/ sinne te herhaal

6. Feel stressed from straining to hear what others are saying 6. Ondervind u stres deur u gedurig in te span om te hoor wat ander sê.

Yes/ Ja **No**/ Nee

15: If you indicated yes in question 14 please list an example (or examples). 15: As u antwoord in vraag 14 ja was, gee asseblief 'n voorbeeld (of voorbeelde). ______________________________

____

____

16: Have you experienced, or are experiencing, any of the symptoms listed below? On a discrete scale of 1-7, where 1 is not perceived and 7 is almost unbearable, where do your symptoms fall? 16: Het u al ooit tevore, of tans, enige van die volgende simptome ervaar? Lusteloosheid, oorwerkte stem, lae werkstevredenheid, gebrek aan motivering, en slaapversteurings. Op 'n skaal van 1-7, waar 1 nie steurend en 7 amper ondraaglik is, waar lê u simptome? Merk asseblief die toepaslike nommer met 'n kruisie.

Please cross the applicable number for each indicator. Merk asseblief die toepasslike nommer met 'n kruisie.

Lack of energy: 1 2 3 4 5 6 7

Lusteloosheid: 1 2 3 4 5 6 7

Voice exertion: 1 2 3 4 5 6 7

Oorwerkte stem: 1 2 3 4 5 6 7

Low job satisfaction: 1 2 3 4 5 6 7

Lae werk tevredenheid: 1 2 3 4 5 6 7

Lack of motivation: 1 2 3 4 5 6 7

Gebrek aan motivering: 1 2 3 4 5 6 7

Sleep disturbance: 1 2 3 4 5 6 7

Slaap versteurings: 1 2 3 4 5 6 7

17: Do you have high blood pressure? 17: Lei u aan hoë bloeddruk?

Yes/ Ja **No**/ Nee **Uncertain**/ Onseker

18: If you indicated yes in question 17, did it develop in the time-

frame that you taught at Rietenbosch Primary? 18: As u antwoord in vraag 17 ja was, het dit ontwikkel tydens u dienstydperk by Laerskool Rietenbosch?

Yes/ Ja **No**/ Nee **Uncertain**/ Onseker

19: How often do learners complain that they cannot hear what you are saying while teaching? 19: Hoe dikwels kla leerders dat hulle nie kan hoor way u sê, terwyl u hulle onderrig nie?

Please cross the applicable words. Merk asseblief die toepaslike woorde met 'n kruisie.

Never/ Nooit **Sometimes**/ Somtyds **Frequently**/ Gereeld **Always**/ Altyd.

20: Can learners always see your face while you teach? 20: Is u altyd sigbaar vir die leerders terwyl u hulle onderrig?

Yes/ Ja **No**/ Nee

21: If no, has it influenced their hearing ability? Have they asked you to repeat questions multiple times? 21: Indien nee, het dit hulle gehoorvermoë beïnvloed? Het hulle u al gevra om vrae herhaaldelik te herhaal?

Yes/ Ja **No**/ Nee

22: Do learners frequently lose their concentration? 22: Verloor leerders gereeld hulle konsentrasie?

Yes/ Ja **No**/ Nee

23: If yes in question 22 what has been the impact on learners' work achievement. Indien u ja geantwoord het in vraag 22 het dit die leerders se skolastiese prestasie beïnvloed? ______________________________

____

____

24: Have learners ever complained about headaches induced by noise? 24: Het leerders al ooit gekla van hoofpyne wat deur geraas veroorsaak word?

Yes/ Ja **No**/ Nee

25: If yes in question 24, is it a frequent occurence? 25: Indien ja in vraag 24, is dit 'n gereelde probleem?

Please cross the applicable word(s). Merk asseblief die toepaslike woord(e) met 'n kruisie.

Sometimes/ Somtyds **Moderately**/ Matig **Frequently**/ Gereeld **Always**/ Altyd.

26: When do you perceive the best listening conditions? 26: Wanneer ondervind u die beste luistergeleenthede?

Please explain your answer. Verduidelik asseblief u antwoord. ________

____

____

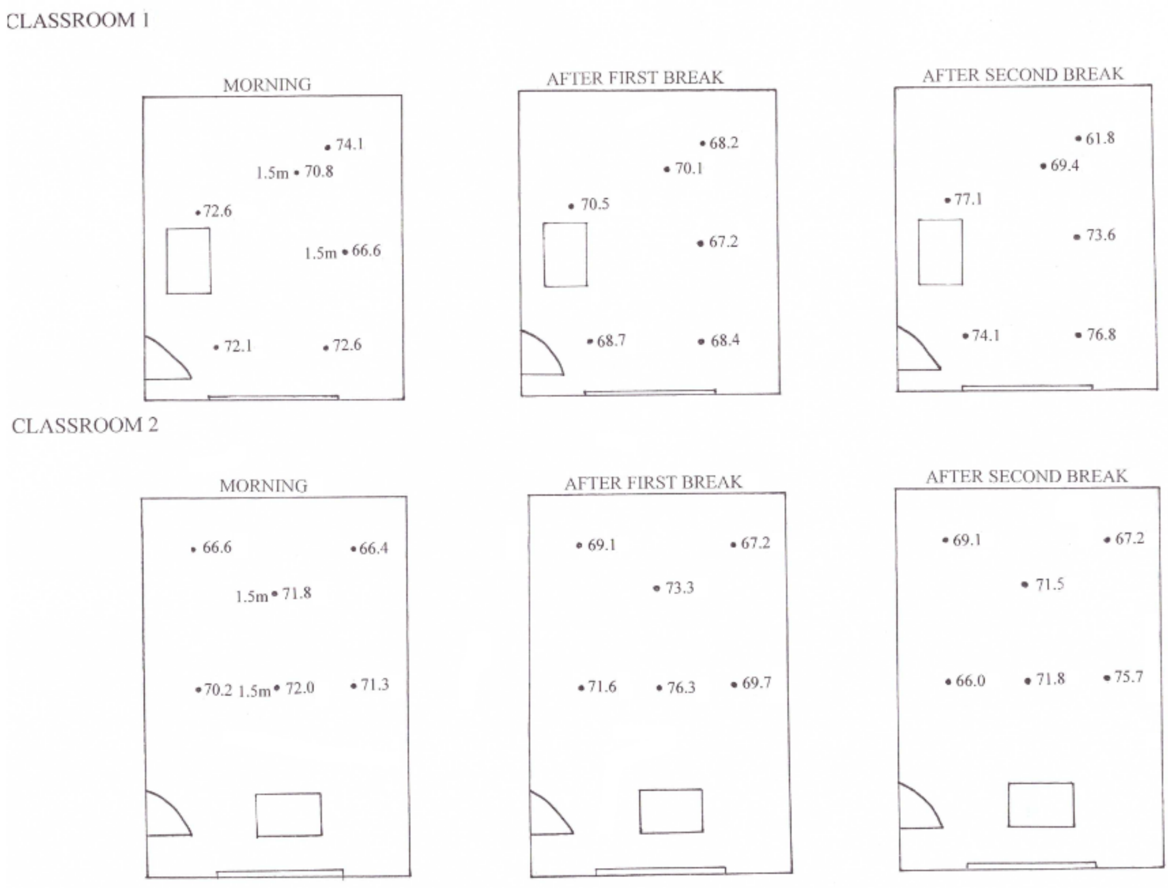
Questionnaire Data

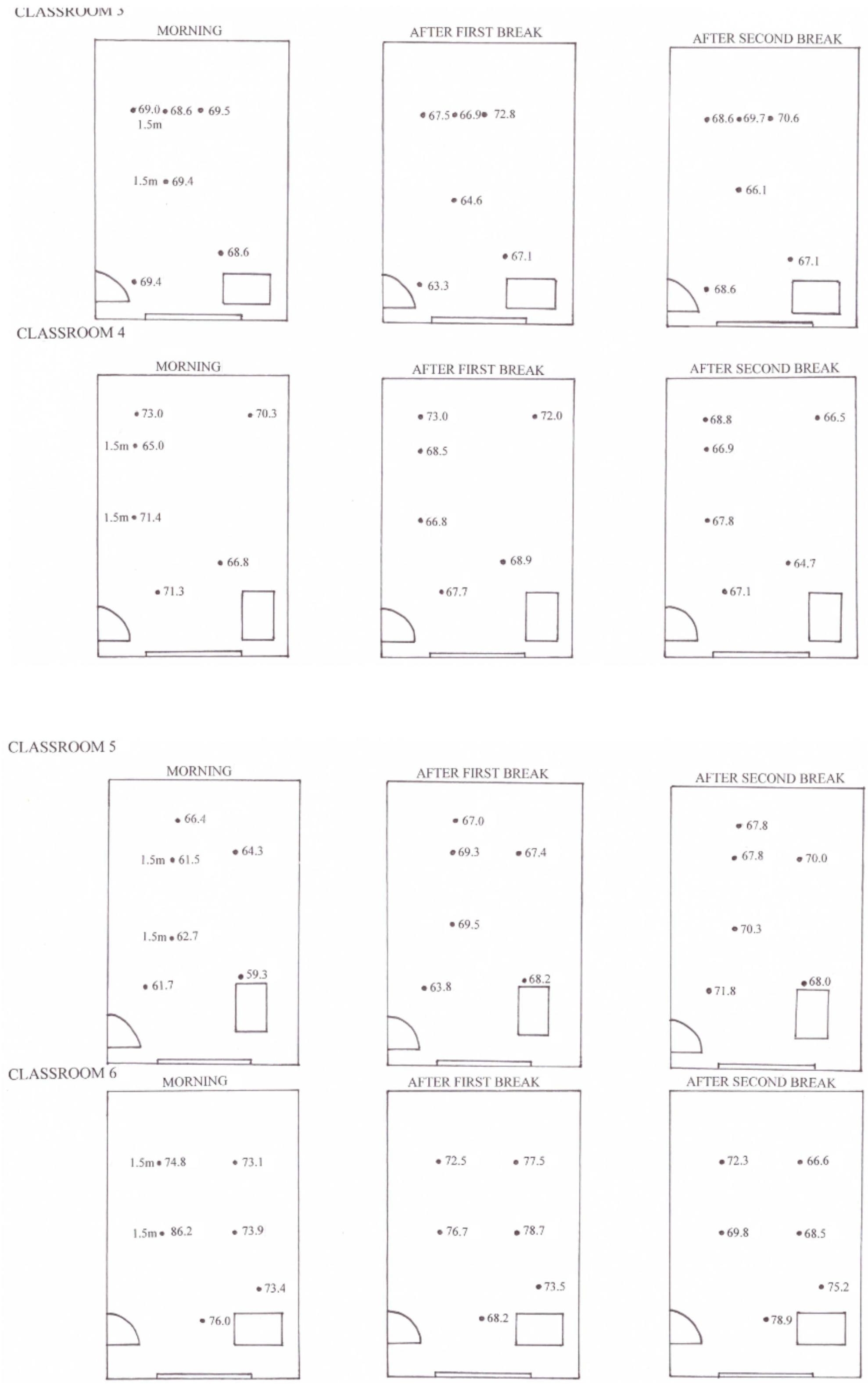
Questionnaire Data Analysis

		Questions 1-26																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Participants 1-30	1	64	16	Y	Y	N	C	Y	C	-	Y	C	Y	Y	Y	C	-	N	-	S	Y	-	Y	C	N	-	C
	2	64	0.083	Y	Y	N	C	N	C	C	Y	-	N	Y	N	-	Y	N	-	S	Y	-	Y	C	N	-	C
	3	61	17	Y	Y	Y	C	N	C	C	Y	C	N	N	N	-	Y	N	-	S	Y	-	Y	C	N	-	C
	4	60	13	Y	Y	N	C	N	C	C	Y	C	Y	Y	Y	C	Y	N	-	F	Y	Y	Y	C	Y	F	C
	5	59	24	Y	Y	Y	-	Y	C	-	Y	C	Y	Y	N	-	-	Y	N	N	Y	-	N	-	N	-	C
	6	58	6	Y	Y	Y	C	-	-	-	Y	C	Y	Y	-	-	Y	Y	N	S	Y	-	Y	C	-	-	C
	7	53	4	Y	Y	N	C	Y	C	-	Y	C	Y	N	N	-	Y	N	-	S	Y	-	Y	C	Y	-	C
	8	53	4	Y	Y	N	C	-	-	-	Y	C	Y	Y	Y	C	Y	N	-	S	Y	-	Y	C	Y	M	C
	9	51	8	Y	Y	N	C	Y	C	C	Y	C	Y	Y	Y	C	Y	Y	N	S	N	Y	Y	C	Y	S	C
	10	49	0.166	Y	Y	N	C	Y	C	-	Y	C	Y	N	Y	-	Y	Y	N	N	Y	-	Y	C	Y	S	C
	11	47	10	Y	Y	N	C	Y	C	C	Y	-	Y	N	Y	C	Y	Y	Y	M	Y	-	Y	C	Y	S	C
	12	45	9	Y	Y	N	C	N	C	-	Y	C	Y	Y	Y	C	Y	N	-	S	Y	Y	Y	-	N	-	-
	13	43	7	N	N	Y	C	Y	C	C	Y	C	N	N	Y	C	Y	N	-	N	Y	-	Y	C	N	-	C
	14	42	6	Y	Y	Y	C	Y	C	C	Y	C	Y	Y	Y	C	Y	N	-	S	Y	-	Y	C	Y	S	C
	15	38	16	Y	Y	N	C	Y	C	C	Y	C	N	N	Y	-	Y	N	-	S	Y	-	N	-	N	-	C
	16	35	2	Y	Y	N	-	Y	C	-	Y	C	Y	Y	Y	C	Y	N	-	M	Y	-	Y	-	Y	S	-
	17	33	3	Y	Y	N	C	Y	C	C	Y	C	Y	Y	Y	C	Y	Y	Y	F	Y	-	Y	C	Y	F	C
	18	29	0.083	N	Y	-	-	Y	C	-	Y	C	Y	N	N	-	Y	N	-	N	Y	-	N	-	N	-	C
	19	29	3	Y	Y	N	C	Y	C	-	Y	C	Y	Y	Y	C	Y	N	-	M	Y	-	Y	C	Y	M	C
	20	28	4	Y	Y	N	C	N	C	C	Y	C	Y	N	Y	C	Y	N	-	M	Y	-	Y	C	N	-	C
	21	28	2	Y	Y	N	C	Y	C	C	Y	C	Y	Y	Y	C	Y	U	-	S	Y	-	N	-	Y	M	C
	22	28	3	Y	Y	N	C	Y	C	-	Y	C	Y	Y	Y	C	Y	N	-	N	Y	-	Y	C	N	-	C
	23	26	4	Y	Y	N	C	Y	C	C	Y	C	Y	Y	Y	C	Y	N	-	M	Y	-	Y	C	N	-	C
	24	25	3	Y	Y	N	C	Y	C	C	Y	C	Y	Y	Y	C	Y	U	-	S	Y	-	Y	C	Y	M	C
	25	25	1	Y	Y	Y	C	Y	C	C	Y	C	Y	Y	Y	C	Y	N	-	-	Y	N	Y	C	N	-	C
	26	24	0.146	Y	Y	N	C	Y	C	C	Y	C	Y	N	N	-	Y	N	-	M	Y	-	Y	C	N	-	C
	27	24	0.916	Y	Y	N	C	Y	C	C	Y	C	Y	Y	Y	C	Y	N	-	F	Y	-	Y	C	Y	F	C
	28	24	1	Y	Y	N	C	Y	C	C	Y	C	Y	Y	Y	C	Y	N	-	A	Y	-	Y	C	Y	F	C
	29	24	0.333	Y	Y	N	C	Y	C	C	Y	C	Y	Y	Y	C	Y	N	-	M	Y	-	Y	C	Y	S	C
	30	23	1	Y	Y	N	C	Y	C	C	Y	C	Y	Y	N	-	Y	N	-	S	N	Y	Y	C	N	-	C

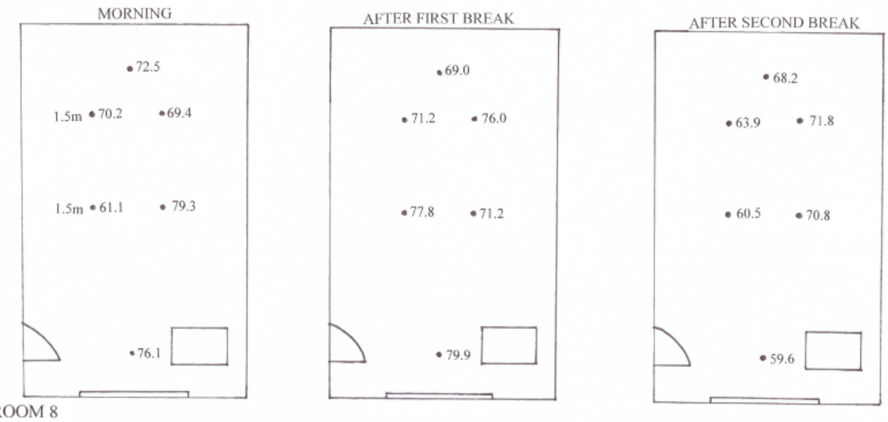
Noise Survey

Noise Survey Measurement Points (Occupied Classrooms)

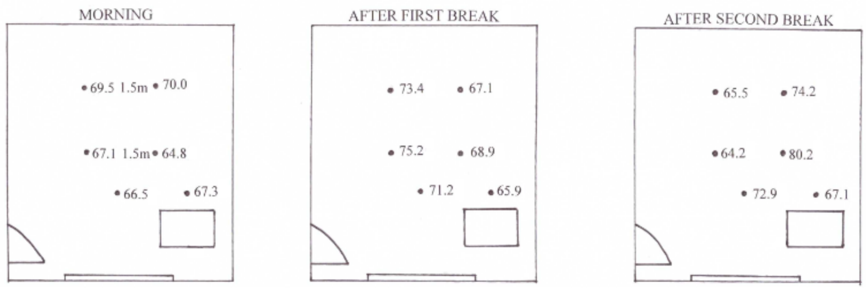



CLASSROOM 3
MORNING
69.0 68.6 69.5
1.5m
1.5m 69.4
68.6
69.4
AFTER FIRST BREAK
67.5 66.9 72.8
64.6
67.1
63.3
AFTER SECOND BREAK
68.6 69.7 70.6
66.1
67.1
68.6
CLASSROOM 4
MORNING
73.0
70.3
1.5m 65.0
1.5m 71.4
66.8
71.3
AFTER FIRST BREAK
73.0
72.0
68.5
66.8
68.9
67.7
AFTER SECOND BREAK
68.8
66.5
66.9
67.8
64.7
67.1
CLASSROOM 5
MORNING
66.4
1.5m 61.5
64.3
1.5m 62.7
61.7
59.3
AFTER FIRST BREAK
67.0
69.3
67.4
69.5
63.8
68.2
AFTER SECOND BREAK
67.8
67.8
70.0
70.3
71.8
68.0
CLASSROOM 6
MORNING
1.5m 74.8
73.1
1.5m 86.2
73.9
73.4
76.0
AFTER FIRST BREAK
72.5
77.5
76.7
78.7
73.5
68.2
AFTER SECOND BREAK
72.3
66.6
69.8
68.5
75.2
78.9

CLASSROOM 7



CLASSROOM 8



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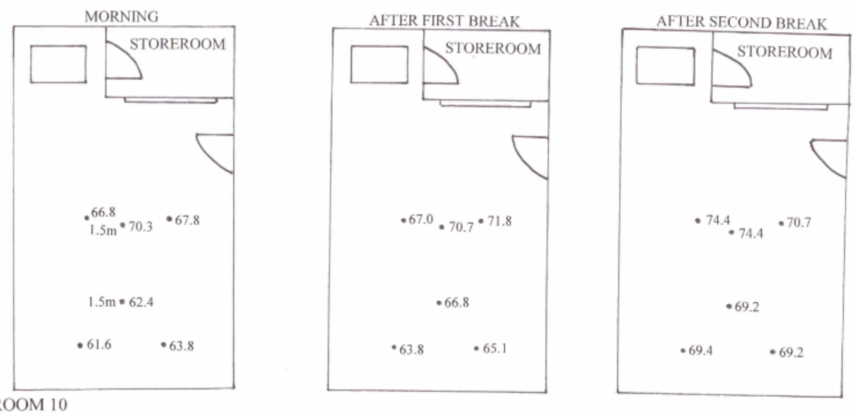

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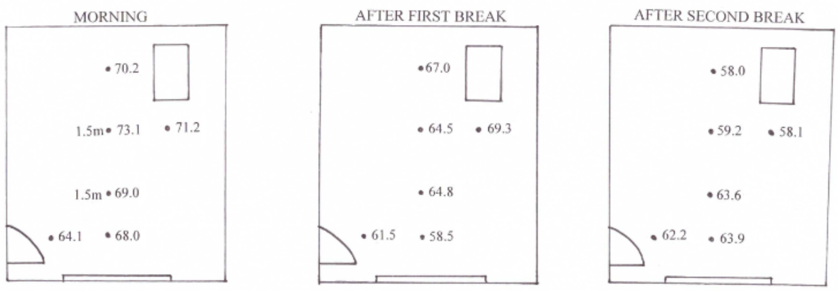

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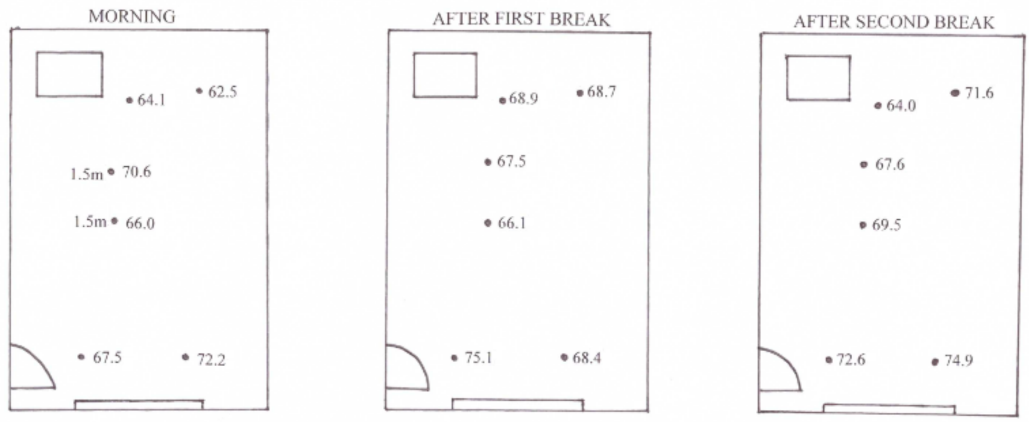
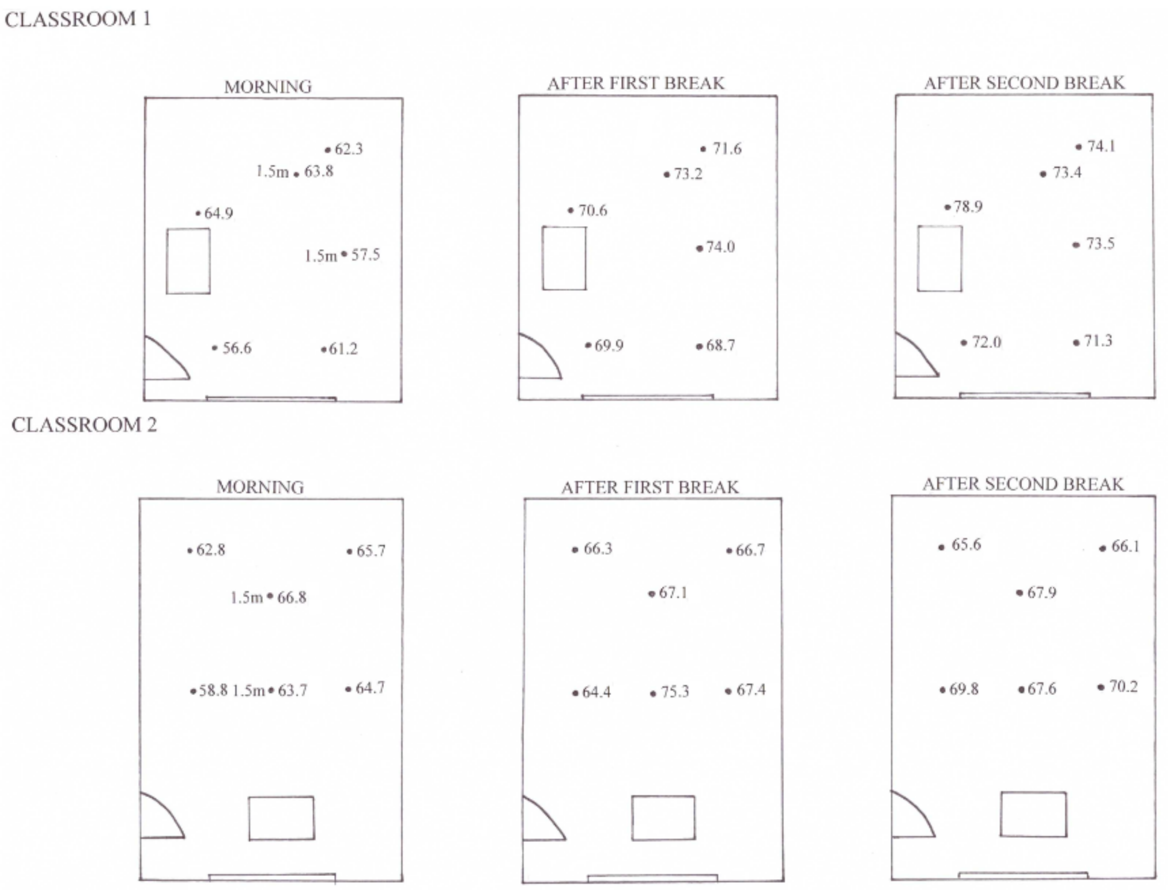


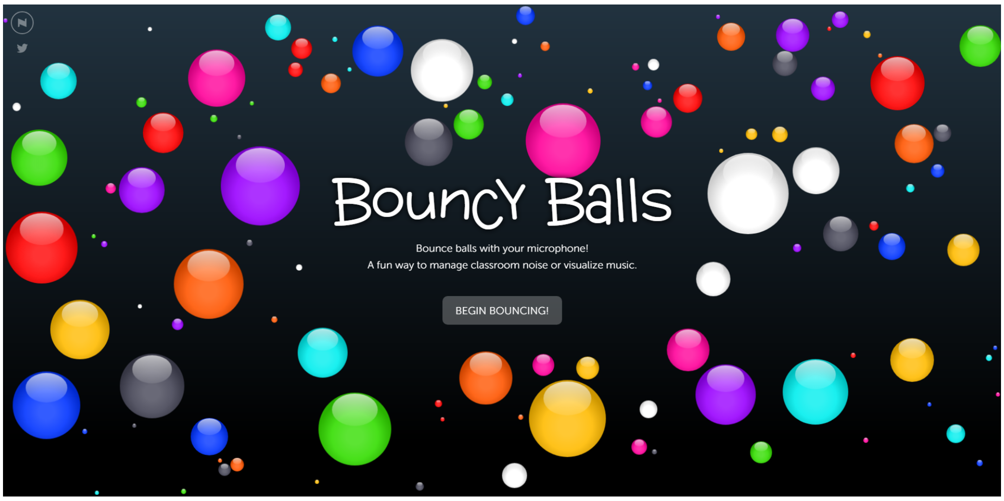
Noise Survey

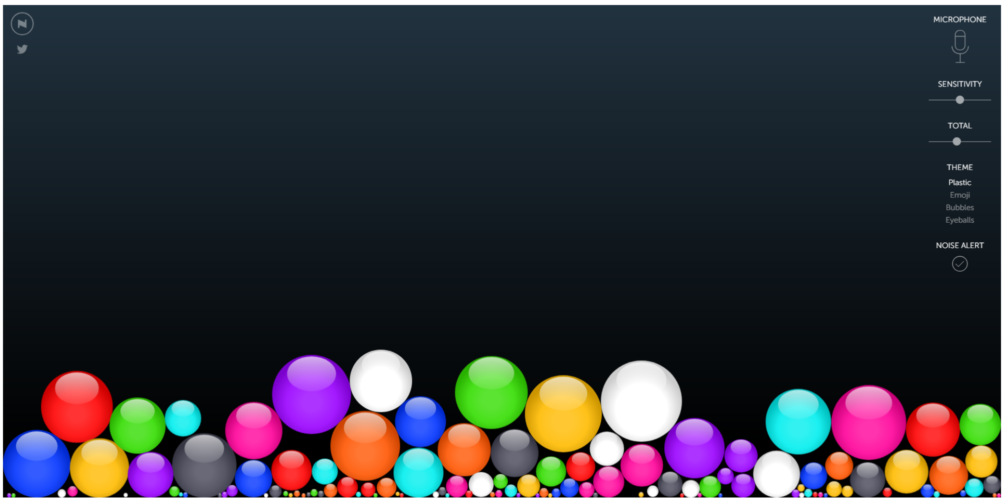
Noise Education Measurement Points (Occupied Classrooms)

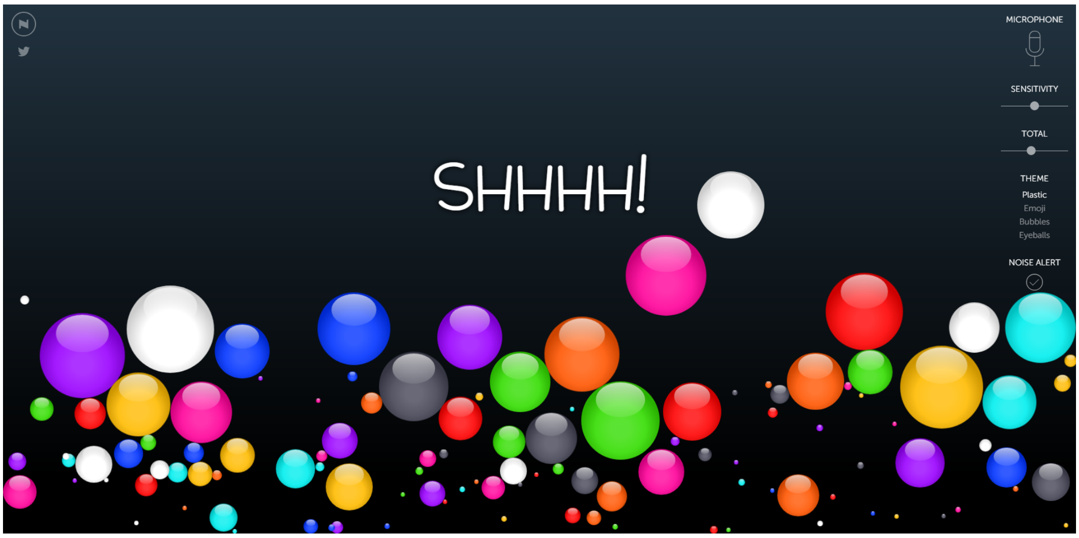


Discussion

Possible Solutions






MICROPHONE
SENSITIVITY
TOTAL
THEME
Plastic
Emoji
Bubbles
Eyeballs
NOISE ALERT
SHHHH!


MICROPHONE
SENSITIVITY
TOTAL
THEME
Plastic
Emoji
Bubbles
Eyeballs
NOISE ALERT
TOO NOISY!